AC 2010-352: INTRODUCING FIRST-YEAR CIVIL ENGINEERING STUDENTS TO SUSTAINABILITY

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Introducing First-Year Civil Engineering Students to Sustainability

Abstract

As articulated in the Body of Knowledge for Civil Engineering, all civil engineering students should be introduced to the concept of sustainability. The objective of this project was to integrate sustainability concepts into the 1-credit Introduction to Civil Engineering course that first year students are required to take at the University of Colorado at Boulder. Student attitudes about sustainability were evaluated using a written survey and in class questions to which students responded using a Course Response System (clickers). Evidence of student learning on sustainability was acquired via student performance on a homework assignment worth 12% of their overall course grade. Evidence that the students incorporated sustainability into their concept of civil engineering was also collected based on other course assignments. There is some evidence that female and minority students may be more likely to articulate the importance of sustainability in the context of civil engineering, although more research is needed on this topic due to the small numbers of female students in the class.

Background

All engineers should be familiar with the concept of sustainability. ABET lists sustainability as one of the constraints for engineering designs under Criterion 3 Program Outcome C.[1] The National Academy of Engineering's (NAE) The Engineer of 2020 report notes "Engineering practices must incorporate attention to sustainable technology, and engineers need to be educated to consider issues of sustainability in all aspects of design and manufacturing."[2] Davidson et al.[3] strongly lobby for the incorporation of sustainability into the "toolbox" of all engineers. This same group recently published the results of a study which attempted to benchmark sustainable engineering education. In their survey of engineering department heads with more than 270 respondents, more than 80% reported teaching sustainable engineering focused courses or the integration of sustainable engineering material into existing courses.[4] Increased attention and interest in teaching engineers about sustainability, sustainable development, and sustainable design is also evident based on the number of papers presented at the ASEE annual conference that include these keywords in their titles, as shown in Figure 1.

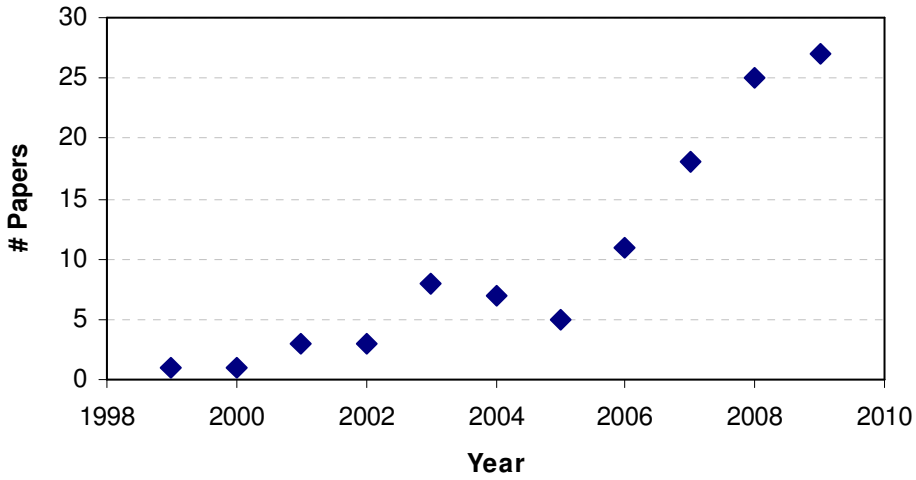

Figure 1. Number of papers presented at the ASEE Annual Conference that pertain to sustainability, sustainable development, or sustainable design based on their titles

In civil engineering, the American Society of Civil Engineers (ASCE) began to strongly endorse the importance of sustainability and sustainable development in 1996 in its Code of Ethics, stating in Fundamental Cannon 1: "Engineers shall hold paramount the safety, health and welfare of the public and shall strive to comply with the principles of sustainable development in the performance of their professional duties" (http://content.asce.org/Sustainability.html).[5] More recently, the ASCE adopted Policy Statement 418 to define "The Role of the Civil Engineer in Sustainable Development."[6] The ASCE Civil Engineering Body of Knowledge 2nd Edition (BOK2) articulates the role of civil engineers "entrusted by society to create a sustainable world and enhance the global quality of life...."[7] The BOK2 lists sustainability as one of the required technical learning outcomes. Individuals with a Bachelor's degree in Civil Engineering should have achieved an application level knowledge (level 3) of Bloom's taxonomy in regards to sustainability. Specifically, civil engineering B.S. graduates should be able to: (1) define sustainability in regards to engineering projects, society, and as an ethical obligation for engineers; (2) explain the properties of sustainability that pertain to engineering projects; and (3) apply the principles of sustainability to the design of engineering systems. Prior to professional licensure, civil engineers should gain through experience Bloom's level 4 such that they can analyze engineered systems for sustainable performance. Examples of efforts to integrate sustainability into civil engineering education have been reported by Sutterer and Robinson[8], Hadgraft et al.[9], Bosscher et al.[10], Lynch et al.[11], Koehn et al.[12], and Bramald and Wilkinson[13]. However, many programs may not yet be meeting the BOK2 requirements in regards to educating students in the area of sustainability. Of ten programs evaluated to determine if all of the sustainability outcome at a given level of achievement was fulfilled by all of their B.S. graduates, only 6, 3, and 2 reported fully meeting the first, second, and third levels of achievement, respectively.[14]

At the University of Colorado at Boulder (CU) some students have said "I'll worry about sustainability if I'm working on an environmental engineering project, but it doesn't impact structural engineering..." or similar statements. Thus, because historically sustainability was largely covered in the environmental engineering courses in their curriculum, the students tended

to compartmentalize this information. However, sustainability is truly important for all civil engineering projects. For example, the external Joint Evaluation Committee (composed primarily of professionals that employ graduates from our program) that evaluated the structural engineering and mechanics courses in the CU curriculum in 2007 suggested that concepts of sustainability should be introduced in one or more courses. Many civil engineering students do recognize the importance of sustainability. A survey on the relative importance and coverage of the ASCE BOK2 outcomes that was administered at the end of the semester in fall 2009 to 68 seniors in the civil engineering capstone design course; 5 of the 62 respondents rated sustainability in the top three most important outcomes among the 24 BOK2 outcomes.[15] In addition, 27 of 58 students listed sustainability as one of the top three topics that should receive more coverage in their B.S. curriculum. Furthermore, in previous surveys of graduating senior students a few comments on sustainability have been made. For example, in May 2005 one student wrote: "I think sustainability should be a required class for all engineers because it is the cutting edge of thinking. CU's engineering program would have a greater appeal if it placed more emphasis on incorporating sustainable ideas." In the senior survey given in May 2007, under the "should improve" category one student wrote: "I like the sustainability and developing world engineering focus that is starting to perk up; I think classes like this need to be offered more often."

Due to the fact that required courses in the civil engineering curriculum at CU currently comprise all but 6 credits of technical electives and 18 credits of humanities and social science electives, it was determined that requiring a new course entirely focused on sustainability was not a viable option. A popular senior elective course "Sustainability and the Built Environment" was taught by civil engineering professor Bernard Amadei from 2003 – 2007; the course counted as a social science elective with the exception of one semester in which the course had a hands-on project requirement.[16] Many other universities have sustainability-focused courses available, as summarized in the benchmarking study conducted by Allen et al.[4] These courses are most often electives and targeted to upper division/graduate level students. In their survey, 64 civil/architectural/environmental engineering courses were identified. The "Green engineering and Sustainability" upper division elective course at Michigan Tech and Yale University is one example.[17] Another example is a seminar course at Lamar University.[12]

An alternative approach to upper level elective courses is to introduce sustainability at the beginning of the civil engineering curriculum. It was hoped that utilizing this strategy would better educate students that all civil engineers need to consider sustainability on all projects. A first-year course focused on sustainability for civil engineering students has been implemented at Newcastle University, which is equivalent to about a 2-3 credit U.S. semester-based course.[13] The course at the University of Colorado that was targeted for inclusion of sustainability was only 1 credit. Achievement of Bloom's level 3 for sustainability in the single unit within this one credit first year course seemed overly ambitious, so the define and explain proficiencies in regards to sustainability were targeted. Sustainability is also covered in the Fundamentals of Environmental Engineering course (taken by juniors), sometimes in Engineering Geology (a sophomore/junior level course), and in the senior capstone design course. The capstone design course reaches Bloom's level 3 analysis; per the syllabus: "Students synthesize technical knowledge from prior courses, incorporating aspects of ethics, sustainability and safety. The

course will consider multiple constraints, including economics and engineering standards as well as social and political issues."

It was also of interest to determine if focusing on sustainability might appeal to groups traditionally under-represented in engineering. This has been proposed in various studies, although not definitively proven.[18] At Carnegie Mellon University in Civil Engineering there were above average percentage enrollments of African American, Asian American, and native American students; this department hosts the Green Design Institute.[18] The leadership of Engineers Without Borders (EWB)-USA student chapters also has a significantly higher representation of women than engineering-wide.[18] The Sustainable Futures Institute at Michigan Technological University also noted a high percentage of female participation in their programs.[19] Nationally, environmental engineering has the highest percentage of female students, with 43.2% of all B.S. degrees in 2007-2008 awarded to women;[20] perhaps this is partially attributable to the obvious linkage of environmental engineering and sustainability. In comparison, only 21.1% of civil engineering B.S. degrees were awarded to women in 2007-2008.[20] Older data for civil engineering employment from 1995 showed 9% women (compared to 17% of BS degrees), 12% Asian, 4% Hispanics, and 2% African-American.[21] The diversity in civil engineering employment was lower than the diversity of all engineering student graduates.

In order to measure students' understanding of sustainability, it was desirable to use an instrument already developed, such as a "sustainability literacy" test. However, such an instrument that pertained to college-level engineering students was not located. Michalos et al.[22] measured knowledge, attitudes, and behaviors towards sustainable development using an instrument composed of 17 true/false knowledge questions, 15 attitudes questions rated on a 5-point Likert scale, and 15 true/false behaviors questions. The survey was administered to households and grades 6 to 12 students in Canada. Most of these items seemed somewhat too generic to use in an engineering context. deVries and Petersen[23] discussed a methodology to understand individuals' values, knowledge, and worldviews pertaining to sustainable development. This was largely proposed to be evaluated via scenarios that are posed. However, no specific evaluation instruments are presented. Spiroupula et al.[24] evaluated primary teacher attitudes on sustainable development in Greece using a four part survey: (1) demographics; (2) environmental literacy; (3) attitudes; and (4) experience and motivation to promote environmental education. The environmental literacy section included an open-ended question to define sustainability; required classification of 6 energy sources as renewable or non-renewable; and ranking the importance of global environmental problems (which seemed more opinion than knowledge based). The five attitude questions were multiple choice/rating questions. Part 4 was simply 2 questions on teacher involvement in environmental programs. Interestingly, this survey seemed more about only green/environmental issues than sustainability. These instruments were consulted when developing the sustainability questions used in this research. The sustainability survey used for this research is presented in the Appendix. Questions 1 and 6 were used by Bramald and Wilkinson[13], while the remaining questions were based on the Kagawa[45] study; questions 2, 3, 4, 5 were identical to Kagawa[45] survey questions and questions 8, 9, 10, 11, 12 were similar.

Research Goals

The goals of this study were to introduce sustainability into a required first year civil engineering course and determine the impacts on the students. The unit on sustainability was coupled with an evaluation of student attitudes and perceptions of sustainability, measured using an anonymous written survey administered in-class and in-class Clicker questions. The success of the module was evaluated in the short term using direct measures of student learning evident from course assignments. It was also of interest to determine if student attitudes or performance varied based on gender or race/ethnicity. Therefore, to the extent possible the results were parsed based on the gender and the race/ethnicity of the students. Data from 2008 when a module of sustainability was not included in the course served as a comparative baseline.

First Year Civil Engineering Course

At the University of Colorado at Boulder (CU), all engineering students are required to take a 1-credit introductory course to their major in the first year. The historical goals of the Introduction to Civil Engineering (EVEN) course were: (1) describe what civil engineering is and what civil engineers do; (2) establish a context for using the information that the students are learning in their other classes; (3) provide a framework for evaluating ethical behavior; and (4) show the breadth and excitement of the civil engineering profession. The course includes a series of modules, followed by guest speakers who are faculty or working engineers to describe the various sub-disciplines in CVEN. Some of these guests mentioned sustainability in their talks; for example, in both 2008 and 2009 the guest speaker on construction management briefly mentioned the increasing importance of LEED certification. There were 6 to 7 written assignments in the course; these are summarized in Table 1. The assignments are presented in Table 1 in the order that the students completed them during the semester. Many of these assignments have been refined over time since I began teaching the course in 1997.

Table 1. Homework Assignments in the First Year Civil Engineering Course at CU

Year	2008	2009
Assignment: description	% course grade	
Introductory Exercise: *basic information on civil engineering*	6	6
Sustainability homework	N/A	12
Ethics paper: *from the Online Ethics Center analyze 3 case studies and read about a moral exemplar; compare ASCE Code of Ethics[5] to CU Student Honor Code*	20	20
Team bridge competition in West Point Bridge Designer: *teams of 4-5 students create a bridge using the WPBD software in an attempt to optimally fulfill specified weighted design criteria and describe their design process*	30	24
Course plan and curriculum mapping: *outline courses that fulfill the CU CVEN requirements and illustrate how these courses teach the skills needed for licensure*	10	10
Civil engineering Controversies, Disasters, and Feats slides and paper	22	16
Professional society meeting write-up and Reflective Essay	12	12

The Civil Engineering course met for 50 minutes once per week over the 15 weeks of the semester. In 2008 and 2009, the course was supported using online facilitation software. This courseware was used to provide homework assignments and associated reading materials to the students, copies of lecture slides, and was used by the students to submit electronic files of

homework for grading. Some of the ~300 students who enter the College as open engineering majors enrolled in the course, rather than a different introductory course that introduced all of the engineering majors.

The basic demographics of the students in the course are summarized in Table 2. The large enrollment boost in 2009 is due in part to acquiring a larger classroom for the course and therefore more non-civil engineering (CVEN) students were allowed to enroll. Some students drop the class or change majors partway through the semester; the demographics shown represent the initial enrollment. The national values for civil engineering and engineering-wide are shown for comparison in italics. The percentage of female and minority students in the first-year civil engineering course at CU are generally similar to the national trends.

Table 2. Demographics of Students in the First Year Civil Engineering Course at CU

Course year	# students	% female	% Hispanic	% Asian-American	% black	% first year	% CVEN majors
2008	56	18	4	4	2	86	79
2009	78	17	12	5	1	65	53
U.S. CVEN	*10,132 G* *50,167 E*	*21.1 G*	*11.3 e*	*6.4 e*	*4.1 e*	*N/A*	*N/A*
U.S. engineering	*74,170 G* *403,191 E*	*18.0 G* *17.9 E*	*6.5 G* *8.1 E*	*13 G* *11.9 E*	*4.7 G* *5.9 E*	*N/A*	*N/A*

N/A = not applicable; G = graduating undergraduates in 2008[20]; E = undergraduate enrollments in Fall 2008[20]; e = undergraduates in fall 2004[25]

Sustainability Module in the First Year Course

The fall 2009 introductory civil engineering course was modified to add an emphasis on sustainability. The learning objective associated with the new sustainability module was: students will be able to define sustainability and explain how it pertains to civil engineering projects. The interesting presentation by Bramald and Wilkinson[13] in summer 2008 was partially responsible for motivating this change. Sustainability was added as a module encompassing the second and third lectures in the course, and a written homework worth 12% of the total course grade. A written pre-survey on sustainability (shown in the Appendix) was distributed at the start of the first sustainability lecture. The survey measured students' self-rated knowledge and attitudes about sustainability. The lecture slides included: definitions of sustainability from the Bruntland Commission[26] and the ASCE[5]; a definition of sustainable engineering[27]; a discussion of the three pillars of sustainability; the importance of sustainability as articulated by ABET[1], the National Academy of Engineering[2], and ASCE[7,28]; unique challenges of international sustainable development[29] and the United Nations Millennium Development Goals[30]; incorporation of sustainability into the engineering design process; global urbanization; global climate change evidence[31], potential impacts[32], and management via the wedge principle[33]; energy consumption and the Human Development Index[34]; global water demands[35]; the Limits of Growth[36]; and life cycle assessment and ecological footprint analysis. The students were supplied with the lecture slides and associated references to learn more on their own. These lectures included in-class response questions using Clickers to gage student attitudes and provide real-time feedback to share the group opinions with the class as a whole.

The homework assignment related to sustainability was due one week after the second sustainability lecture. The homework assignment included six questions. First, the students were asked to define sustainability and identify the three pillars of sustainability. This provided evidence of whether the students achieved the minimum level of knowledge to satisfy BOK2 level 1 proficiency. Second, the homework required the students to read the Royal Academy of Engineering's "Engineering for Sustainable Development" report[37], identify the guiding principles of engineering for sustainable development, and select which they deemed most important and discuss why. Third, the students discussed the sustainability aspects of the Jubilee River, UK, flood control project.[37] Fourth, the students read and summarized the Civil Engineering and Climate Change Protocol.[38] Fifth, the students selected 1 of 4 documents related to climate change impacts on civil engineering, and discussed these impacts. [32,39,40,41] Finally, the students read the ASCE's U.S. infrastructure report card[42], selected one of the case studies, and discussed how it demonstrated fulfillment of each of the three pillars of sustainability. The third and fifth portions of the assignment provided direct evidence that the students attained level 2 in Bloom's taxonomy, comprehension of sustainability. Web-links to each of the readings were provided in the assignment to enable the students to access the required materials to complete the assignment. The assignments were graded by an undergraduate teaching assistant, and then the author re-read the assignments to document the students' demonstrated knowledge of sustainability.

Other Assignments that Provide Evidence of Student Attitudes Regarding Sustainability

The electronic files of the course assignments from 2007 to 2009 were examined using the word search function in Windows Explorer to look for the terms "sustainability" and/or "sustainable". In the first assignment that was due the second week of class, students were asked to define civil engineering and select the five most important skills for civil engineers. The students may have elected to include reference to sustainability in their discussion, but were not prompted to do so.

In the West Point Bridge Designer team assignment in 2009, the bridges were graded on criteria that embraced sustainability. Specifically, the weighted judging criteria to determine the best bridge were: economics (cost) 42%; environmental impacts 22%; social (aesthetics by vote of class) 13%, and deflection during truck load 23%. This is the first year that environmental impact was included among the grading criteria for the bridge. In 2008 the bridges were judged based on: economics (cost) 47%; deflection under truck load 38%; and aesthetics by vote of the class, 15%. In 2009 the potential environmental impacts of bridges were discussed in class, such as: that excessive "cut" of the land down to the river greatly disturbs the natural environment; a pier in the middle of the river will disturb the riverbed during construction and therefore impacts fish spawning; energy use during manufacture of the steel (quenched and tempered steel goes through two heating cycles thus consuming more energy, etc); energy consumption and air pollution during construction (bridges with fewer members can likely be constructed more rapidly); etc. The student teams wrote a justification of how they determined their best team bridge. Students were also provided with two reports that related to life cycle assessment of bridges.[43, 44]

Other assignments in the course also provide some insight into student attitudes regarding the importance of sustainability. Student's completed an outline of courses they would take to earn their BS degree in civil engineering and then mapped these courses to the BOK2. This required the students to identify which courses in their curriculum would teach them about sustainability. The other course assignments did not ask the students anything specific in regards to sustainability, but students may have included this in their discussion. The ethics assignment required the students to compare the ASCE Code of Ethics to the student code of conduct, required them to use the online ethics website to explore three case studies and a moral exemplar of their choice. After using the word search function, the assignments were also examined manually to ensure that the use of the term "sustainable" in the document was not based solely on the quotation of the ASCE Code of Ethics Fundamental Canons (which was a required portion of the assignment), but rather the student was citing the mandate for sustainable development in their justification of the ethical course of action in the case studies and/or for the moral exemplars. For the controversies, disasters, or feats paper, students were assigned to one of 15 topics (such as the bridge collapse in Minneapolis, the levee failures in New Orleans, etc.), conducted research on this topic, and then wrote a 3 to 6 page essay describing the project and the contributions of civil engineers. In the final assignment the students were asked to reflect on civil engineering and what they had learned during the semester.

Results

Sustainability Survey Results

In the first homework assignment in the course in 2009 (prior to the lectures on sustainability), 23% of the students included the words "sustainability" or "sustainable" in their discussion; this was similar to the 2008 students at 17%. A higher percentage of the female and minority students included sustainability in their definition and/or discussion of civil engineering (see Table 4). Based on the results of the first homework, it was expected that some of the students already had some familiarity with sustainability. This was evaluated on the day the sustainability unit was introduced in lecture, by asking the students to complete a 12-question survey (shown in the Appendix) at the beginning of class.

Sixty-nine of the 78 students completed the survey, and 74% correctly identified the three pillars of sustainability as economic, environmental, and social; by comparison, only 57% of the students who logged in their responses using the in-class clicker system correctly identified the three pillars of sustainability. The reason for the differences in the hard copy responses versus the in-class course response system (Clickers) is unclear, although some of the students may not have submitted both the written survey and Clicker responses. Among the female students, 80% correctly identified the three pillars of sustainability on the written survey. The students most commonly indicated that they were slightly familiar with the term sustainability (average 2.8 where 2=somewhat familiar and 3=slightly familiar). Only 10% of the students reported having a previous course in sustainability, and 10% also indicated that they had previously been involved in an out-of-school sustainability-related activity. Table 3 summarized the average student ratings of their personal level of agreement with 7 statements on a scale of 1 (strongly disagree) to 4 (strongly agree). These results indicate that students are generally supportive of including sustainability in their education as civil engineers. There were not significant differences in these responses for female vs. male students.

Table 3. Student Responses to the In-class Sustainability Survey (shown in Appendix)

Statement	Average Student Rating
Sustainability is a key component of civil and environmental engineering	3.55
Sustainability is a key component of all engineering disciplines	3.25
Sustainable development is a good thing	3.55
I am a passionate advocate of sustainability	2.83
Studying sustainability is a waste of time	1.62
The earth has plenty of natural resources for future generations	1.86
Technological progress will overcome all ecological problems we face and eliminate extreme poverty within my lifetime	1.86

When asked in-class on how severe they thought problems related to climate change would be, 47% indicated moderate and 38% said severe. For the most severe environmental problem currently facing our planet, depletion of natural resources ranked the highest (49% of the students), followed by climate change (20%), water issues (19%), loss of habitat (7%), and air pollution (7%). The in-class course response system was a nice method to stimulate discussion.

Sustainability Assignment

In general, the students performed well on the sustainability homework assignment, earning an average and median percentage of 91% and 93%, respectively. The definitions demonstrated a range of depth of understanding, but most of the students (77%) covered the key aspects including all three pillars. The most common elements lacking from the student definitions of sustainability were a clear indication of preservation for future generations (19%), social impacts (8%), and/or economic impacts (3%). However, some students simply quoted the Brundtland[26] (14%), Mihelcic[27] (8%), or ASCE[5] (1%) definitions. All of the female students had complete sustainability definitions. Among the American caucasian non-hispanic males, only 75% had complete sustainability definitions; similar to the 78% of the Hispanic students with complete definitions and 67% of Asian-American students with complete definitions. Therefore, female students showed somewhat better attainment of level 1 knowledge of sustainability than their male peers.

The students felt that the most important of the 12 sustainable development principles presented by the Royal Academy of Engineering[37] were: 1. look beyond your own locality and the immediate future (27%), 3. seek a balanced solution (14%), and 12. practice what you preach (13%). The most popular document of the four climate change readings selected by the students was the report on the U.S. transportation system[39] (50%), followed by the global climate change document[40] (27%). Therefore, the list of choices may be narrowed in the future.

The final question on the homework assignment allowed the students to demonstrate that they could explain how the three pillars of sustainability were being fulfilled with one of the "raising the grade" examples in the ASCE infrastructure report card. On this question, 20 of the 69 students discussed dams while the other topics were less frequently selected. The economic factor was the most clearly described component in the student discussions; only two students failed to include any mention of economics in their discussion and 1 poorly described it. For the social pillar, three students failed to discuss how the project considered social impacts and eight students had a very weak discussion of this aspect. The social impacts commonly discussed

were human health and safety with improved bridges, dams, and levees; less delays in traffic and during construction activities; and jobs involved with rehabilitation activities. Environmental impacts was the sustainability pillar that the students did the poorest job describing. Six students made no mention of the environmental benefits of the project and four student discussions very weakly included environmental aspects. Many students noted the environmental benefits of reduced air pollution due to traffic delays on roads and at airports, and less consumption of natural resources due to fuel consumption during construction and/or transportation. The percentage of students from different demographic groups whose answers fully addressed all of the sustainability pillars were: 64% females, 79% U.S. Caucasian males, 75% Hispanics, and 100% Asian-Americans. Therefore, more male students demonstrated comprehension of sustainability aspects of civil engineering projects.

Bridge Assignment

Of the 16 teams, the average score on the environmental criteria was 91%. Only one team completely ignored environmental impacts by making a very large cut and putting a pier in the river. Other teams addressed environmental to varying degrees in their design and discussion. For example, one team wrote: "[The] bridge spanned the entire canyon's length, so the landscape was left intact. With the arch bridge, there was no burrowing or excavation done to lessen the span of the bridge. The arch bridge is completely made from carbon steel, and some of the members are hollow, too. The hollow tubes lessen the amount of material needed for manufacturing, and carbon steel requires the least amount of energy to create in comparison to high-strength low-alloy steel and quenched and tempered steel." Although the technical validity of the statements is questionable, it indicates that the students were at least considering various possibilities in terms of environmental impact. Another group wrote: "Although bridge two cut into the earth and may have a slightly negative impact in that area, it is made of minimal material and therefore should take less time and equipment to build; therefore, decreasing its overall impact on the environment. ...the use of large atmosphere-polluting machines can be kept to a minimum." In discussing one of the other pillars of sustainability, another group wrote: "... we didn't really have a social audience to dictate the direction and final design of the bridge...." One group stated: "From this project, we learned how important it is to balance environmental, financial, and societal situations. It is important that your bridge does not damage the environment, it does not cost too much, and it does not put the public in any danger. Overlooking any one of these key factors results in an unsuccessful bridge." This indicates that a properly designed project is an effective method to reinforce "lecture" based instruction on sustainability.

Other Course Assignments

In the course mapping assignment, students were asked to list one or more courses in their curriculum plan that fulfilled each of the 24 BOK2 outcomes. For the sustainability outcome, only 60% of the students listed the 1-credit Introduction to Civil Engineering course as fulfilling the "sustainability" requirement in the BOK2. The next most popular courses listed as fulfilling this requirement were: Fundamentals of Environmental Engineering (31%), Senior Capstone Design (21%), and Introduction to Construction (16%). All of these are correct responses. It was interesting that students listed a significant number of additional courses – in 2 cases stating "all CVEN courses", 1 student listing 20 different courses, etc.

Table 4 summarizes the number and percentage of students from different demographic groups who included sustainability in the discussions within the various homework assignments in the course. In 2009 when sustainability was covered as a unit in the course, 38% of the students later discussed sustainability in their ethics assignment; compared to a similar 36% students including sustainability on the same assignment in 2008. Sustainability was discussed in reference to a case study about potentially hazardous waste disposal and moral exemplar Fred Cuny. In 2008 when sustainability was not an explicit topic covered in full lectures and with an assignment, only 2 of 54 students (1 a female student) in the course discussed sustainability in their paper on a civil engineering project/controversy. By comparison, 17 of 71 students (including 3 females, 3 minority males, and 1 foreign student) in 2009 discussed sustainability in some fashion on this same assignment. In their final course essay, sustainability was discussed by only 7% of the students (3 were non-Caucasian males (Hispanic, black, and Asian-American) and 1 was a female) in 2008 compared to 51% of the students in 2009. Thus, even when the students were not explicitly required to discuss or consider sustainability in later course assignments they did consider it more frequently in 2009 when it was a specific topic covered earlier in the semester. In comparison, in 2008 the percentage of students discussing sustainability decreased from homework 1 to homework 7.

Table 4. Demographics of Students Who Discussed Sustainability in Various Assignments

Assignment	Year	# students	% students	% female	% Hispanic	% Asian	% black
Definition and overview	2008	5 / 29 †	17	0	0	0	0
	2009	17 / 75	23	33	43	25	0
Ethics	2008	10 / 28 †	36	50	0	0	NA
	2009	28 / 74	38	25	44	67	0
Controversy paper	2008	2 / 54	4	10	0	0	0
	2009	17 / 71	24	27	25	33	0
Final essay & professional society meeting	2008	4 / 56	7	10	50	50	100
	2009	39 / 72	55	55	50	100	100

* Note: not all of the students submitted the assignment, so the percentages are calculated from the fraction of students who submitted the assignment
† Based on the electronic files that were available for analysis; NA since essay from student fitting this demographic were not available for examination

Conclusions

The importance of the addition of sustainability into the curriculum for civil engineering students is supported by the ASCE Body of Knowledge. The basic understanding of sustainability and showing how sustainability has been implemented in civil engineering projects is easily incorporated into a first year course for civil engineers. The students largely agreed that sustainability was important and were interested in learning how climate change could impact the work of civil engineers. They retained an increased awareness of sustainability at the end of the semester, 12 weeks after the sustainability assignment was due, as evidenced by significantly more discussion of sustainability in their final course essays. Gender was not shown to cause significant differences in student interest or abilities in regards to sustainability.

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APPENDIX: Pre-survey to evaluate students' attitudes toward sustainability

PARTICIPANT INFORMED CONSENT

Completing the questions below will indicate that you have been informed about the study and that you agree to participate. The purpose of this study is to learn about student attitudes and how these may change while students earn their degrees in Engineering. This is not a test, so there are no right or wrong, good or bad answers. All responses will be anonymous and confidential: the top part of this form will be cut away from the bottom to award attendance points regardless of whether or not you complete the questions. The results in an aggregated form may be presented at conferences or in journals related to engineering education. Your participation entails no risk to you; it will not impact your grades. You are being asked to take part in a research project conducted by **Angela R. Bielefeldt, Ph.D., P.E.**, a faculty member in the University of Colorado at Boulder's Department of Civil, Environmental, & Architectural Engineering, 428 UCB, Boulder, CO 80309. Professor Bielefeldt can be reached at Angela.Bielefeldt@colorado.edu, 303-492-8433.

1. Select circle the 1 best answer below: What are the three pillars of sustainability?
(a) Finance: Infrastructure : Political
(b) Infrastructure: Political : Social
(c) Economic : Political : Social
(d) Economic : Environmental : Social
(e) Environmental : Financial : Political

2. Please rate your personal level of familiarity with the term SUSTAINABILITY:
(a) Very familiar (b) somewhat familiar (c) slightly familiar (d) not at all familiar

3. Please rate your personal level of familiarity with the term SUSTAINABLE DEVELOPMENT:
(a) Very familiar (b) somewhat familiar (c) slightly familiar (d) not at all familiar

4. Have you previously taken a formal course which addressed sustainability or sustainable development?
YES NO UNSURE

5. Have you previously been involved in an out-of-school sustainability-related activity?
YES NO UNSURE

Rate your personal level of agreement/disagreement with each of the following statements:

	Strongly disagree	Disagree	Agree	Strongly Agree
6. Sustainability is a key component of civil engineering				
7. Sustainability is a key component of all engineering disciplines				
8. Sustainable development is a good thing				
9. I am a passionate advocate of sustainability				
10. Studying sustainability is a waste of time				
11. The earth has plenty of natural resources for future generations				
12. Technological progress will overcome all ecological problems we face and eliminate extreme poverty within my lifetime				

Questions derived from Bramald and Wilkinson (2009), ASEE Annual Conference and Exposition, Paper AC 2009-541;and Kagawa (2007), International Journal of Sustainability in Higher Education, 8 (3), 317-338.