Undergraduate Civil Engineering Sustainability Education Metric (UCESEM): Benchmarking Civil Engineering Program Performance

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Abstract –While ratings of metrics such as the U.S. News and World Report issue on 'America's Best Colleges' and the 'Green Report Card' motivate colleges to surpass their competitors, no similar metric exists to measure performance of a program with regard to sustainability education. This paper describes the development of a comparative metric for undergraduate civil engineering sustainability education. The metric is tested on civil engineer-applicable syllabi included in the Benchmarking Sustainable Engineering Education Final Report. Generation of metric categories, assignment of weightings, and testing of the metric on syllabi identified further areas for research.

Keywords: Sustainability, Engineering Education, Benchmarking, Metric.

BACKGROUND

As world governments continue to recognize the need to operate leaner, with a decreasing impact on the environment; as corporations respond to the 'energy crisis' and desire to be competitive with their challengers; as citizens of the world pursue an intrinsic connection to their environment and products they consume, so is there a need to inform these stakeholders in methods available to minimize negative impacts of their operations while improving the sustainability of the environments within which they operate. In response to this growing need, the United Nations decreed the 'United Nations Decade of Education for Sustainable Development', February 2003, which gives Higher Education Institutions further incentive to integrate sustainability [Haigh, 12].

Sustainability Engineering Education Metric Drivers

Buildings in the U.S. account for 39% of total energy use, 12% of total water consumption, 68% of total electricity consumption, and 38% of carbon dioxide emissions [EPA, 10]. Employment in the construction industry is projected to increase from the approximately 6.9 million jobs in 2004 to 7.7 million jobs in 2014, an increase of nearly 800,000 jobs [ETA, 11]. "Environmentally friendly construction" professionals are needed because "demand is booming…but it's booming so fast that there aren't enough skilled professionals to do the work" [Krieger, 15]. The impacts of civil engineer construction products in conjunction with the growth rate and the increasing attention on sustainable practices requires engineering education to ensure future engineer professionals are equipped to perform sustainably. Faculty must issue students the tools to incorporate sustainability.

Educational metrics such as the annual university rankings reported by U.S. News & World Report are utilized by future university students worldwide. For instance, in 2005, U.S. News & World Report sold 45,000 newsstand copies of the "Best Colleges" edition, which was in addition to a paid subscriber list of 2 million. Additionally, they sold "several hundred thousand" copies of their 280-plus page "America's Best Colleges" newsstand guide, which included a directory of 1,400 colleges [Morse, 16; Su, 23]. Metrics such as these are the missing piece for education in sustainability and their inclusion would aid to provide topic and method benchmarking, which could facilitate standardization upon those topics that are considered to be the civil engineer's education foundation. Metrics provide a framework along with a comparative and competitive means to evaluate similar programs. This phenomenon

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is facilitated through the LEED certification process and the Green Report Card, but a metric to evaluate sustainability in engineering programs does not yet exist.

A metric assessing sustainability education for civil engineers would serve multiple ends. Companies are already familiar, and in some cases develop, their own internal evaluation system for hiring from various colleges and universities, and a civil engineering sustainability education metric will help to quantify the anticipated education of new hires [Service, 22]. Students and parents searching for a comprehensive civil engineering education would be empowered to further delineate the factors important to them in their education. Above all, a recognized sustainability metric would encourage institutions to improve their focus on sustainability and sustainable issues, through their desire to achieve top rankings and remain competitive with their peers.

LITERATURE ANALYSIS

The literature analysis was conducted in order to identify the existing work in the areas of sustainability education and metrics. Identified civil engineering education stakeholders included industry, faculty and students. These stakeholders were used to categorize the literature. The intersection of those users and their expectations in regards to sustainability should be the primary criteria that would coordinate to form the evaluation metric.

Methods of Measurement

The first step in UCESEM literature analysis required identification of existing sustainability measurement tools and metrics for assessing sustainability in universities, their programs and courses. These tools differ in their scale of application, the person who applies them and the utility of their outcomes.

Sustainability is measured overall by organizations interested in furthering sustainability, typically through sustainable development, such as the International Institute for Sustainable Development (IISD). It is also currently achieved through individual and project sustainability measurement such as LEED Accredited Professionals and the LEED project certification process. Project engineers may utilize any of the 275 green building data selection tool categories such as life cycle analysis and case studies, when they make design decisions [Keysar, 14].

Current methods for assessing universities with regard to sustainability include the Presidents' Climate Commitment and Green Report Card. As of November 2009, 659 colleges and universities have signed the Presidents' Climate Commitment. Presidents that sign the commitment agree to various measures for sustainable campus operations, some within a particular timeline [ACUPCC, 4]. Whether schools decide to sign the Presidents' Climate Commitment or not, the sustainability of campus operations is captured in the Campus Sustainability Report Card; also known as the 'Green Report Card', it evaluates the quality and comprehensiveness of the campus sustainability practices of 332 institutions. The first and only rating scheme available to measure campus sustainability practice, the report card for 2008 resulted in a 97% participation rate from the 300 colleges invited to participate [SEI, 24].

Program sustainability inclusion is a requirement of ABET Engineering Criteria 2000. ABET Criterion 3a-k were divided into 'hard' and 'soft' skills. Of note are the parallels between Criterion 3h, "understand the impact of engineering solutions in a global, economic, environmental, and societal context", and the sustainability pillars of environment, economic and social [ABET, 1].

Finally, the research identified one method for assessing the coverage of sustainability a course provides. The Sustainability in Higher Education Assessment Rubric (SHEAR) is an evaluation tool of coursework that empowers faculty to "shape effective programs and courses of their own to teach concepts of sustainability to their students" by ranking knowledge and awareness, skill development, lifelong learning, partnerships, and reflection. [Riley, 20].

Stakeholder Expectations and Frameworks

The first stakeholder of three is the construction and design industry, since they are a major source of demand and investment for education [Huntzinger, 13; Myers, 18]. The literature identified four major frameworks measuring sustainability for industry [ConstructionSkills, 8; Keysar, 14; MRM, 17; USGBC, 25]. A survey conducted in 2006 at three major university construction programs garnered responses from 87 companies recruiting new hires and indicated that 65% expect graduates to have some knowledge of green building [Ahn, 2].

Faculty, the second stakeholder group, are motivated by ABET but have found that its “new ‘soft,’ or intangible, skills […] have proven difficult to define, teach, and measure, leaving educators grappling for instructional methods that can be used to instill the new [soft] skills” [Riley, 20].

Students, the final stakeholder, represent the future civil engineer professionals. A survey showed that 68% of 12,715 high school students applying to college said they would like to have information about a college’s commitment to the environment [SEI, 24]. Student expectations for “environmental commitment” drove two-thirds of respondents to state that it would be a “factor in where they applied” [Berman, 6].

Case Studies

The final step in the literature analysis identified existing case studies of sustainability integration. Existing case studies provided examples of philosophies such as “bolted-on” or “built-in” sustainability instruction [Huntzinger, 13] and methods such as hands-on learning [Pearce, 19]. The University of Florida’s efforts to categorize courses that addressed sustainability [Appledorn, 5] were identified as potential criteria for the metric. The literature analysis also identified the Center for Sustainable Engineering [CSE, 7]. Their work includes faculty education workshops and a website with peer-reviewed sustainable engineering education materials [Engineering, 9]. The CSE-authored *Benchmarking Sustainable Engineering Education Final Report* provided statistics and syllabi for coverage of sustainability at universities that responded to their survey [Allen, 3].

DEVELOPMENT OF THE UCESEM

The UCESEM utilized existing frameworks and results in its development [Allen, 3; ConstructionSkills, 8; Riley, 20; SEI, 24]. Additionally, characteristics from a case study and attitudinal surveys were compiled to develop criteria, along with a suggested weighting, to generate a preliminary evaluation matrix for undergraduate civil engineering programs. Once the literature analysis for existing frameworks and attitudinal reports was complete, the following methodology in Figure 1 was developed in order to develop and test the UCESEM.

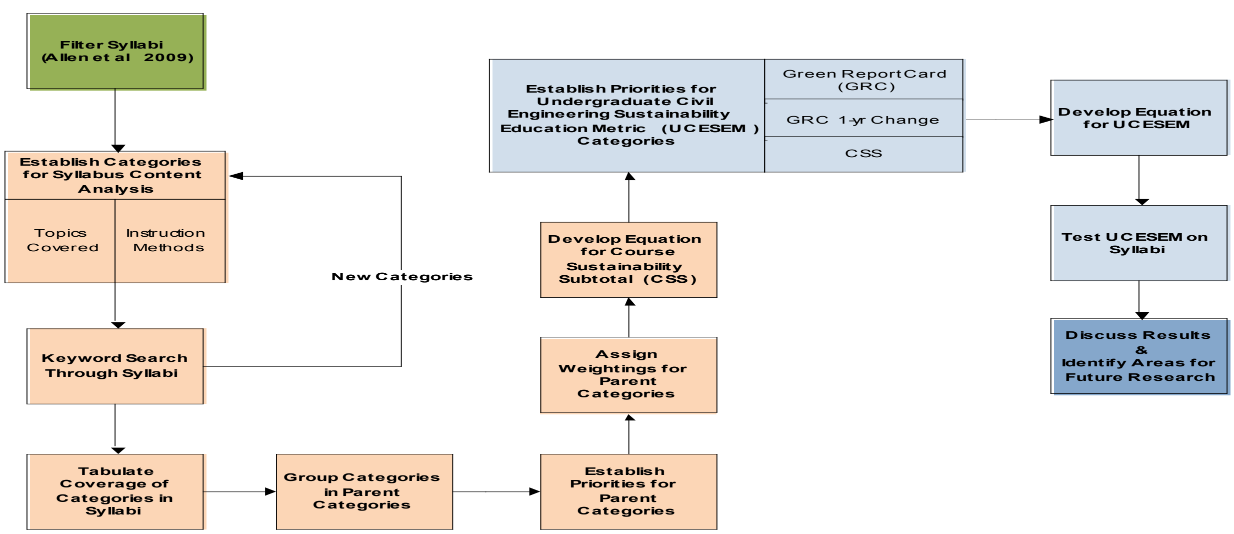

Figure 1 UCESEM Development Methodology

Sample Set Selection

The focus for this study was to assess the undergraduate civil engineering programs. Without having information as to the core courses and approved technical electives for each program represented in the CSE study, another method was devised to capture classes that an undergraduate civil engineer might take. The process to establish the sample set from the Benchmarking Sustainability Engineering Education Final Report is illustrated in Figure 2.

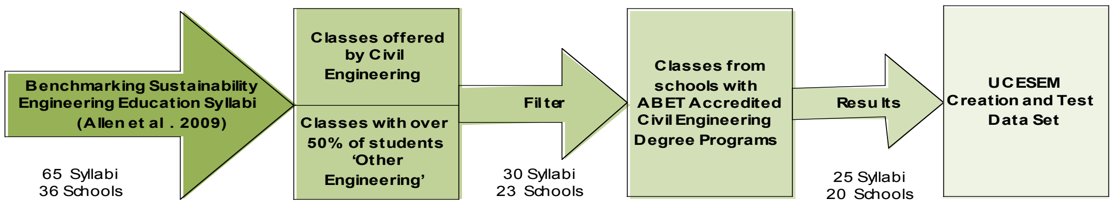

Figure 2 Syllabi Filter Process

The first step taken was to identify the syllabi that would be used to generate and test the metric. This was the best method to ensure face validity of the metric construct, as well as demonstrating the UCESEM results. The Benchmarking Sustainability Engineering Education Final Report contained an appendix of 65 syllabi that were submitted from 36 schools [Allen, 3]. These syllabi spanned the focuses of engineering education, such as electrical, mechanical and civil. The Benchmarking report asked syllabi submitters to supply standard information for each syllabus such as what department offered the course and the level and major of enrolled students.

The classes offered by civil engineering departments were selected, as those are classes most likely taken by undergraduate civil engineers and should be included in the metric development. However, undergraduate programs do not solely consist of courses offered by the student's major department. A civil engineer might take a course offered by the mechanical engineering or public policy departments. In order to capture this aspect of the learning experience for an undergraduate civil engineer, the syllabi which reported over 50% of their students being 'other engineering' were also included. These classes could conceivably have civil engineers enrolled, taking it as a technical elective, especially due to the high percentage of engineering majors outside of the department that offered the class. Once this filter was complete, 30 syllabi at 23 schools remained.

Though the benchmarking report focused on universities with degrees that were ABET accredited, this did not guarantee that the filtered syllabi were at schools with an accredited civil engineering degree. The 30 classes were filtered to highlight only those that had an ABET accredited civil engineering degree. The remaining 25 classes at 20 schools made up the set for metric development and the first test set for the UCESEM.

Content Analysis

The syllabi from the CSE benchmarking report were not in a standard format, as they were from many different institutions, and different programs within those schools. As the syllabi were non-uniform with different methods for outlining the course, addressing topics, methods, and calendar in different combinations, it was determined that content analysis would be the best method to achieve the goals of quantity and quality using the content analysis method of category counts. This project used human-based review of the syllabi, which was possible due to the manageable sample size of 25 syllabi. The categories were established by using prior variables identified in many of the references found in the literature analysis such as the Penn State SHEAR rubric, the CSE survey-suggested categories, and other existing frameworks for sustainability knowledge and tools.

Initially, content analysis of the syllabi focused on the 'objectives' and 'outcomes' to include awareness and skills that the successful student should garner upon completion of the course. However, this proved impossible, since all syllabi were not formatted the same way. As stated earlier, in an effort to ensure the reliability of the process, an inconsistently-applied method for reviewing the syllabi would not be appropriate. The second attempt was to review objectives, outcomes, course description and course topics sections of the syllabi. Most of the syllabi had at least two of these sections, but a few relied heavily on the course schedule to outline the covered material. Finally, this showed that the best way to standardize the review and capture the content of the course was to analyze each syllabus in its entirety for topics, tools, and methods. Reviewing the entire syllabus was time-intensive, but it did not leave any stone unturned, no matter what heading the faculty might use for the syllabus sections.

Categories for Syllabus Content Analysis

The first step towards quantifying the syllabi through content analysis was to establish the categories through which their content would be captured. While it is challenging to establish metrics for quality, as it can be viewed as subjective, this project strove to identify categories which could indicate quality, and identified two methods of instruction to capture this aspect of the course. Quantity categories are simpler to establish, as there are many topics and tools within sustainability which could be used to indicate coverage within the syllabus. The categories for the UCESEM syllabus assessment included those identified through stakeholder expectations, from the SHEAR rubric, the CSE *Benchmarking Sustainable Engineering Education Final Report*-defined categories, and from other frameworks [Allen, 3; ConstructionSkills, 8; Riley, 20; Segalas, 21; USGBC, 25].

While most of the eight categories of the SHEAR could not be implemented consistently across the syllabi, from an outside perspective, three of the categories could: "knowledge and awareness", "skill development" and "application in diverse settings". The first two categories were covered through a thorough review and accounting of the sustainability topics and tools addressed in the syllabi. The final category, "application in diverse settings", was intended to address the coverage of "diverse learning experience; a hands-on project; civic engagement; applied research/community outreach and education; community service". The CSE questionnaire suggested the following subtopics for sustainability in engineering: life cycle analysis, natural resource management, climate change, design for environment, policy and regulations, renewable energy, industrial ecology, economics, green design, material flow analysis, pollution prevention, and reuse and/or recovery of products and materials [Allen, 3].

Following review for key terms and methods throughout the syllabi, other categories started to emerge. In an effort to ensure face validity, these categories were cross checked with the reference literature and they were found to be mentioned in different articles, with considerable overlap. The additional categories present in the syllabi that were covered by at least two of the classes were included to capture either knowledge and awareness or skills garnered from the course. The two-class minimum was not required for the methods of instruction parent category, as the creative instruction initiatives of even one class should be included. The inclusion will provide a benchmark for the other classes to consider its implementation.

Finally, in order to ensure a solid foundation in sustainability, the three pillars of sustainability, economic, environmental, and social were included. A class might receive double credit for covering Design for the Environment or Economics, both a pillar and related topics in the topic category, but the benefits of a solid foundation, represented in coverage of the pillars, were decided to outweigh the small effect that double-counting would have.

These criteria combined to form the metric for the Course Sustainability Subtotal (CSS). Some of the sustainability keywords from the syllabi were not phrased exactly as the category. For instance, the category 'Technology Assessment Tools' was identified to capture software tools and familiarization covered in the course, while 'Global Considerations' was used to give credit to any mention of 'global' concerns. A category and keyword reference was created to ensure consistency in evaluation of the syllabi.

Key aspects of content analysis include measurement, indication, representation and interpretation. In order for a content analysis to be successful and complete, each of these aspects should be covered [Weber, 26]. Measurement should include a quantification of categories. The CSS category coverage was denoted as yes-present or blank-absent for each category. The topic categories were subtotaled, as were the methods of instruction categories, and these combine to complete the measurement aspect. Next, the indication aspect strives to assess quality of the measurements. The additional parent category of sustainability pillar coverage was created to capture which topics would count as coverage of one of the three pillars of sustainability: environment, economic and social. These categories address the sustainability foundation coverage. Foundation is important, not always seen, but indicates quality in building structures and education. The representation aspect was covered by detailing the keywords and intent of the category. Finally, interpretation was accomplished by the creation of an equation to value the category coverage, student level, and offering department. The CSS equation facilitates interpretation and comparison of the scores between syllabi, while the UCESEM equation facilitates comparison between universities.

Once all of the syllabi were reviewed, through content analysis, in their entirety, for the topics, skills, and methods, the challenge then became how to capture this data and consolidate the results into one value which could facilitate program comparison. Each of the subcategories would require a weighting, as each should not be taken linearly. A course that covered 5 sustainability topics, with less than 10% of the course focusing on sustainability, should not be scored higher in sustainability than a course that covered 4 topics with 25-50% of the class focused on sustainability. The process to establish the weightings for the parent categories is detailed in the following section.

Metric Equation Development

Each of the parent categories was prioritized by the researcher based on information gathered through the course of this investigation in the order shown and then assigned weights. The CSE benchmarking report survey requested that submitters of syllabi address, among other things, the percent of the course that focused on sustainability, as well as the level of the students that took the course. The respondents could choose less than 10%, 10-25%, 25-50% or more than 50% to describe the portion of the course that focused on sustainability [Allen, 3]. These were broken out into 1, 2, 3, or 4, respectively, for the purpose of this metric, in order to roll the response up into an equation to quantify the range that was selected for the sustainability focus of this course. Additionally, the levels of the students, undergraduate, lower division, upper division, or graduate were streamlined into undergraduate, undergraduate and graduate, and graduate categories for the UCESEM. Each was assigned a number, 1, 2, and 3, respectively, in order to roll the category up into an equation for the overall course evaluation.

The percent of the course that focused on sustainability was deemed the most important category because it represents the attention placed on sustainability throughout the course. This was a self-reported percentage range by the CSE respondents. The coverage of the three pillars of sustainability – environmental, economic and social – is the next-highest ranked, as they represent the foundation in sustainability. The depth of each of these pillars is reflected through the overall focus on sustainability from the previous category. The categories of topics that were identified allowed credit for familiarization with sustainability knowledge and skills, and although this parent category has the third highest ranking, each category does not considerably affect the course's overall score.

Student level and offering by civil engineering reflected the probability that undergraduate civil engineers would be required to, or have access to, the course. As most undergraduates take core courses early in their degree program, it was inferred that the lower the level of the students taking the class, the higher the probability that the class was a core course. The higher the student level, it became more likely that the class was a technical elective and not taken by all graduates of the program. Additionally, although a course may be a graduate course and/or offered by the public policy department, for instance, undergraduates may still have access to the course and civil engineers may take the course; this was reflected in the CSE response showing that over 50% of the course was 'other engineering'.

The method of instruction category was allotted 2.5% per method. These aspects of sustainability education were highlighted in the SHEAR rubric as being important because "teaching lessons in context and connecting them to students' own lives and careers brings about the sense of responsibility desired of students" [Riley, 20]. Once the weights were established, the Course Sustainability Subtotal equation was developed, as is detailed in Figure 3.

$$CSS = WT_P * \frac{P}{3} + WT_B * \frac{B}{22} + WT_F * \frac{F}{4} + WT_L * \frac{4-L}{3} + WT_M * \frac{S+C}{2} + WT_{CE} * (1, if\ offered\ by\ CE | 0, if\ not\ offered\ by\ CE)$$

$WT_P = Weight\ Factor\ for\ Pillar\ Coverage = 25\%$

$P = Total\ Number\ of\ Pillars\ Addressed\ by\ Course$

$WT_B = Weight\ Factor\ for\ Breadth\ of\ Topics\ and\ Skills = 25\%$

$B = Total\ Number\ of\ Topics\ and\ Skills\ Covered\ by\ the\ Course\ (out\ of\ 22)$

$WT_F = Weight\ Factor\ for\ Percent\ of\ course\ Focused\ on\ Sustainability = 30\%$

$F = \%\ of\ Course\ Focused\ on\ Sustainability\ (1 = < 10\%, 2 = 10 - 25\%, 3 = 25 - 50\%, \quad 4 = > 50\%)$

$WT_L = Weight\ Factor\ for\ Student\ Level = 10\%$

$L = Student\ Level\ (1 = undergraduate, 2 = undergraduate\ \&\ graduate, 3 = graduate)$

$WT_M = Weight\ Factor\ for\ Methods\ for\ Instruction = 5\%$

$S = Course\ utilizes\ Site\ Visits / Field\ Trips$

$C = Course\ includes\ Community\ Engagement$

$WT_{CE} = Weight\ Factor\ applied\ if\ Course\ Offered\ by\ Civil\ Engineering = 5\%$

Figure 3 Course Sustainability Subtotal (CSS)

Universities with more than one course in sustainability required a method for combining the scores into one. An average alone of the scores would not be a fair representation, because it would only serve to lower high, or increase low, scores to an average. In the end, the researcher utilized the following equation in Figure 4 to reflect the quantity and quantity of civil engineering sustainability.

$$UC = WT_{CS} * \frac{CS_1 + CS_2 + CS_n}{n} + WT_N * \frac{n}{n_{max}}$$

$WT_{CS} = Weight\ Factor\ for\ Course\ Sustainability\ Score$ = 75%

$CS_{1...n} = Course\ Sustainability\ Score\ for\ course\ 1\ thru\ n\ for\ one\ University$

$WT_N = Weight\ Factor\ for\ Number\ of\ Sust.Courses\ Available\ to\ CE\ Undergrads$ = 25%

$n = Number\ of\ Courses\ for\ one\ University$

$n_{max} = Maximum\ Number\ of\ Courses\ available\ at\ any\ one\ University\ in\ the\ Metric$

Figure 4 University Course Sustainability Subtotal (UC)

Quantity and quality were not given the same weighting, as is reflected in the preceding equation. A ratio weighting of 3:1, Course Sustainability Score to number of sustainability courses, was assigned to capture the importance of quality to quantity, respectively. The University Course Sustainability Subtotal is one of the three categories included in this first iteration of the UCESEM.

Finally, 75% of the UCESEM score comes from the assessment of the sustainability courses offered from the UC. The Green Report Card is 20% of the score because it represents the institution's commitment to sustainability. The remaining 5% of the total score captures the change in Green Report Card score from the previous year. The Green Report Card scores were translated to the 4.0 scale so that they might be calculated within the metric. A negative change would subtract from the course score. The UCESEM calculation is illustrated in Figure 5.

$$UCESEM = WT_{UC} * UC + WT_G * GRC + WT_{GC} * GRC$$

$WT_{UC} = Weight\ Factor\ for\ University\ Course\ Sustainability\ Subtotal = 75\%$

$UC = University\ or\ College\ Course\ Sustainability\ Subtotal$

$WT_G = Weight\ Factor\ for\ Green\ Report\ Card = 20\%$

$GRC = Green\ Report\ Card\ Score\ from\ Current\ Year$

$WT_{GC} = Weight\ Factor\ for\ Green\ Report\ Card\ Score\ Change\ from\ Previous\ Year = 5\%$

$GC = Difference\ between\ Current\ Year\ G\ and\ Previous\ Year\ (may\ be\ negative)$

Figure 5 Undergraduate Civil Engineering Sustainability Education Metric (UCESEM)

FINDINGS AND DISCUSSION

Findings from the syllabi analysis for each of the universities are included in Table 1. The roll up of these scores, using the UCESEM equation in Figure 5 above, is included in Table 2. Additionally, the syllabi analysis identified the top five covered sustainability topics were, in order: the environmental pillar, the economic pillar, life cycle analysis/planning, the social pillar, and global considerations.

The methods utilized to develop the UCESEM are not yet validated and were calculated with a limited data set of syllabi. For instance, it should be noted that scores for some schools may be higher than depicted in the table, as they may have more courses in sustainability, but were not submitted in the CSE survey request. Additionally, one of the syllabi did not respond to the percent of the course that focused on sustainability. This affected the results of the score for this school, the University of Florida. A basic sensitivity analysis shows that if assuming since the course was titled 'Sustainable Engineering', if it had reported 'over 50%' of the course focusing on sustainability, the course and school scores would have moved the University of Florida into the #6 ranking in the UCESEM. This variance illustrates the impact that the course's focus on sustainability has for the overall Undergraduate Civil Engineering Sustainability Education Metric. The course's focus on sustainability was deemed the most important and therefore, absence of data for this category strongly impacted the university's score. During the transition to the metric implementation, the category could be answered through systematic review of the course schedule with total topics covered and those that fit within the sustainability categories from the metric could be separately identified. Finally, an overall percentage of sustainability focus could be determined and included in the metric.

The Benchmarking Report did not include all schools, or all classes within the schools, that educate civil engineering undergraduates. Additionally, since it was a survey of accredited engineering programs, it only captured courses that were offered by colleges of engineering. However, technical electives for civil engineering undergraduates could be located outside of a college of engineering. For instance, Virginia Tech has many other opportunities for civil engineers, particularly within the Department of Building Construction, under the College of Architecture. The University of Florida benchmarking report identified 15 colleges or universities with similar sustainability 'groupings' [Appledorn, 5]. Further testing and implementation of the metric would capture many of these courses, as long as at least 50% of the students are 'other engineering'.

CONCLUSION

The research identified the need for coverage of sustainability for undergraduate civil engineers and the benefits a metric of the coverage would provide. This project identified categories that could combine to form a method for assessment. The currently assigned weights serve the purpose of getting the ball rolling towards a metric, but the first step in further research would be the validation of the categories and weights. Not only does this metric have the capability of being implemented in a similar fashion as the U.S. News & World Report and the Green Report Card, but once vetted by education and industry professionals may serve as a general framework for sustainability topics for current and future courses. When the education sector is aware of how they compare and fully understands the needs and wants of the industrial sector to which they are providing graduates, they may better produce results that meet or exceed those expectations.

Table 1 Course and University Sustainability Subtotals

	Arizona State University	University of California, Berkeley	University of California, Davis		Carnegie Mellon University			University of Delaware	University of Florida	Georgia Institute of Technology			University of Houston	University of Illinois at Urbana-Champaign	Michigan Technological University	University of Michigan	University of Nebraska-Lincoln	University of New Hampshire	Oregon State University	University of the Pacific	Rice University	Santa Clara University	University of South Florida	The University of Toledo	University of Virginia	Coverage of Topic
CSE Syllabus offered by CE or with over 50% 'other engineering students	10	6	29	64	21	35	37	33	55	5	16	34	18	39	57	53	47	38	54	56	12	60	51	19	62	
Three Pillars of Sustainability																										
Environmental	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x		92%
Economic		x	x	x	x				x	x		x			x	x	x	x	x		x	x	x			60%
Social	x			x	x	x	x		x	x		x			x	x			x			x	x			52%
Life Cycle Analysis/Planning		x	x	x	x			x				x			x	x	x	x		x		x	x	x		56%
Design for the Environment (DFE)		x				x		x										x								16%
Industrial Ecology	x	x				x						x						x								20%
Material Flow Analysis (MFA)			x		x	x	x						x											x		24%
Natural Resource Management	x		x				x	x										x			x					24%
Policy and Regulations									x		x						x		x	x	x					24%
Economics (excluding short-term cost analysis)		x	x							x		x						x			x	x				28%
Pollution Prevention		x	x					x			x	x	x	x			x	x								36%
Climate Change											x	x				x			x		x	x				24%
Renewable Energy											x							x	x		x					16%
Green Design/Engineering			x		x				x						x			x	x	x						28%
Reuse and/or Recovery of Products and Materials														x												4%
Decision Making									x	x					x						x			x		20%
Systems Engineering/Approach	x	x								x													x			16%
Project Life-cycle cradle to grave		x	x							x						x										16%
Environmental/Sustainability Ethic	x									x																8%
Technology Assessment Tools		x			x	x	x				x				x									x		28%
LEED																		x		x		x		x		16%
Global Considerations	x			x		x	x	x	x		x	x			x				x	x	x	x				52%
Sustainable Development							x								x				x			x		x		20%
History of Sustainability/Environmental Concerns (not case studies)							x					x														8%
Integration with other (non-CE) topics/studies	x																			x						12%
Site Visits/Field Trips		x		x													x			x	x		x			24%
Community Engagement				x																						4%
Offered by Civil Engineering	x	x	x	x	x	x	x	x		x			x	x			x	x		x	x	x	x	x	x	76%
Student Level	1	2	1	1	3	2	2	2	1	1	3	3	1	3	3	2	2	2	1	1	2	1	3	3	1	
% of course focused on sustainable engineering	4	4	4	4	4	4	4	4	0	3	4	4	1	2	4	4	4	4	4	4	3	4	3	4	1	
Course Sustainability Subtotal (CSS)	0.67	0.67	0.70	0.72	0.68	0.64	0.65	0.56	0.40	0.68	0.48	0.66	0.33	0.34	0.65	0.65	0.62	0.69	0.72	0.51	0.59	0.77	0.58	0.53	0.23	
University CSS (UC)	0.59	0.59	0.70		0.74			0.50	0.38	0.71			0.33	0.34	0.57	0.57	0.55	0.60	0.62	0.46	0.52	0.66	0.52	0.48	0.25	
Average UC	***0.53***																									

Legend	
Student Level	
1	Undergraduate
2	Undergraduate/Graduate
3	Graduate
% of Course Focused on Sustainability	
1	< 10%
2	10-25%
3	25-50%
4	> 50%

Table 2 UCESEM Results

	UCESEM	2010 Green Report Card (GRC)	2009 GRC	GRC One-Year Change	University Course Sustainability Subtotal (UC)
University of New Hampshire	1.19	3.7	3.7	0	0.60
University of California, Davis	1.18	3.3	3.3	0	0.70
Carnegie Mellon University	1.16	3	3	0	0.74
Georgia Institute of Technology	1.13	3	3	0	0.71
Arizona State University	1.12	3.7	3.3	0.4	0.59
Santa Clara University	1.09	3	3	0	0.66
Oregon State University	1.08	3.3	3	0.3	0.62
University of Michigan	1.04	3.3	3	0.3	0.57
University of California, Berkeley	1.04	3	3	0	0.59
Rice University	0.95	3	2.7	0.3	0.52
University of Florida	0.93	3	3.3	-0.3	0.38
University of Nebraska-Lincoln	0.87	2.3	2.3	0	0.55
University of Delaware	0.82	2	2.3	-0.3	0.50
University of Illinois at Urbana-Champaign	0.79	2.7	2.7	0	0.34
University of Virginia	0.77	2.7	3	-0.3	0.25
University of South Florida	0.74	2	1.7	0.3	0.52
The University of Toledo	0.67	2.3	1.3	1	0.48
University of Houston	0.64	2.7	1.7	1	0.33
University of the Pacific	0.6	2	1	1	0.46
Michigan Technological University		N/A	N/A		0.57

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