

Sustainability Principles within a Construction Education Curriculum Based on Student Learning Outcomes

Keith Rahn, M.A.
Auburn University
Auburn, Alabama

Sustainability in construction involves creating methods to conserve or prevent the depletion of natural resources and provide a quality environment for occupants in buildings. Sustainability is not an independent component in the construction process and affects different levels from planning through deconstruction. Construction management students entering the civil, industrial, institutional, commercial and residential markets must have an understanding of sustainable construction principles. The question is how to properly integrate the broadly based concepts of sustainability into construction program curriculum and assess the student learning outcomes (SLO). Post-secondary construction degree programs been challenged to meet governing accreditation criteria. This study examines how Auburn University Building Science (BSCI) program is integrating the principles of sustainable construction while performing a curriculum revision to meet the recently adopted American Council of Construction Education (ACCE) SLO standards. Each of the twenty prescribed student-learning outcomes requires programs to interpret the meaning based on the culture of the program, faculty and industry perceptions. Course learning objectives developed to each consented SLO meaning. Results of the curriculum revision presented shows a shift from a dedicated one-hour course on sustainable construction to integration across the curriculum and assessment in a final "capstone" class.

Key Words: accreditation, construction, learning, outcomes, sustainability

Introduction

Sustainability knowledge and generalization to all facets of any and every construction project is imperative. Integration of sustainability practices to the current curriculum is necessary for the development of future professionals needed to staff/man the industry. These professionals are of vital importance for an ever-changing environmental landscape. Environmental factors and history dictate the need for use of sustainability principles across all disciplines to lessen the environmental impact of construction on natural resources.

American Council of Construction Education (ACCE) mandated twenty student-learning outcomes for incorporation to current curriculums at the university level. Since the inception of student learning outcomes (SLO) standards, Auburn University has been working to develop course-learning objectives for each SLO meaning. This paper narrows the focus to #18 – understand the basic principles of sustainable construction of the 20 established.

Sustainability in construction involves creating methods to conserve or prevent the depletion of natural resources and provide a quality environment for occupants in buildings. To further foster development of conservation methods, the program utilized faculty and industry professionals to define the principles of sustainable construction. This realization by specifying the level of understanding needed for graduates to meet the minimum need of contractors and industries hiring these professionals in this specific region. Auburn University Building Science (BSCI) faculty are considering the method and placement of sustainability practices within the new curriculum.

Input from industry advisory board, two focus group events and current assessment data help guide the decision process.

The previous assessment method by ACCE was "hours based". This method's lack of flexibility for changes made curriculum development difficult for implementing new industry technology and methods. Inherently in the previous assessment, the guideline process delayed new to the governing procedures. New concepts such as Sustainability, BIM and Lean Construction industry were stand-alone courses within the curriculum. Many of these new concepts affect the industry in different ways and infusion throughout the curriculum is important. SLO assessment flexibility allows these concepts implementation into the curriculum at different points of the degree program. Auburn Building Science current curriculum model provides a 1-hour course "Introduction to Sustainable Construction" during the second semester of the student's first year in the program. Data from faculty assessment of required sustainable criteria in student's Senior Thesis Capstone project and results of exit interviews show a lack of understanding in comparison of other SLO measurement.

Auburn has sought to create measurable goals since implementing the integration of sustainability practices within the curriculum and across disciplines and has utilized the final capstone project as a source for identifying the individual student sustainability knowledge in addition to other industry practices. Since the fall 2014 semester, the program has been introducing new evaluation rubrics based on the proposed SLO's. Sustainability was one of the first rubrics developed and its use in evaluating student performance began in fall 2014. Each sustainable student-learning objective uses a 5-point scale. A rubric revision completed in fall 2015 continues as the current model used by instructors. By measuring the current curriculum with the new SLO assessment, data collected provides information of the effectiveness of the existing model structure for student learning in the area of sustainability.

Sustainability is a dynamic component of construction. Through accreditation, the university responsibility to develop measurable goals specific to construction. While limitations exist within the current curriculum model, Auburn University BSCI has demonstrated the use of data collection over multiple semesters as a measurable SLO with regard to accreditation and specifically sustainability.

Literature Review

Sustainability is a significant component of current construction practice yet opportunities to incorporate sustainable techniques have failed to generalize across the broad spectrum of construction discipline specialties. Utilization of current technology and advancements to insure positive outcomes for continued and future use is imperative. This has further challenged educators as well as industry professionals (Murray & Cotgrave, 2007).

Ahn and Pearce (2007) further establishes sustainability as an integral facet of construction and cites the cost savings during the life of a building when these practices are incorporated. Technology advances, however, has left current curriculums scrambling to incorporate practical sustainability methods that are up-to-date. Increasing effectiveness and value addition of sustainability practices is the amalgamation of BIM and sustainability combined with technology, research and collaboration (Berck-Gerb, et al, 2011). Academic institutions may also influence the speed at which industry accepts these practices; however, it has been difficult to discern whether academia or industry is leading the way.

Standardization of designing while incorporating sustainable theories is necessary to environmental ramifications and construction (Alahmad, Brink, Brumbaugh, & Rieur, 2011). Assimilation of sustainability within academic core measures to produce measurable goals and graduates needed by industry to complete project specific requirements and mandates. Construction firms often employ encouragement through funding additional training, continuing educational opportunities and examinations for LEED AP certification. Ahn and Pearce (2007) feel these contractor incentives are a direct attempt to foster companywide practice of the importance of sustainability inclusion in future projects. Construction professionals must rely on trade publications and conferences to decipher an ever-changing landscape of regulations and technological advancements.

Standardization of designing while incorporating sustainable theories is necessary for construction practices (Alamed, et al., 2011). Brown, Bornasal, Brooks, and Martin (2015) indicate that the current sustainability knowledge base has been industry dictated with academia responding by incorporation to the current curriculum. Again, citing the limitations dictated by lack of standardized practices. Varied and inconsistent academic incorporation has created barriers to further development of the sustainability knowledge base and established strategies not suitable for introduction of specific goals to the curriculum. The Top-down paradigm and best practices have shown to limit progress where curriculum development is desired (Brown, et al., 2015).

Cotgrave and Kokkarinen (2011) worked to further foster sustainability literacy by students with curriculum simulation. The model demonstrated changing student attitudes as well as differing knowledge basis for full and part time students. Construction management and building surveying students indicated most knowledge specific to sustainability initially combined with an overall false perception by students that best practices currently utilized.

SLO's as prescribed by ACCE require assimilation of sustainability within academic core measures to produce measurable goals and graduate outcomes (Alamad, et al, 2011). Conversion of current curriculum to incorporate sustainability into each facet is necessary with regard to positive impacts concerning the built environment. Current curriculums have been limited secondary to historical developments proceeding and a "disciplines-based framework" (Iyer-Raniga & Andamon, 2016). Rahn and Farrow (2016) cited the critical need for industry engagement in curriculum development. Lockrey and Bissett Johnson (2013) also present a need for industry-based partnerships with regard to curriculum review and refinement to improve learning outcomes with diverse outcomes established by cohort.

The understood value is recognized, however, no standardized protocol exists regarding course topic content. This also conveys a deep need for collaboration to incorporate sustainability within the core content and education of construction professionals (Wang, 2009). Curriculum reform is necessary to develop technical construction and problem-solving skills. 8-factors established as problems within current paradigms, which are as follows (Wu, Feng, Pienaar, & Zhong, 2015):

- Construction technology
- Information technology
- Problem-solving skills
- Construction economics
- Risk management
- Basic theories
- Business management
- **Sustainability science**

Steineman (2003) suggests student development through the introduction of sustainability in current curriculum with multidisciplinary adoption of subject matter. This introduction through problem-based learning (PBL) and is thought to be critical to skill development. Chau (2007) suggests a multidisciplinary skill set for knowledge to prevent environmental degradation; however, cites limitations with problem-based learning as a tool. Dib and Adamo-Villani (2014) propose no clear teaching method or curriculum design with utilization of serious games versus traditional learning methods. Game use within their study led to significantly increased procedural knowledge gains.

“Learning is important to sustainability (Foster, 2011).” Teacher objectives need to establish in conjunction with industry professionals. Further development of course objectives through utilization of the taxonomy for learning aids in creating a knowledge base for further generalization of a skill set into a student’s ability to create during their professional career.

Methodology

The American Council of Construction Education (ACCE) established minimum student learning objectives for construction education in 2015. Contact hours for specific courses and subject matter were required up until that point. The standards established were clear and direct and results in the university developing a construction curriculum based on the minimum standards; however, the accreditation body mandated no defined incorporation of the standards to the curriculum. Twenty prescribed student-learning outcomes (SOL) incorporated into the curriculum through collaborative program development by and between industry professionals, program faculty and institutional goals.

Resource were provided Auburn University Building Science faculty specific to the course learning outcomes. Members of the faculty to further foster discussion and development of learning outcomes reviewed this information. Bloom’s taxonomy provided to faculty members as the structured learning hierarchy model in which further reflected on the twenty prescribed student-learning outcomes. Poster size Bloom’s taxonomy pyramid with levels illustrated for each SLO outcome provided a creative way to show learning objectives. Faculty then populated the poster size pyramid with notes specific to the SLO identified and the hierarchical value level determined. These faculty suggestions placed on large “Post It®” notes to add suggested class level learning outcomes to achieve the overall class learning outcomes (Fig. 1). Industry focus group workshops used the same method.

Figure 1: Faculty input on learning outcomes for each SLO

Focus groups in Atlanta, GA and Birmingham, AL met to further develop and address areas that lacked sufficient detail specific to each SLO. The focus groups consisted of graduates of the program and industry professionals. Participants were knowledgeable specific to the industry with many years of experience.

The university tasked with determining how to achieve SLO mandated by ACCE. Outcomes have demonstrated moving away from the traditional “hours-based” curriculum and developing rather a hybrid curriculum specified by region and industry. SLO #18, understand the basic principles of sustainable construction, requires a minimum level of understanding in regards to Bloom’s taxonomy. Figure 2 illustrates the levels and stated outcomes for SLO #18 at Auburn University.

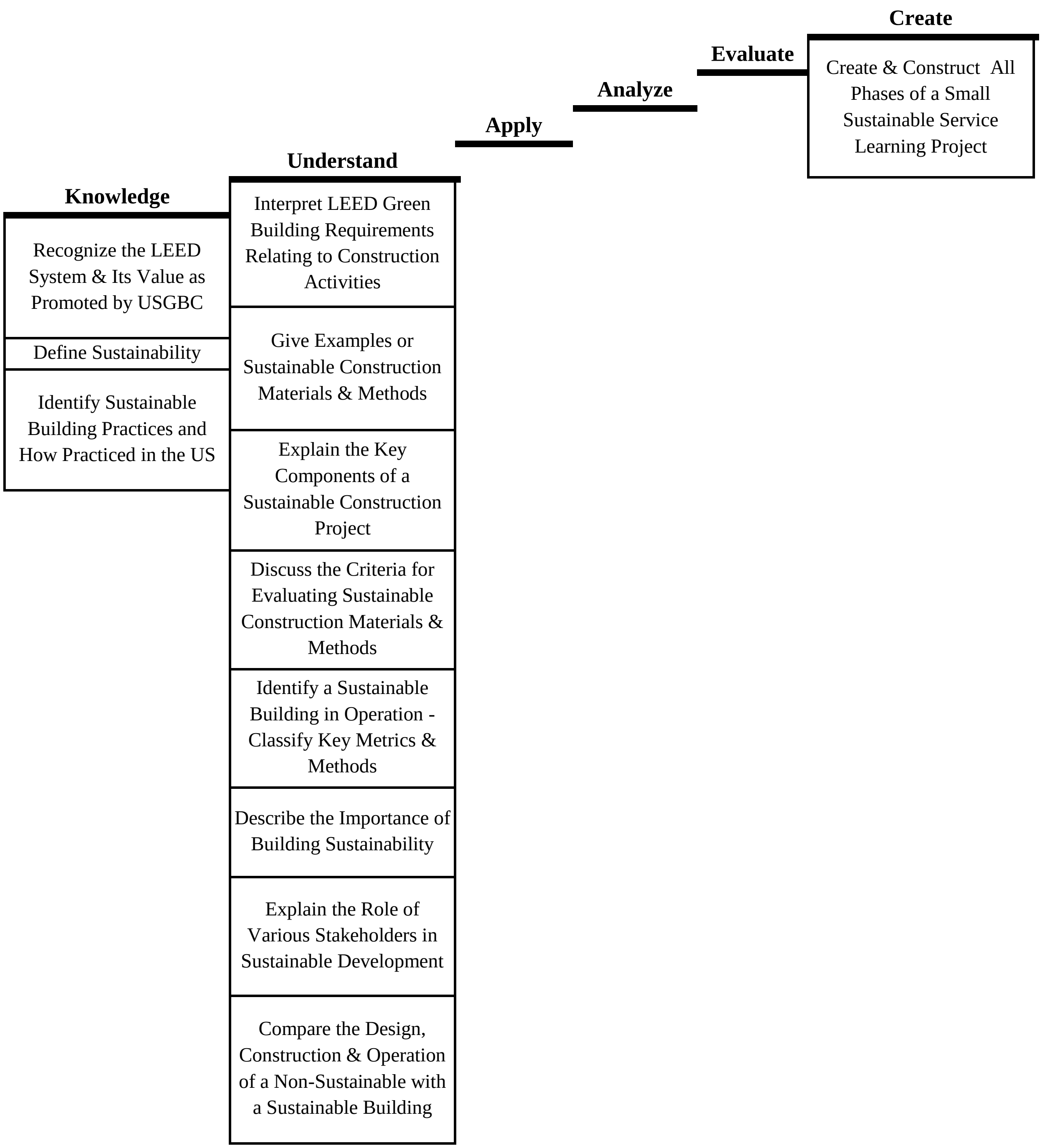

Figure 2: SLO #18 showing Bloom's Taxonomy Ladder and final learning outcomes

The research uses two data collection instruments to evaluate the level of student learning in relationship to SLO #18 outcomes and current curriculum model. First, the evaluation results by BSCI faculty of the thesis student performance to sustainable outcomes. Second, the exiting student perception of their ability to meet the sustainable outcomes.

Students must successfully complete their "Capstone" thesis during their final semester in the program. Each student must supply a set of construction documents, which meets the specified guidelines set by the faculty. Thesis guidelines are provided to the student before registering for the course and they are online in the schools webpage. The document clearly defines all the submission requirements and SLO evaluation rubrics. Figure 3 shows the criteria and each associated key metric required for evaluation of student competency based on the fall 2015 revisions. Each key metric is scored with a 5-point scale with five being all requirements are met and one for lack of evidence of student competency.

Criteria	Key Metric
Environmental impacts of construction activities on the site	Identify requirements that control site erosion and sedimentation
	Identify and describe 6 specific measures
Fundamental commissioning and verification	Identify and summarize project commissioning & verification requirements
	Identify and describe contractors responsibilities
	Identify 6 pieces of equipment and describe one process in detail
Environmentally preferable products	Choose 3 environmentally preferable products
	Explain how products are environmentally preferable
Reduce construction waste	Identify 3 material streams
	Describe how materials are collected and processed
	Site utilization plan for CWM
Indoor air quality (IAQ) management plan	Identify requirements and procedures and describe protecting the air distribution system
	Example of protecting absorptive material

Figure 3: Faculty sustainable criteria and metrics for evaluating "Capstone" thesis projects

Graduating students are required to attend an exit interview with the school head at the end of each semester. During the interview process, students are asked to rate their perception of ability to meet each of the 20 ACCE SLO's. Responses are recorded on a 5-point scale with five being "Strongly Agree" and one "Strongly Disagree".

Data Results

Tables 1 and 2 show the faculty averaged evaluation score of student performance based on SLO #18 criteria. Data collected and used for this research was from fall 2014 through fall 2015. The criteria revision in fall 2015 and evaluation scores shown in table 2.

Sustainable Evaluation Criteria For SLO #18	Evaluation Period		
	Fall 2014	Spring 2015	Summer 2015
Identify the appropriate LEED rating system for your project	4.47	4.48	4.32
Identify a material that has recycled content and provide documentation showing source of information	4.65	4.72	3.64
Calculate the % of the recycled material based on value	3.71	4.64	3.95
Provide a map of locally resourced material	4.59	4.28	2.41
Provide a table of locally resourced material	4.24	4.72	4.00
Calculate the $ amount that would be required to achieve 2 LEED points	3.94	4.48	3.82
Identify recycling service provider and services provided	3.94	4.42	3.68
Average Score Based on 5 Point Scale	4.22	4.51	3.51
Average Score Based on 100% Scale	84.37%	90.17%	70.13%
Number of Students Evaluated	17	25	25

Table 1: Student evaluation scores (5 point scale) based on Thesis Capstone performance to SLO #18

Sustainable Evaluation Criteria For SLO #18 - Revised	Evaluation Period
	Fall 2015
Environmental impacts of construction on site	4.52
Fundamental commissioning and verification	4.16
Environmentally preferable products	4.04
Reduce construction waste	4.28
Indoor Air Quality (IAQ) management plan	3.88
Average Score Based on 5 Point Scale	4.18
Average Score Based on 100% Scale	83.52%
Number of Students Evaluated	25

Table 2: Student evaluation scores (5 point scale) based on revise guidelines for Thesis Capstone performance to SLO #18

Table 3 illustrates the percentage of students scoring at or above various competency thresholds overall for SLO #18. Data based on the overall sustainability instructor evaluation determined by criteria performance.

Semester / Year	Percentage of Students Scoring Above			
	60% or 3.0	70% or 3.5	80% or 4.0	90% or 4.5
Fall 2014	94%	76%	59%	47%
Spring 2015	92%	88%	76%	64%
Summer 2015	64%	52%	36%	24%
Fall 2015	88%	88%	56%	28%
Average over 4 Semesters	84.5%	76.0%	56.8%	40.8%

Table 3: Percentage of students scoring above prescribed percentages

A comparison of the exit interview perception of SLO #18 in relation to the average score for all other SLO has shown in Table 4 based on student responses.

Semester / Year	# Reporting	Average score for SLO #18	Average score for other SLO's	Difference in score
Fall 2014	8	4.25	4.46	(.21)
Spring 2015	28	4.29	4.56	(.27)
Summer 2015	21	4.00	4.39	(.39)
Fall 2015	20	3.75	4.16	(.41)
Average over 4 Semesters	19.25	4.07	4.39	(.32)

Table 4: Student exit survey results concerning their perception of meeting SLO #18 outcomes

Conclusion

Sustainable knowledge and generalization to all facets of construction project is imperative. Curriculum revisions need to better support the delivery of sustainable concepts to students. Overall, sustainable evaluation data is good at 4.11 out of 5 point average based on faculty scores over four semesters, but shows the need for improvement. Faculty evaluations have been inconsistent each semester with no upward trend and student perception of their ability to meet SLO #18 outcome data consistently been lower compared to the others (Table 4). For the last three semesters of data, the student's perception of SLO #18 has declined. A common concern of students during the exit interviews is the amount of time between Introduction to Sustainability and the thesis evaluation process (Figure 4).

The BSCI program is in the process of revising the curriculum model to meet the new ACCE SLO standards, industry needs and the quality of education for students. In response to the data collected in the relation to SLO #18, the proposed curriculum model will eliminate the current introduction to sustainability course and distribute sustainable concepts in several courses throughout the curriculum (Figure 5).

Course	Sustainability Lectures	Semester
Introduction to Sustainability	14	2nd
Thesis (SLO #18 Assessment)		8th

Figure 4: Current Curriculum Model

Course	Sustainability Lectures	Semester
Introduction to Construction	2	1st
Material and Methods	3	2nd
Mechanical Systems in Buildings	6	6th
Electrical Systems in Buildings	1	
Analyzing Construction Methods and Materials	2	7th
Thesis (SLO #18 Assessment)		8th

Figure 5: Proposed Curriculum Model

Data collection will continue, through the BSCI quality control program, to evaluate the student performance concerning SLO #18. Further study will compare ACCE student learning objective performance changes due to the new curriculum model and methods of properly infusing concepts over several courses.

References

Ahn, Y. H., & Pearce, A. R. (2007). Green construction: Contractor experiences, expectations, and perceptions. *Journal of Green Building*, *2*(3), 106–122. doi:10.3992/jgb.2.3.106

Alahmad, M., Brink, H., Brumbaugh, A., & Rieur, E. (2011). Integrating sustainable design into architectural engineering education: UNL-AE program. *Journal of Architectural Engineering*, *17*(2), 75–81. doi:10.1061/(asce)ae.1943-5568.0000038

Brown, S., Bornasal, F., Brooks, S., & Martin, J. P. (2015). Civil engineering faculty incorporation of sustainability in courses and relation to sustainability beliefs. *Journal of Professional Issues in Engineering Education and Practice*, *141*(2), C4014005. doi:10.1061/(asce)ei.1943-5541.0000225

Chau, K. W. (2007). Incorporation of sustainability concepts into a civil engineering curriculum. *Journal of Professional Issues in Engineering Education and Practice*, *133*(3), 188–191. doi:10.1061/(asce)1052-3928(2007)133:3(188)

Cotgrave, A. J., & Kokkarinen, N. (2011). Promoting sustainability literacy in construction students. *Structural Survey*, *29*(3), 197–212. doi:10.1108/02630801111148185

Dib, H., & Adamo-Villani, N. (2014). Serious sustainability challenge game to promote teaching and learning of building sustainability. *Journal of Computing in Civil Engineering*, *28*(5), A4014007. doi:10.1061/(asce)cp.1943-5487.0000357

Foster, J. (2011). Sustainability and the learning virtues. *Journal of Curriculum Studies*, *43*(3), 383–402. doi:10.1080/00220272.2010.521260

Iyer-Raniga, U., & Andamon, M. M. (2016). Transformative learning: Innovating sustainability education in built environment. *International Journal of Sustainability in Higher Education*, *17*(1), 105–122. doi:10.1108/ijshe-09-2014-0121

Lockrey, S., & Bissett Johnson, K. (2013). Designing pedagogy with emerging sustainable technologies. *Journal of Cleaner Production*, *61*, 70–79. doi:10.1016/j.jclepro.2013.05.005

Murray, P. E., & Cotgrave, A. J. (2007). Sustainability literacy: The future paradigm for construction education? *Structural Survey*, *25*(1), 7–23. doi:10.1108/02630800710740949

Rahn, K. A., & Farrow, C. B. (2016). How is a Construction Curriculum Built from a Set of Learning Outcomes?

Steinemann, A. (2003). Implementing sustainable development through problem-based learning: Pedagogy and Practice. Journal of Professional Issues in Engineering Education and Practice, 129(4), 216-224. doi:10.1061/(asce)1052-3928(2003)129:4(216)

Wang, Y. (2009). Sustainability in construction education. *Journal of Professional Issues in Engineering Education and Practice*, *135*(1), 21–30. doi:10.1061/(asce)1052-3928(2009)135:1(21)

Wu, P., Feng, Y., Pienaar, J., & Zhong, Y. (2015). Educational attainment and job requirements: Exploring the gaps for construction graduates in Australia from an industry point of view. *Journal of Professional Issues in Engineering Education and Practice*, *141*(4), 06015001. doi:10.1061/(asce)ei.1943-5541.0000245