

## **A Method for Assessing Engineering Leadership Content in the Engineering Curriculum: A First Look at Civil Engineering Project Management Courses**

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## **Abstract**

The National Academy of Engineering, industry, educators, and professional engineering societies communicate the need for the 21<sup>st</sup> century engineer to understand the principles of leadership and to be prepared to lead in a variety of venues, including government. While many engineering schools support this proposition, many also lack an explicit functional mechanism by which to achieve it. Some schools may seek implicitly to foster leadership development in students through co-curricular group activities. Some existing engineering course curricula may contain implicit and explicit leadership components.

There is interest within the engineering leadership academic community to identify opportunities within the engineering curriculum for the integration of leadership learning. A first step towards this identification is the benchmarking of existing leadership content. We propose a standardized method for identifying the presence of engineering leadership content in curricula and suggest that the search for existing leadership content in the system of engineering courses should begin with exploration of a course that is likely to support this content: project management.

While leadership may exist in various other facets of engineering curricula, the American Society of Civil Engineers proposes that the civil engineering curriculum should prepare students for leadership, and civil engineering project management courses serve as a likely location to gauge the presence and prevalence of such preparatory leadership content. For the purposes of this paper, management and leadership are considered distinct yet related domains, and entry-level civil engineering project management served as a litmus test for identifying leadership elements within existing engineering curricula.

It was found that a standardized method of identifying implicit engineering leadership content within civil engineering project management curriculum yielded consistent results among three independent analysts (this paper's authors). Moreover, at the ten universities graduating the largest number of civil engineering undergraduates, two (of eight) engineering leadership criterion emerged as the most widely integrated within the current curriculum: "The Ability to Conceive and Design within Realistic Constraints," and "Understand Economic, Environmental, Global and Societal Contexts and Impacts." One criterion emerged as entirely absent from the ten universities: "Reflection and Lifelong Learning."

## **Introduction and Background**

Much has been written on the distinctions between management and leadership. Bass (1990) separates management from leadership in the following way: leaders facilitate interpersonal interactions and positive working relations and generate excitement at work; managers investigate, evaluate, supervise and control; leaders send out clear signals framing their purpose and mission and behave as themselves; managers are silent or ambiguous about their purpose and are more likely to see themselves as playing a part in a drama.<sup>5</sup> Similarly, Toor and Ofori (2008) separate management and leadership in engineering into two entirely different functions, and therefore define engineering managers and leaders as two distinct people; however, they acknowledge the usefulness of management skills in leadership and leadership skills in management.<sup>13</sup>

There are familial similarities between facets of management and leadership that argue perhaps for a continuum approach to their distinction. Within the domain of management, some observe a spectrum that distinguishes between *successful* managers at one end and *effective* managers at the other: successful managers receive quick promotions, while effective managers care for people, cultivate loyalty, and achieve high team performance.<sup>11</sup> The behaviors associated with effective management sound a great deal like the behaviors Bass (1990) associated with leadership. Further supporting this continuum concept, the total work of engineering management is seen by some to be comprised of (1) technical work, (2) conceptual work, (3) human work (i.e. leadership);<sup>9</sup> within this framework, engineering leadership exists as an important behavioral component of engineering management.<sup>7</sup>

It is not unreasonable then to allow management and leadership to be viewed as separate but partially related domains; this perspective allows mutual exclusivity at the respective unrelated domain extremes while accounting for the complementary nature of the skills and behaviors inherent in each at the common extremes. If one accepts this conceptual model, then an academic door opens that allows for - and perhaps requires - developing leadership skills within project management courses. Conversely, this approach also suggests a value for introducing certain project management tools and skills within leadership curricula. Notwithstanding the continued lively discussion on the topic, this continuum abstraction is an important foundation upon which this paper is premised: although leadership and management are two different systems, leadership and management are related; leadership and management are not entirely mutually exclusive and instead exist on a continuum; opportunities exist to find leadership in management curriculum just as opportunities exist to find management in leadership curriculum; opportunities exist to effectively incorporate elements of leadership into management curriculum just as opportunities exist to effectively incorporate elements of management into a leadership curriculum.

There is interest within the engineering leadership academic community to identify opportunities within the engineering curriculum for the integration of leadership learning. A first step towards this identification is the benchmarking of existing leadership content to identify promising entry and expansion points. To facilitate this benchmarking, this paper proposes a standardized framework. The American Society of Civil Engineers (ASCE) Engineer of 2025 challenged academia to provide “a more robust educational path for civil engineers that prepares them for leadership and provides the multifaceted non-technical skills to serve on projects affecting the public good”.<sup>3</sup> The ASCE Body of Knowledge (BOK) explicitly identifies leadership as an outcome (number 20 in ASCE, BOK2) necessary for entry into the professional practice of civil engineering.<sup>4</sup> At the undergraduate level, the ASCE BOK expects students to achieve leadership knowledge (define leadership), comprehension (explain leadership) and application (apply leadership). In 2008, Program Criteria for Civil and Similarly Named Engineering Programs were proposed by ASCE and accepted by ABET as accreditation requirements. These (civil engineering) programs are expected to provide a level of leadership comprehension for students such that students are able to explain the role, responsibilities, and attitude of a leader and the essential elements of leadership principles; this comprehension can be developed within existing courses, projects, or other forms of learning experiences.<sup>2</sup>

As the search for life in our solar system has begun with an exploration of the planet judged most likely to support life, Mars, we propose a similar approach for the search for leadership content in the system of engineering courses. As such, we present an initial exploration of a discipline and course most likely to support this content: civil engineering project management. Our justification for this investigation is that while management and leadership are not equivalent, one is more likely to find elements of leadership present in a project management class than to find those elements in, for example, a

thermodynamics class. Furthermore, assessing a facet of the curriculum that is likely to contain the sought-after evidence provides a viable opportunity to initially test this study's methodology for identifying engineering leadership content.

For the purposes of this paper, introductory civil engineering project management served as a litmus test for identifying leadership elements within existing engineering curricula. The introductory civil engineering project management curriculum was expected to be more ubiquitous and accessible to undergraduate engineering students than explicit leadership classes, and the subject more broadly embraced by the academic status quo: a 2005 study of over 40% of the US civil engineering programs (i.e. 90 programs studied out of 213 total) identified that while 37.8% of programs studied required a course in project management, only three of these programs (i.e. 3.33%) required a discrete course in either team building or leadership.<sup>12</sup> Although a semantic distinction exists within course titles, we maintain that civil engineering project management course content can include leadership elements of team development and effective communication; it can even explore the economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability of a project design and its impact in a global, economic, environmental, and societal context.

The paper offers a rubric for identifying the presence of leadership-related course content in an engineering class, tests this rubric, and reports the observed nature and extent of extant leadership within traditional introductory civil engineering project management courses at the largest US civil engineering programs. Introductory civil engineering project management course content was surveyed and the extent to which leadership-related content is currently incorporated within the curriculum identified. This paper represents a first step towards identifying and benchmarking the existence of elements of leadership within the engineering curriculum, and identification of opportunities for the integration of leadership within existing curriculum.

## **Methods**

Civil engineering project management (PM) syllabi were collected from ABET accredited US engineering schools graduating the largest numbers of BS civil engineers.<sup>14</sup> Each school's civil engineering department received an email requesting the syllabus for its introductory, undergraduate project management course. Schools were informed that the project involved researching course content within civil engineering project management courses. Syllabi were acquired for all schools solicited except for two that indicated that they did not have the relevant course. The ten resulting syllabi were analyzed for leadership content.

As mentioned earlier, there exist specific ABET requirements within the civil engineering curricula for students to be able to comprehend and explain the basic concepts of leadership. Because of this, syllabi were analyzed for the explicit word "leadership" to determine the presence of any explicit content addressing this required educational outcome. Recognizing that engineering programs may elect to develop leadership principles, attitudes, and capabilities without the explicit use of the word "leadership", a structured process and defined criteria for analyzing course syllabi for implicit leadership content was developed relying upon the following defined frameworks and models: (1) ABET a-k learning outcomes, (2) peer reviewed literature,<sup>6</sup> and (3) the Gordon-MIT engineering leadership capability categories,<sup>8</sup> which are based in large part upon the Ancona (2007) leadership model.<sup>1</sup> This structured process allows for future application in other engineering disciplines that do not have explicit leadership-specific comprehension requirements for the evaluation of courses other than project management, and/or for application on a larger-scale study,

Table I, below, summarizes the ABET learning outcomes that were considered and relied upon in part in developing a frame of reference for analyzing leadership content (note: the differences between EC2000 and EC 2002 are for criteria c and h).

**Table I – Summary of ABET Learning Outcomes: 2000 and 2002**

<b>ABET Designator</b>	<b>ABET EC2000 (a)-(k) Learning Outcomes</b>	<b>ABET EC2002 (a)-(k) Learning Outcomes</b>
<b>(a)</b>	An ability to apply knowledge of mathematics, science and engineering	An ability to apply knowledge of mathematics, science and engineering
<b>(b)</b>	An ability to design and conduct experiments, as well as to analyze and interpret data	An ability to design and conduct experiments, as well as to analyze and interpret data
<b>(c)</b>	An ability to design a system, component or process to meet desired needs	An ability to design a system, component or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
<b>(d)</b>	An ability to function on multidisciplinary teams	An ability to function on multidisciplinary teams
<b>(e)</b>	An ability to identify, formulate, and solve engineering problems.	An ability to identify, formulate, and solve engineering problems.
<b>(f)</b>	An understanding of professional and ethical responsibility.	An understanding of professional and ethical responsibility.
<b>(g)</b>	An ability to communicate effectively.	An ability to communicate effectively.
<b>(h)</b>	The broad education necessary to understand the impact of engineering solutions in a global / societal context.	The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.
<b>(i)</b>	A recognition of the need for, and an ability to engage in life-long learning.	A recognition of the need for, and an ability to engage in life-long learning.
<b>(j)</b>	A knowledge of contemporary issues	A knowledge of contemporary issues
<b>(k)</b>	An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

Table II, below, correlates the criteria employed in this paper for assessing PM course syllabi for leadership content with the ABET EC2002 outcomes, a salient literature reference<sup>6</sup>, and the Gordon-MIT engineering leadership capabilities<sup>8</sup>. The right-most column in Table II lists these derived criteria.

**Table II – Correlation: Bowman and Farr, Gordon-MIT, and This Study’s Engineering Leadership Criteria**

<b>ABET Designator</b>	<b>Bowman and Farr Engineering Leadership Criteria Correlated with ABET (a)-(k) Outcomes</b>	<b>Gordon-MIT Engineering Leadership Program: Leadership Capability Categories Correlated with ABET (a)-(k) Outcomes</b>	<b>Derived Criteria for Engineering Leadership Employed in this Study</b>
(a)	Not Assessed	<b>Technical Knowledge and Reasoning:</b> Essential to the effective execution of engineering leadership is a deep working knowledge of a technology or discipline.	Not Assessed
(b)	Not Assessed		
(c)	Not Assessed	<b>Visioning:</b> creating purposeful, compelling and transformational images of the future, and identifying what could and should be.	<b>Criterion 1: Conceive and Design within Realistic Constraints</b>
(d)	An ability to function on multidisciplinary teams	<b>Relating:</b> developing key relationships and networks within and across organizations, including listening to others to understand their views, and advocating for your position.	<b>Criterion 2: Function within and Lead Multi-Disciplinary Teams</b>
(e)	An ability to identify, formulate, and solve engineering problems.	<b>Delivering on the Vision:</b> leading transformation by designing processes and approaches to delivering on the vision, to move from abstraction to innovation, invention and implementation, i.e., to get the engineering done.	<b>Criterion 3: Identify, Formulate and Solve Engineering Problems</b>
(f)	An understanding of professional and ethical responsibility.	<b>The Attitudes of Leadership:</b> Core Personal Values and Character	<b>Criterion 4: Understand and Demonstrate Professional and Ethical Responsibilities</b>
(g)	An ability to communicate effectively.	<b>Relating:</b> developing key relationships and networks within and across organizations, including listening to others to understand their views, and advocating for your position.	<b>Criterion 5: Understand Others and Communicate Effectively</b>
(h)	The broad education necessary to understand the impact of engineering solutions in a global / societal context.	<b>Making Sense of Context:</b> making sense of the world around us, and coming to understand the context in which the leader is operating - making a mental map of the complex environment, and explaining it simply to others.	<b>Criterion 6: Understand Economic, Environmental, Global and Societal Contexts and Impacts</b>
(i)	A recognition of the need for, and an ability to engage in life-long learning.	<b>The Attitudes of Leadership:</b> Core Personal Values and Character	<b>Criterion 7: Recognize the Value of Reflection and Life-Long Learning</b>
(j)	A knowledge of contemporary issues	<b>Making Sense of Context:</b> making sense of the world around us, and coming to understand the context in which the leader is operating - making a mental map of the complex environment, and explaining it simply to others.	<b>Criterion 8: Maintain Knowledge of Contemporary Issues</b>
(k)	Not Assessed	Not Assessed	Not Assessed

## Data Analyses

Syllabi from the ten US universities with the largest annual number of undergraduate civil engineering graduates were reviewed and, using the framework described herein, evaluated for leadership content. This paper's three authors independently and specifically evaluated content from the "Course Schedule" or "Topics" section. These sections were chosen because they appeared to consistently provide evidence of what material the professor intended to cover. A set of key words associated with each engineering leadership criterion was established in advance of the screening process. These key words, combined with the criteria titles themselves, as shown in Table III, comprise the filtering mechanism with which engineering leadership content was identified in syllabi. Different versions/tenses of the key words were also counted (e.g. "Ethics" and "Ethical" would both pertain to Criterion 4). The establishment of these specific key word filters was intended to minimize subjectivity among independent reviewers.

**Table III - Key Words Associated with Criteria**

<b>Engineering Leadership Criteria</b>	<b>Associated Key Words</b>
Criterion 1: Conceive and Design Within Realistic Constraints	Conceive, design
Criterion 2: Function within and Lead Multi Disciplinary Teams	Team
Criterion 3: Identify, Formulate and Solve Engineering Problems	Problem-solving, decision, critical thinking, reasoning and judgment
Criterion 4: Understand and Demonstrate Professional and Ethical Responsibilities	Ethics
Criterion 5: Understand Others and Communicate Effectively	Communicate
Criterion 6: Understand Economic, Environmental, Global and Societal Contexts and Impacts	Sustainability, environment, system
Criterion 7: Recognize the Value of Reflection and Life-Long Learning	Project learning, reflect
Criterion 8: Maintain Knowledge of Contemporary Issues	Case study

If a topic contained at least one of the key words associated with the criteria in Table III, the evaluator considered the depth of coverage using an evaluation scale. Table IV contains the evaluation scale used to quantify depth of coverage.

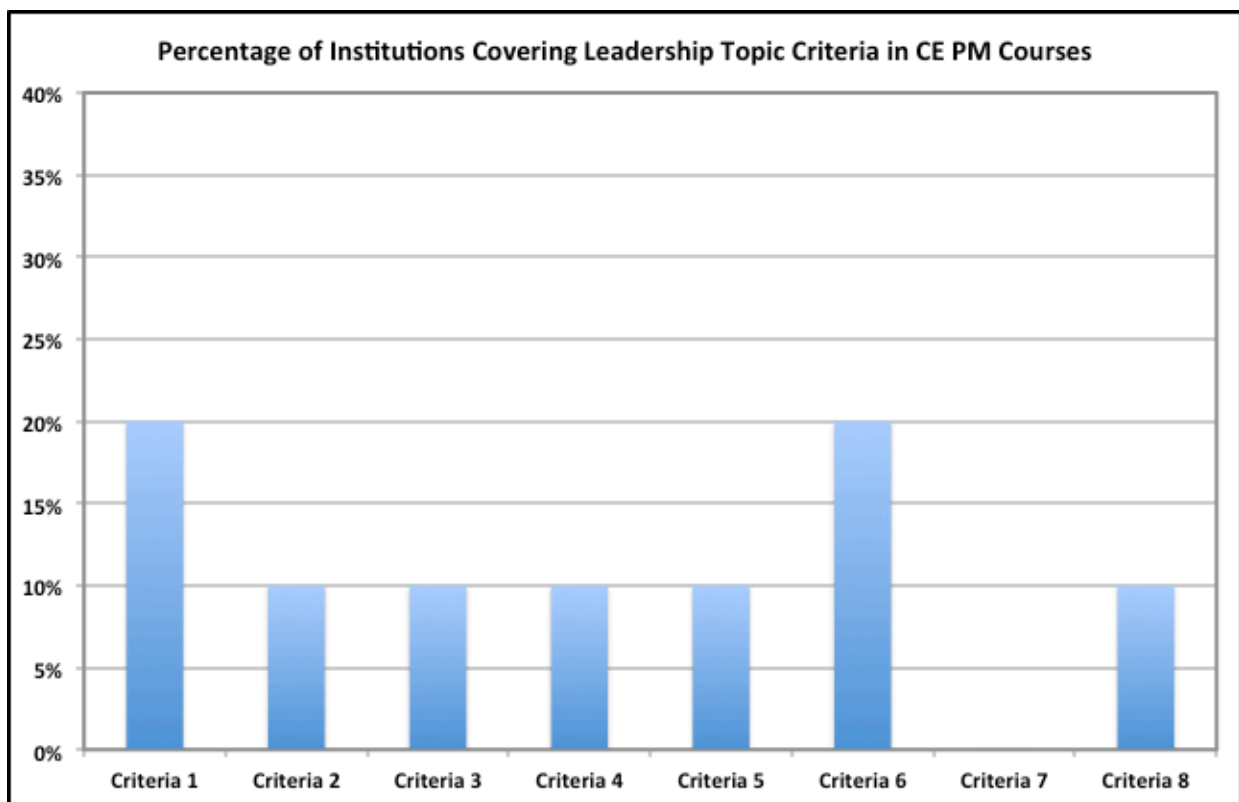
**Table IV – Evaluation Scale – Depth of Coverage**

0 = Content not present
1 = Content is implicitly present (key word not used to describe the topic, but topic suggests key word)
2 = Content is explicitly present as portion of a lesson
3 = One lesson is dedicated to the content; content is explicitly present (key word used to describe the topic)

The percent agreement between each authors' assessment for the course content reflected an estimate of analytical objectivity. In many instances an agreement of 80% between independent evaluators is considered acceptable.<sup>8</sup> The percentage agreement between any two scorers' codes for the selected items in this analysis was approximately 90%. After discussion regarding divergences, all authors were in full agreement regarding the assessed results.

## Results

None of the syllabi analyzed contained the explicit word "leadership" or otherwise indicated that this content was specifically addressed within the course curriculum. The results of the analysis of implicit leadership content using the developed framework appear in Figures 1 and 2. Of the eight leadership criteria evaluated, seven were identified as present in various percentages in this sample (n=10), as shown in Figure 1; Criterion 7 (Recognize the Value of Reflection and Life-Long Learning) was absent.

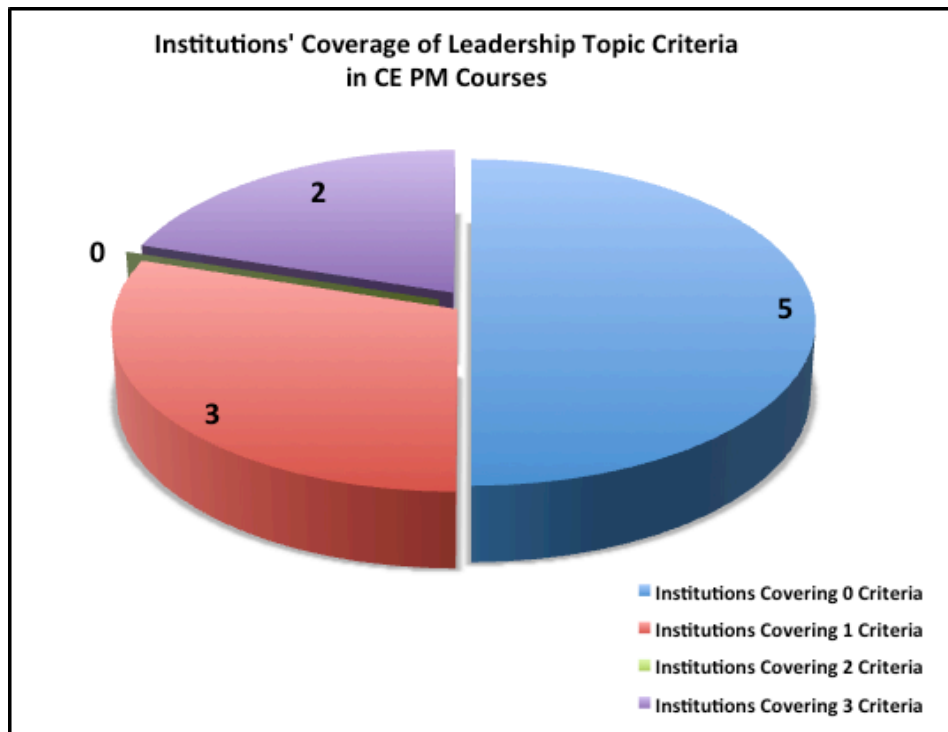


**Figure 1: Coverage of Leadership Topic Criteria in PM Courses**

Criterion 1 (Conceive and Design within Realistic Constraints) and Criterion 6 (Understand Economic, Environmental, Global and Societal Contexts and Impacts) were the most frequently covered leadership topic criteria among the institutions analyzed.

Figure 2 summarizes the number of leadership criteria covered by institutions. Of the 10 institutions analyzed, half of them (5) covered none of the leadership criteria.





**Figure 2: Institutions' Coverage of Leadership Topic Criteria in CE PM Courses**

Of the institutions where leadership content was identified in civil engineering project management, three of the ten institutions covered one of the eight leadership criteria, while two of them covered three or more criteria. The depth of coverage, as assessed by the rubric in Table IV, appeared to vary by both criteria and by institution. The depth of coverage measure may prove valuable for future studies that employ this methodology on a larger scale, or for institutions wishing to perform a self-assessment of leadership content.

## Discussion

Recent trends and interests in engineering leadership education include defining and assessing leadership competence, and the integration of leadership subject matter within the engineering curriculum. Leadership competencies were defined in this paper and used to assess the content of existing civil engineering PM curriculum to gauge the current degree of leadership skills integration within this curriculum. Inherent in this analysis is the assumption that a course syllabus contains and accurately reflects all elements covered within that course. This assumption may be unfair in that it converts a multidimensional experience into a two-dimensional reflection upon which this analysis is based. We recognize that leadership content not explicitly labeled as such or implicitly present as related capabilities on a syllabus may still exist when that course is delivered; however for the purpose of this study, only defined content on syllabi were considered.

Because PM can be viewed as sharing adjacent and complementary domain space with leadership, and because introductory PM classes were evaluated, we expect these results to be favorable indicators and not representative of the current state of leadership integration within the broader engineering curriculum. We also expect that civil engineering PM courses represent a viable avenue by which to integrate engineering leadership into the engineering curriculum in the future.

Although this paper has focused on civil engineering project management, facets of leadership education exist in other civil engineering courses, extracurricular opportunities, and across the engineering curriculum in other academic venues within the schools reviewed. For example, structured elements of leadership skills development may be present in some Engineers Without Borders chapters. At Penn State University, group development and team building are essential elements taught within first year engineering design (EDSGN 100), a course required by most engineering majors. At the University of Illinois, all civil engineering students are required to complete course work in systems engineering (CE 201) and engineering risk and uncertainty (CE 202); while neither of these classes contains the explicit word “leadership”, the material inherent has clear contributions to effective engineering leadership capabilities and behavior. And finally, many universities have fine elective engineering leadership programs that deliver explicit leadership content to students.

Criteria 1 and 6 were the most prevalent found in the curricula reviewed. Criterion 1 (Conceive and Design within Realistic Constraints) is based upon ABET outcome c (an ability to design a system, component or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability), and the Gordon-MIT “Visioning” capability category (creating purposeful, compelling and transformational images of the future, and identifying what could and should be). The design focus of this outcome affords it strategic importance in satisfying ABET requirements. While the focus of programs may be biased towards the “conceive” and “design” tools, opportunities exist for educating students in how to effectively transform these designs into compelling graphic depictions and develop students’ abilities to effectively orally communicate these depictions to others.

Criterion 6 (Understand Economic, Environmental, Global and Societal Contexts and Impacts) is based upon ABET outcome h (The broad education necessary to understand the impact of engineering solutions in a global / societal context.), and the Gordon-MIT “Making Sense of Context” capability category (making sense of the world around us, and coming to understand the context in which the leader is operating - making a mental map of the complex environment, and explaining it simply to others.). The presence of this criterion is perhaps reflective of the desire to better incorporate elements of sustainable development into the civil engineering curriculum. Opportunities exist for programs lacking in systems thinking to incorporate that material within this element.

The absence of criterion 7 (Reflection and lifelong learning) is of special interest even in the absence of seeking a leadership nexus. Given that when closing a project the last task of a project manager should be reflection and documentation of project learning to preserve and advance institutional knowledge, this criterion should be considered as an integral component of an effective project management curriculum. Without reflection and learning, project managers may condemn themselves to repeat unpleasant pasts.

## **Conclusions**

The ASCE BOK defines leadership knowledge, comprehension and analytical ability as an outcome obtainable during undergraduate studies and necessary for entry into the practice of civil engineering at the professional level. ABET defines leadership as a necessary content component within the civil engineering curriculum. The presence of explicit leadership content was not apparent in the syllabi analyzed – a fact which pointed to the need for establishing a standard framework for uncovering implicit content. Facets of implicit leadership competency development, identified using the framework approach introduced in this paper, were identified through syllabi analyses. In summary:

1. Although no broad consensus exists regarding the definition of engineering leadership competencies, the process and results offered here are provided with hopes that they will contribute to the advancement of that definition process.
2. Within the ten schools investigated one competency was absent: (7) Recognize the Value of Reflection and Life-Long Learning.
3. Within the ten schools investigated, the competencies most prevalent were: (1) Conceive and Design within Realistic Constraints, (6) Understand Economic, Environmental, Global and Societal Contexts and Impacts.
4. Although management and leadership are not equivalent, elements of leadership can be found within a PM curriculum.
5. Although management and leadership are not equivalent, opportunities exist for the incorporation of elements of leadership within a PM curriculum.

This study focused on one engineering course within one engineering department at ten engineering universities. While leadership content exists elsewhere within the engineering curriculum, it is hoped that this paper represents an incremental first step towards benchmarking, and perhaps offers an avenue via which leadership curricular content might be better designed, integrated, and identified.

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