



## Competition-Based Learning Activities within Civil Engineering Education:

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# **Competition-Based Learning Activities within Civil Engineering Education: A Critical Review of Current Options**

Structured, competition-based learning activities have been used in the process of educating aspiring civil engineers for many years. Some of the better known and more widely adopted intercollegiate competitions include the American Society of Civil Engineers' Concrete Canoe Competition and the American Society of Civil Engineers/American Institute for Steel Construction's National Steel Bridge Competition. Beyond these common competitions, it is estimated that upwards of 38 additional competitions, sponsored by various organizations, are in use to varying extents by civil engineering programs throughout the United States.

Data collected during this study enabled a thorough investigation of national and regional civil engineering competitions. A detailed analysis of each identified competition has been performed by the investigation team. In addition, a survey of ABET, Inc. accredited civil engineering programs heads was performed to capture the frequency and distribution of individual competitions, as well as an assessment of the department heads' perceived educational value to the participants of each competition. An existing, well-established, and validated education metric has been used as the tool by which each competition is evaluated.

Given the resource investment required to participate in many of the competitions currently in use, it is anticipated that the results of this study will be of interest to civil engineering program administrators, faculty members, sponsoring agencies associated with current competitions, and developers of future civil engineering competitions.

## **Introduction**

In the last decade, civil engineers have faced some incredibly difficult and ill-defined challenges in the form of natural disasters and other events that have impacted the built environment. The most recent, and arguably one of the more challenging events of the decade, was Superstorm Sandy—a storm of epic magnitude that landed center of mass on one of the most complex built-up environments in the nation—the coastal area surrounding New York City. In the days following the storm, engineers and public officials struggled with challenges like restoring an adequate gasoline supply to the region, pumping twice the amount of water estimated from underground transportation tunnels, and restoring electricity to enable local residents to clean-up and get on with their lives—to name just a few. While this paper is not focused on the response to the storm or the tremendous damage it caused, it is focused on better preparing civil engineers to understand the complexity of infrastructure systems, the interaction between government and private sectors, and the multitude of unknowns that can and will occur to wreak havoc at the most inopportune moment.

While most civil engineering educators and practitioners readily acknowledge the importance of exposing students to situations requiring them to solve “ill-defined,” “wicked,” or “nasty” problems, there are currently no nationally sponsored competitions that offer such an opportunity. In fact, the most frequently cited competitions are the American Society of Civil Engineers (ASCE) Concrete Canoe Competition and the ASCE/American Institute for Steel

Construction (AISC) National Student Steel Bridge Competition, neither of which requires students to face problems in any of the former three categories. During the time the authors have been a part of civil engineering education as students or faculty members, both competitions have undergone some change, but are still largely the same and highly constrained to the point that student designs all look fairly similar from year to year. In addition, the competition rules have become so complex that student teams are often disqualified on minor technicalities that can sour the learning experience. While it can be argued that complex rules mimic the way things are in the modern engineering world, the counter argument is that they require an unreasonable amount of time to decipher and understand, stifle creativity, and don't really set the conditions for students to solve a or ill-defined, wicked, or nasty problem.

While the authors are not in favor of discarding current student competitions, they are frustrated by the lack of nationally sponsored opportunities that expose students to real engineering issues, the solution of which could allow them to make a meaningful impact on the world around them. After all, when asked why they decided to study civil engineering, or any field of engineering for that matter, students often respond "because I want to make a difference." In addition, current competitions focus more on technical aspects of a problem and don't seem to focus enough on the social, economic and business challenges of the problem – the ones that engineers traditionally have the most trouble addressing.

The authors acknowledge that in addition to the concrete canoe and steel bridge competitions there is a much wider pool of civil engineering student challenges in existence that haven't been fully identified to the national audience. While most of these competitions require a significant investment of resources, including faculty/staff time and departmental fiscal support, the engineering education literature appears to be devoid of a recent, critical assessment of civil engineering competition-based learning activities and their associated learning value. Accordingly, the research questions associated with this study are: 1.) What civil engineering-related intercollegiate competition-based learning activities are currently in use in the United States, and 2.) What is the perceived learning value associated with particular identified competition? For clarification, the authors define competition-based learning activities as a structured learning activity involving intercollegiate competition, for credit or not for credit, which could be either a capstone or non-capstone event. While a competition-based learning activity could be used as a capstone event, not all capstone events are structured as intercollegiate competitions.

## **Literature Review**

A significant amount of education literature underscores the value competition can provide in enhancing student learning. For example, Dave<sup>[1]</sup>, Kimbrough<sup>[2]</sup>, and Burguillo<sup>[3]</sup> all point to several benefits of incorporating competition into the classroom. Even Lowman<sup>[4]</sup>, although reticent about graded competition between students, acknowledges the motivational aspects that a students' competitive instincts can provide. Among the items highlighted in the literature were increased motivation, interaction, and the increased inspiration for students to pursue further learning in topics of personal interest related to the competition. Even literature that criticizes competition-based learning, such as Pinski et al.<sup>[5]</sup> and Cooley et al.<sup>[6]</sup>, come to the conclusion that competitions are typically viewed as positive by a majority of students. Further, these

critical views highlight some common concerns worth noting, including the increased instructor burden to generate the competition activity, especially finding an activity that challenges all but does not overwhelm the weakest students. However, that concern is applicable only to class-level or course-level competitions.

Intercollegiate competitions are not generated by an individual instructor/course director. Beyond this obvious difference, there are many other differences that the casual observer could identify, which make inferring greater learning-value seem plausible. Fortunately there is a modest body of evaluative work on the intercollegiate competition approach.

Cooley et al.<sup>[6]</sup>, evaluated a West Virginia University (WVU) capstone project in electrical engineering, where rather than a typical project, the students chose their work with the specific intent to enter it into an intercollegiate design competition. Only a portion of the course population completed projects as part of the intercollegiate design competition. This provided a good opportunity to contrast the learning of the competition group with the learning of the rest of the course population. The faculty involved from WVU offered an insightful list of observations contrasting their competition group with the rest of the students. Those observations are paraphrased below:

1. Competitions simplify the problem definition phase of problem solving, allowing students to delve more quickly and deeply into the rich technical challenge typically involved.
2. Competitions that attempt to incorporate some real world requirements such as safety, economics, aesthetics, and stakeholder interaction are inherently shallower than “real world” projects.
3. Competitions typically involve significant team decision making processes, which are valuable experiences.
4. Competitions tend to provide more “closure,” as they must come to fruition during the window of the competition. This ensures students are provided with prompt feedback on what they have designed.
5. Observing results generated by other schools provides the opportunity to see the possibilities of alternate courses of action that were taken by other competitors.

Phillip Wankat<sup>[7]</sup> conducted a thorough investigation about consistently successful programs; including the concrete canoe competition and the national steel bridge competition, as well as a long list of other undergraduate competitions. While Wankat’s goal was not to specifically assess the learning-value of the competitions, his work is a great source of data to begin to address that question. Wankat notes that there was significant agreement amongst the universities surveyed that students learn many practical aspects of engineering that they would not learn elsewhere. This statement aligns well with Cooley’s comments 1, 3, and 4, especially since complete physical products are often the required outcome. One of Wankat’s faculty survey questions was whether or not the competition experience appeared to have any long-lasting impact. The results of that study indicate possible long term impact and suggest an increase in student self-taught learning.

The national ASCE concrete canoe competition, as it is currently conducted, is based on what was initially a series of local concrete canoe races. Races were first held in the 1960’s on a

local-level as intramurals. In the 1970s the first regional competitions were held, and in 1988, ASCE with sponsorship provided by Master Builders, Inc., organized the first national competition in East Lansing, Michigan. In the last decade this competition has even expanded into European nations.<sup>[8]</sup> With 24 consecutive years of experience at the national level, the concrete canoe competition typifies the type of intercollegiate competition investigated in this study.

According to the National Student Steel Bridge Competition website, the first steel bridge competition was held locally in 1987 in a Michigan regional competition that included Wayne State and Michigan Tech.<sup>[9]</sup> This competition concept quickly spread to other regions, and by 1992, the first National Student Steel Bridge Competition was held at Michigan State University. Twenty years of longevity and a strong national following have also resulted in thorough documentation and analysis of this competition.

These two intercollegiate competitions are prevalent in the civil engineering educational community. Of all the competitions that this study investigated, these two have generated by far the largest number of studies and associated publication. Many of these studies did have the specific goal of evaluating the learning value of the competition, but the level of rigor associated with the assessment in most of these studies was rather limited.

A number of publications have claimed positive educational results from both the Concrete Canoe Competition and the National Student Steel Bridge Competition. Sirianni et al.<sup>[10]</sup> published the results of a survey they conducted in 2003 at the Rochester Institute of Technology (RIT) that queried student perceptions on how much RIT students advanced skills in specific areas as a result of their general college experience. The survey also allowed students to identify if they had participated in either the canoe or steel bridge competition. Thus, allowing participants and non-participants to be contrasted. In every category of the survey, students that participated in the competitions reported higher self-achievement than non-participants. This mirrors the observations reported by advisors for these and similar competitions as noted by Wankat.<sup>[7]</sup> Sulzbach<sup>[11]</sup> provided further corroboration of the student-perceived value of the Concrete Canoe Competition and claims that it provided an enhanced student education. Ed Koehn<sup>[12, 13]</sup> presented results of a survey of two years worth of student participants in the canoe and steel bridge competitions from Lamar University which indicated that in many areas students perceive substantially enhanced levels of achievement due to their competition participation. Koehn's<sup>[13]</sup> study highlighted that while there are areas of substantially enhanced achievement related to structural engineering in the canoe and bridge competitions, the same cannot be said for many outcomes related to the other sub-disciplines of civil engineering.

Not all reviews and observations of these two competitions are wholly favorable. Labossière & Bisby<sup>[14]</sup> cite the Concrete Canoe Competition and National Student Steel Bridge Competition as examples of competitions and activities that don't quite accurately simulate the real engineering activities that would help a student experience meaningful design opportunities. They advocate for work on actual projects. While the final product may not reflect student designs, owners and design engineers could benefit from student insights. This concept matches well with Cooley's<sup>[6]</sup> second item listed previously.

Further, although the concrete canoe and steel bridge are competitions defined and organized outside of a university, they are often considered to be extracurricular activities at a particular school. For both the students and the advisors who participate in them, there is some level of extra effort required. Houston<sup>[15]</sup> advocated that higher participation rates would result from officially crediting the work both students and faculty put in by incorporating the competitions into an actual course. This extra, un-credited work is often cited as a contributing factor that limits overall participation. The Sirianni et al.<sup>[10]</sup> survey at RIT attempted to identify factors students consider when choosing to participate or not, and while lack of awareness was one reported factor, the main concern was the availability of time to participate. A number of participants in the Sirianni et al. study also suggested that participants receive course credit.

In addition to reviewing the literature for content related to competition-based learning activities, specific effort was made to identify a metric that could be used to evaluate the learning potential associated with such competitions. ASCE publishes a set of criteria they use when giving consideration towards endorsing a new competition.<sup>[8]</sup> Notably, that set of criteria does not focus on what the competition participants stand to learn by participating in the endeavor. The RIT survey<sup>[10]</sup> represents a logical set of questions, but did not flow from a solid consensus set of criteria that would make it a more widely applicable survey instrument. Koehn's<sup>[12, 13]</sup> study attempted to apply a more widely applicable set of criteria; specifically, the ABET Engineering Criteria 2000 document, and the various subject areas required for civil engineering programs that it specified. However, accreditation criteria constitutes an outcomes-based assessment and thus, intentionally does not provide specific metrics that could have been adopted for the current study.

ASCE's Body of Knowledge (BOK2) has previously been used as a general assessment tool, but the authors' investigation did not reveal specific prior application as a metric to evaluate competition-based learning activities. The evolution of the current, 2<sup>nd</sup> edition, of the Body of Knowledge has been well documented.<sup>[16-22]</sup> The BOK2 details a comprehensive list of 24 outcomes required for entry into professional practice. It includes a system of identifying the level of achievement expected of an engineering apprentice using the well-established Bloom's Taxonomy.<sup>[23]</sup> Further, the BOK2 allocates responsibility for and the timing of the achievement of each of the 24 outcomes, whether it is during the completion of a bachelor of science in civil engineering, while earning a master's degree or 30 graduate-level credits in an engineering specialty, or during pre-licensed experience with industry as an engineering intern.<sup>[23]</sup>

As was intended, it has become increasingly common to use the BOK2 to assess and/or redesign civil engineering programs at a university (e.g. Koehn *Body of Knowledge (BOK) Outcomes in an ABET Curriculum*<sup>[24]</sup> and Welsh<sup>[25]</sup>). The BOK2 has even been used in the design of individual courses.<sup>[26]</sup> The current study appears to be the first to use the BOK2 to assess intercollegiate competitions.

## Methods

To address the first point of inquiry associated with this study, what intercollegiate competition-based learning activities are in use, the authors began by conducting an internet search. The focus was to identify and document an all inclusive list of intercollegiate competitions held at the

local, regional, and national levels. Websites and publications for both national and regional industry trade associations, technical institutes, and other groups were reviewed to identify the competitions identified. In many cases, competitions were identified that occur in conjunction with annual conferences within a specific sub-discipline of civil engineering. Only competitions that are currently active are included on the list.

The second point of inquiry, what is the perceived educational value of the commonly utilized intercollegiate competition-based learning activities, was accomplished by conducting a survey of civil engineering program department heads. To a limited extent, this survey also helped to expand the list of existing competitions.

The online survey creation and administration website SurveyMonkey® was used in support of this process. The custom survey utilized for this study consisted of 11 items. The survey was designed to collect information associated with feedback from a single department head specific to an individual competition. The survey incorporated a loop to permit recording of data for programs that participated in multiple competitions. A copy of the survey can be found in Appendix A.

The survey required respondents to evaluate the perceived educational value of individual competitions-based learning activities relative the 24 Outcomes identified in the BOK2.<sup>[23]</sup> Each Outcome was evaluated as being “Not Applicable” (Outcome is not satisfied by this competition), “Very Limited” (Outcome is satisfied to a very limited extend by this competition), “Somewhat” (Outcome is somewhat satisfied by this competition), “Significantly” (Outcome is significantly satisfied by this competition), or “Completely” (Outcome is completely satisfied by the competition). A definition of each Outcome was provided within the survey using the precise language that ASCE uses to in the BOK2 document. Refer to Appendix A to read the list of Outcomes and associated definitions.

A request to complete the survey was sent via email through the ASCE department heads listserv in mid-October. A general description of the research program was described in the survey. A single reminder email was sent to the same group approximately one month later. In total, there are 273 subscribers in the listserv. The only incentive used to encourage participation was the offer to share a copy of related subsequent publications.

Limited manipulation of the collected survey data was required. Duplicates and improperly completed surveys were eliminated from the data set.

## **Results**

The attempt to use the internet to develop a comprehensive list of civil engineering intercollegiate competition-based learning activities generated a final list of 40 unique competitions. A summary of those competitions is included in Appendix B of this document. The summary table identifies the date of inception, the participation level (regional or national), sponsoring organization, a website where additional information can be identified, and the type of culminating activity associated with the individual competition (e.g., product, research paper, presentation, etc.).

The listserv survey administered to civil engineering program heads generated a total of 50 responses. That is a response rate of slightly more than 18%. The respondents represented 32 different academic institutions. Among those 50 respondents, 97 competition statements were reported. A competition statement is defined as feedback received on any competition and does not directly account for duplicates. From that set of competition statements, 23 were removed for either bad or incomplete data. This resulted in a final data population of 74 competition statements. When duplicates were considered within this data set, only 11 unique competitions were discussed by the survey respondents. Two of those competitions were not previously identified in our initial internet search, but are now included in the summary table in Appendix B.

Table 1 is a summary of the 11 unique competitions reported by the civil engineering program heads. Also reflected in this table is the frequency with which individual competitions were reported, and the average and maximum number of years that programs have been involved with individual competitions. Clearly not all 40 competitions listed in Appendix B were subsequently evaluated during administration of the civil engineering program head survey. While all of the competitions identified are considered active, the individuals who responded to the survey simply did not represent academic institutions that engaged in a large number of those competitions.

Table 1: Reported Competitions, Frequency, and Years of Participation

Competition	Frequency	Years Participated	
		AVG	MAX
Steel Bridge	37.8%	15.2	30
Concrete Canoe	36.5%	20.3	35
PCI Big Beam	8.1%	5.5	10
Mead Ethics Paper	5.4%	12	25
Timber Bridge	2.7%	10	15
EERI Student Design	2.7%	6	8
Geo Challenge	1.4%	6	6
ASC Design Build & Commercial	1.4%	7	7
ASCE Indiana Section Senior Design	1.4%	18	18
ITE Traffic Bowl	1.4%	10	10
AWWA/WEF Wastewater Design	1.4%	5	5

The program head reported perceptions of the educational value of individual competitions as evaluated relative to the 24 BOK2 Outcomes were converted to numerical values to permit inter-competition comparisons. Reported values of “Not Applicable” were assigned a value of 1, reported values of “Very Limited” were assigned a value of 2, reported values of “Somewhat” were assigned a value of 3, and so on. Thus, a competition with a high perceived educational value would have a high score.

Table 2 provides a summary of average perceived education value of each competition rated relative to all 24 Outcomes. This table also provides an average score on individual Outcomes



across all 11 competitions (right hand column) and an average score on individual competitions across all 24 Outcomes (bottom row). Conditional color formatting has been used to highlight the spectrum of scores ranging from a minimum of 1.0 (light yellow) to a maximum of 5.0 (dark orange).

Table 2: Average Reported Perceived Educational Value of Competitions

	Steel Bridge	Concrete Canoe	PCI Big Beam	Mead Ethics Paper	Timber Bridge	EERI Student Design	Geo Challenge	ASC Design Build & Commercial	ASCE Indiana Section Senior Design	ITE Traffic Bowl	AWWA/WEF Wastewater Design	Average
<b>Math</b>	3.00	2.79	3.67	1.50	4.00	3.50	2.50	2.50	2.50	2.50	2.50	2.88
<b>Natural Sciences</b>	2.17	2.36	3.17	1.75	3.00	3.00	2.83	2.83	2.83	2.83	2.83	2.37
<b>Humanities</b>	1.66	1.71	1.33	3.25	1.50	1.00	2.17	2.17	2.17	2.17	2.17	1.74
<b>Social Sciences</b>	1.52	1.61	1.17	3.25	1.50	1.00	2.33	2.33	2.33	2.33	2.33	1.64
<b>Material Science</b>	3.41	4.00	3.67	1.75	4.00	3.00	2.83	2.83	2.83	2.83	2.83	3.51
<b>Mechanics</b>	3.90	3.64	3.50	1.25	4.00	4.50	3.00	3.00	3.00	3.00	3.00	3.58
<b>Experiments</b>	3.45	4.04	4.17	1.25	2.50	3.50	2.83	2.83	2.83	2.83	2.83	3.53
<b>Prob. Recog. &amp; Solving</b>	4.10	4.11	3.83	1.75	4.00	4.00	4.17	4.17	4.17	4.17	4.17	3.96
<b>Design</b>	4.34	4.30	4.33	1.25	4.00	4.00	4.33	4.33	4.33	4.33	4.33	4.13
<b>Sustainability</b>	1.86	2.93	2.17	2.25	3.00	2.50	3.17	3.17	3.17	3.17	3.17	2.43
<b>Contemporary Issues</b>	1.72	1.89	1.33	4.25	1.50	1.00	3.00	3.00	3.00	3.00	3.00	1.95
<b>Risk &amp; Uncertainty</b>	2.62	2.32	2.67	2.00	3.00	4.00	3.00	3.00	3.00	3.00	3.00	2.55
<b>Project Management</b>	4.07	4.32	3.67	1.75	4.00	3.50	4.33	4.33	4.33	4.33	4.33	4.00
<b>Breadth</b>	1.97	2.43	1.80	1.50	3.00	2.50	3.17	3.17	3.17	3.17	3.17	2.23
<b>Technical Specialization</b>	3.41	3.04	4.00	1.75	3.50	4.00	3.33	3.33	3.33	3.33	3.33	3.25
<b>Communication</b>	3.59	4.11	3.67	4.50	3.50	3.00	4.50	4.50	4.50	4.50	4.50	3.87
<b>Public Policy</b>	1.45	1.44	1.17	3.75	1.50	1.00	2.67	2.67	2.67	2.67	2.67	1.61
<b>Business and Public Admin.</b>	1.62	1.96	1.17	3.25	1.50	1.00	2.67	2.67	2.67	2.67	2.67	1.84
<b>Globalization</b>	1.41	1.46	1.33	3.25	1.50	1.00	2.83	2.83	2.83	2.83	2.83	1.61
<b>Leadership</b>	4.17	4.25	4.00	1.75	4.00	3.50	4.17	4.17	4.17	4.17	4.17	4.03
<b>Teamwork</b>	4.21	4.43	4.00	1.25	3.00	3.00	4.83	4.83	4.83	4.83	4.83	4.09
<b>Attitudes</b>	3.10	3.32	3.00	4.00	3.00	2.00	4.00	4.00	4.00	4.00	4.00	3.25
<b>Lifelong Learning</b>	3.07	3.26	2.83	3.25	3.50	3.00	3.67	3.67	3.67	3.67	3.67	3.19
<b>Prof. &amp; Ethical Responsib.</b>	2.41	2.61	2.17	4.25	2.50	2.50	3.50	3.50	3.50	3.50	3.50	2.64
<b>Average</b>	2.84	3.01	2.83	2.49	2.94	2.71	3.33	3.33	3.33	3.33	3.33	2.91

## Discussion

As indicated in Table 1, the competitions most frequently reported were the steel bridge and concrete canoe competitions. This was supported, anecdotally, through the literature review and internet search with the frequency that papers have been published related to these competitions and the frequency that ASCE student chapter website pages discussed their participation. These competitions are among the most readily recognized and oldest engineering competitions. Notably, the frequency with which other competitions were reported was significantly lower.

Only two competitions were reported in the surveys that were not previously identified in the authors' search of the literature and the internet. This suggests that the majority of civil engineer competitions in use are readily available on the web and being publicized for all to participate in.

From the survey results, only four of the BOK2's twenty-four Outcomes received a score of 4.00 (Significantly Applicable) or higher. Those four Outcomes were: Design (avg. = 4.13), Project Management (avg. = 4.00), Leadership (avg. = 4.03), and Teamwork (avg. = 4.09). It is not surprising that these four particular Outcomes ranked highly in the survey as the nature of the current competitions in use and reported by the survey respondents focus on operating within a team and coming up with a design that meets unique challenges.

Surprisingly, the Problem Recognition Outcome and Communication Outcome averaged slightly below 4.00. These two Outcomes were anticipated to be the focus of most every civil engineering competition and were expected to score higher.

At the other end of the spectrum, six of the BOK2's twenty-four Outcomes received a score of 2.00 (Very Limitedly Applicable) or less. Those six Outcomes were: Humanities (avg. = 1.74), Social Sciences (avg. = 1.64), Contemporary Issues and Historical Perspectives (avg. = 1.95), Public Policy (avg. = 1.61), Business and Public Administration (avg. = 1.84), and Globalization (avg. = 1.61). This suggests that the current competitions in use and reported in the survey have a low perceived educational value in these particular areas.

Perhaps more interesting are the handful of BOK2 Outcomes that are not on either the high or low end of the survey results. Ideally, one would expect that engineering competitions would greatly support students learning in Math (avg. = 2.88), Materials Science (avg. = 3.51), Mechanics (avg. = 3.58) and Experiments (avg. = 3.53).

When considering the data on an Outcome-by-Outcome basis, the frequency that individual competitions appear in the data set must be considered. The assigned scores for high frequency competitions, such as the steel bridge and concrete canoe, are likely to skew the overall average for individual Outcomes. For example, if the steel bridge and concrete canoe both received high scores from the majority of the individual survey respondents for a particular Outcome, while other competitions received lower scores on the same Outcome, it is possible that the Outcome average will be skewed.

The overall mean for all BOK2 goals over all competitions was 2.91. This would suggest that in-general the competition-based learning activities are perceived to be Somewhat Applicable to

the BOK2 Outcomes as a whole. This result appears to fit well with the limited amount of predominately anecdotal evidence found in the literature review.

For the BOK2 Outcomes with over 4.00 on the survey, nearly all of the competitions scored those Outcomes as a 3.00 or higher. The loan outlier was the Mead Ethics Essay, which consistently scored below a 2.00 in each of the previously mentioned four high ranking BOK2 Outcomes. Since the Mead Ethics Essay is a different type of competition (individual research paper competition), it makes sense that this competition will score lower in categories that other more traditional competitions score higher in (e.g. Teamwork, Leadership, etc.). However, the Mead Ethics Essay did score higher than the other competitions (over 4.00 average) in three Outcomes; Contemporary Issues, Communication, and Professional & Ethical Responsibility. These are Outcomes where all other competitions scored less than a 2.00 on average.

When viewing Table 2 in columnar manner, comparisons can be made between individual competition-based learning activities. However, again the frequency of survey respondents must be considered when evaluating this data. Competitions beginning with the timber bridge and all additional columns to the right in Table 2 have a low n-value relative to the number of survey respondents who evaluated that competition. The numbers reported for those competitions will simply represent the opinions of a small number of survey respondents.

If making comparison between only those competitions with a reasonable number of respondents (steel bridge, concrete canoe, big beam, and ethics paper), the average value across all 24 Outcomes shows very little variability between the competitions. As noted previously, no single competition seems to score high on all 24 Outcomes. Rather, each of the current competitions tends to score high on particular Outcomes, and low on others.

Looking across the full data set, it can be observed that none of the eleven evaluated competitions earned a perceived educational value score higher than 4.00 in Natural Sciences, Humanities, Social Sciences, Sustainability, Breadth, Public Policy, Business & Public Administration, Globalization, and Lifelong Learning. Yet, the importance of each of these Outcomes in the process of developing well prepared civil engineers is evidenced by their inclusion in the BOK2.

## **Summary Findings**

The first research questions posed in this study set the goal of identifying all intercollegiate competition-based civil engineering learning activities in current use. Between the extensive internet-based search and feedback provided during the survey of civil engineering program heads, the authors can comfortably conclude that the list compiled in Appendix B is nearly comprehensive. However, it is always possible that a competition slipped through the net of this investigation.

The second research question posed in this study set the goal of attempting to evaluate the perceived educational value of the primary competition-based civil engineering learning activities in current use. Perceived value data was collected via survey of the civil engineering program heads and was measured in context of the American Society of Civil Engineers' BOK2

Outcomes. While certain Outcomes scored well for most competitions, no single Outcome scored high among all competitions. Likewise, certain competitions scored high on particular Outcomes, but no single competition scored high on all 24 Outcomes.

The authors are not suggesting that existing competitions are at fault/failing/deficient simply because they do not perform well in particular BOK2 Outcomes. The competitions evaluated in this study were not initially developed with the intent of being all encompassing.

It is also important to note that the authors are not suggesting that competitions alone are a means of satisfying the BOK2 Outcomes. The BOK2 allocates responsibility for and the timing of the achievement of each of the 24 outcomes, whether it is during the completion of a bachelor of science in civil engineering, while earning a master's degree or 30 graduate-level credits in an engineering specialty, or during pre-licensed experience with industry as an engineering intern.<sup>[23]</sup> Thus, truly achieving at the levels prescribed in the BOK2 could not be accomplished during an undergraduate experience.

However, in a time when civil engineer educators do expect our program graduates to achieve at a particular level of Bloom's Taxonomy in all 24 BOK2 Outcomes, why is it that we don't have a competition-based civil engineer learning activity that better addresses the areas that have been clearly identified in this study as currently lacking. Those areas could include humanities, social sciences, sustainability, contemporary issues, public policy, business & public Policy, and globalization. It is beyond the scope of this study to consider what a competition would look like that could more broadly encompass most, if not all of the BOK2 Outcomes. In closing, for the good of our students, the practice of engineering, and our society, the authors challenge industry organizations such as ASCE, AISC, and others to develop and endorse competitions that will better prepare our students to solve "ill-defined," "wicked," or "nasty" problems they will most certainly face during their careers.

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# Appendix A

## SurveyMonkey® Administered Survey

### Competition-Based Learning

\*1. Please enter the name of your academic institution. (Note: Items with an asterisk are required fields)

\*2. Please enter your name.

\*3. Please enter your title/position.

\*4. Does the civil engineering program that you are affiliated with currently participate in or did they previously participate in any intercollegiate competition-based learning activities? Examples of competition-based learning activities would include, but not be limited to: ASCE Concrete Canoe Competition or AISC/ASCE Steel Bridge Competition.

- YES  
 NO

Next

### Competition-Based Learning

\*1. Identify by name one of the competition-based learning activities that your civil engineering program has participated in or does participate in.

Competition-Based Learning Activities

Choose one from the pull-down menu. If the activity is not shown, select "other" and fill in the blank space below.

Other (please specify)

2. Please identify the sponsor(s) of the competitions-based learning activity. This question may be left blank if sponsor information is unknown.

\*3. Is the competition identified in the prior questions conducted at the local, regional, and/or national level? (select all that apply)

- Local  
 Regional  
 National

4. Approximately how many years has your civil engineering program participated in this competition-based learning activity?

Years

Provide your best estimate by selecting the number of years from the pull-down menu to the right. This question can be left blank if you are unable to provide an estimate.

\*5. Listed below are the 24 Outcomes specified within the American Society of Civil Engineer's Body of Knowledge, Version 2 (BOK2) along with a description of the outcome at the bachelor's degree level. For the competition-based learning activity you identified above, within a single academic year, please rate the level to which you believe the activity satisfies each outcome.

- Not Applicable = Outcome is not satisfied by this competition  
Very Limited = Outcome is satisfied to a very limited extent by this competition  
Somewhat = Outcome is somewhat satisfied by this competition  
Significant = Outcome is significantly satisfied by this competition  
Completely = Outcome is completely satisfied by this competition

	Not Applicable	Very Limited	Somewhat	Significant	Completely
1. MATH. Solve problems in mathematics through differential equations and apply this knowledge to the solution of engineering problems.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2. NATURAL SCIENCES. Solve problems in calculus-based physics, chemistry, and one additional area of natural science and apply this knowledge to the solution of engineering problems.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3. HUMANITIES. Demonstrate the importance of the humanities in the professional practice of engineering.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4. SOCIAL SCIENCES. Demonstrate the incorporation of social sciences knowledge into the professional practice of engineering.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5. MATERIAL SCIENCE. Use knowledge of materials science to solve problems appropriate to civil engineering.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6. MECHANICS. Analyze and solve problems in solid & fluid mechanics.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
7. EXPERIMENTS. Analyze the results of experiments and evaluate the accuracy of the results within the known boundaries of the tests and materials in or across more than one of the technical areas of civil engineering.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
8. PROBLEM RECOGNITION & SOLVING. Develop problem statements and solve well-defined fundamental civil engineering problems by applying appropriate techniques and tools.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
9. DESIGN. Design a system or process to meet desired needs within such realistic constraints as economic, environmental, social, political, ethical, health and safety, constructability, & sustainability.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
10. SUSTAINABILITY. Apply the principles of sustainability to the design of traditional and emergent engineering systems.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
11. CONTEMPORARY ISSUES & HISTORICAL PERSPECTIVES. Drawing upon a broad education, explain the impact of historical and contemporary issues on the identification, formulation, and solution of engineering problems and explain the impact of engrg solutions on the economy, environment, political landscape, and society.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
12. RISK and UNCERTAINTY. Apply the principles of probability and statistics to solve problems containing uncertainties.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
13. PROJECT MANAGEMENT. Develop solutions to well-defined project management problems.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
14. BREADTH. Analyze and solve well-defined engineering problems in at least 4 technical areas appropriate to civil engineering.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
15. TECHNICAL SPECIALIZATION. Define key aspects of advanced technical specialization appropriate to civil engineering.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
16. COMMUNICATION. Organize and deliver effective verbal, written, virtual, and graphical communications.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
17. PUBLIC POLICY. Discuss and explain key concepts and processes involved in public policy.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
18. BUSINESS and PUBLIC ADMINISTRATION. Explain key concepts and processes used in business and public administration.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
19. GLOBALIZATION. Organize, formulate, and solve engineering problems within a global context.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
20. LEADERSHIP. Apply leadership principles to direct a small, homogeneous group.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
21. TEAMWORK. Function effectively in an intradisciplinary team.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
22. ATTITUDES. Explain attitudes supportive of the professional practice of civil engineering.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
23. LIFELONG LEARNING. Demonstrate the ability for self-directed learning.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
24. PROFESSIONAL and ETHICAL RESPONSIBILITY. Analyze a situation involving multiple conflicting professional and ethical interests to determine an appropriate course of action.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

6. Please use the space below to provide any additional comments or thoughts you would like to share about this particular competition-based learning activity.

\*7. Has your civil engineering program participated in or does your civil engineering program currently participate in another intercollegiate competition-based learning activity?

- YES  
 NO

### Competition-Based Learning

Thank you for participating in this survey. The information you have provide has been recorded and will assist with the study. The results will be presented at the American Society for Engineering Education annual conference in June, 2012. Please direct any questions or concerns you may have to Dr. Brock E. Barry (brock.barry@usma.edu or 845.938.5850).

## Appendix B

### Tabular Listing of Civil Engineering Intercollegiate Competition-Based Learning Activities

Competition	Inception	Participation Level	Sponsor	Website	Competition Culminates in:			
					Research Paper	Static Display	Hands on	Present.
Architectural Engineering Student Competition	2013	National	ASCE/ Charles Pankow Foundation	<a href="http://content.asce.org/studentcompetition/">http://content.asce.org/studentcompetition/</a> <a href="http://www.concrete.org/STUDENTS/ST_COMP ETITIONS.HTM">http://www.concrete.org/STUDENTS/ST_COMP ETITIONS.HTM</a>				x
Art of Concrete Comp.	2012	Regional	ACI	<a href="http://www.concrete.org/STUDENTS/ST_COMP ETITIONS.HTM">http://www.concrete.org/STUDENTS/ST_COMP ETITIONS.HTM</a>		x		
AWWA/WEF Wastewater Design	2002	National	AWWA/WEF	<a href="http://www.workforwater.org/page.aspx?id=145">http://www.workforwater.org/page.aspx?id=145</a>				x
Balsa Tower	2012	Regional	SouthEast ASCE Regional	<a href="http://www.eng.fsu.edu/asce2012/competitions.php">http://www.eng.fsu.edu/asce2012/competitions.php</a>			x	x
Big Beam	2005	National	PCI, Sika	<a href="http://www.pci.org/education/big_beam/index.cfm">http://www.pci.org/education/big_beam/index.cfm</a> <a href="http://water.epa.gov/infrastructure/greeninfrastructure/crw_challenge.cfm">http://water.epa.gov/infrastructure/greeninfrastructure/crw_challenge.cfm</a>			x	x
Campus Rainworks Challenge	2012	National	EPA	<a href="http://region3.ascweb.org/Competition/competition_rules_and_guidelines.htm">http://region3.ascweb.org/Competition/competition_rules_and_guidelines.htm</a>		x		x
Commercial Computational Mechanics Poster Competition	1997ish 2010	Regional National	Associated Schools of Construction (ASC) ASCE/ Engineering Mechanics Institute	<a href="http://region3.ascweb.org/Competition/competition_rules_and_guidelines.htm">http://region3.ascweb.org/Competition/competition_rules_and_guidelines.htm</a> <a href="http://emipmc12.nd.edu/Competitions.html">http://emipmc12.nd.edu/Competitions.html</a>			x	x
Concrete Canoe	1971	National	ASCE	<a href="http://www.asce.org/concretecanoe/">http://www.asce.org/concretecanoe/</a> <a href="http://www.concrete.org/STUDENTS/ST_COMP ETITIONS.HTM">http://www.concrete.org/STUDENTS/ST_COMP ETITIONS.HTM</a>		x	x	x
Concrete Construction Comp.	2003	National	ACI	<a href="http://www.concrete.org/STUDENTS/ST_COMP ETITIONS.HTM">http://www.concrete.org/STUDENTS/ST_COMP ETITIONS.HTM</a>	x			
Concrete Projects Comp.	1988	National	ACI	<a href="http://www.concrete.org/STUDENTS/ST_COMP ETITIONS.HTM">http://www.concrete.org/STUDENTS/ST_COMP ETITIONS.HTM</a>			x	x
Concrete Skee Ball	2012	Regional	SouthEast ASCE Regional	<a href="http://www.eng.fsu.edu/asce2012/competitions.php">http://www.eng.fsu.edu/asce2012/competitions.php</a>			x	x
Concrete Toboggan	1974	National	University of Calgary	<a href="http://www.gnctr2013.com/">http://www.gnctr2013.com/</a>		x	x	x
Daniel W. Mead Ethics Essay	1939	National	ASCE	<a href="http://www.asce.org/Content.aspx?id=12884905620">http://www.asce.org/Content.aspx?id=12884905620</a> <a href="http://region3.ascweb.org/Competition/competition_rules_and_guidelines.htm">http://region3.ascweb.org/Competition/competition_rules_and_guidelines.htm</a>	x			x
Design Build	1997ish	Regional	Associated Schools of Construction (ASC)	<a href="http://www.concrete.org/STUDENTS/ST_COMP ETITIONS.HTM">http://www.concrete.org/STUDENTS/ST_COMP ETITIONS.HTM</a>				x
Egg Protection Device	1988	National	ACI	<a href="http://www.concrete.org/STUDENTS/ST_COMP ETITIONS.HTM">http://www.concrete.org/STUDENTS/ST_COMP ETITIONS.HTM</a>				
Environmental- Soda bottle filter	2005ish	Regional	SouthEast ASCE Regional	<a href="http://www.eng.fsu.edu/asce2012/competitions.php">http://www.eng.fsu.edu/asce2012/competitions.php</a>			x	
Experimental Analysis and Instrumentation Poster	2012	National	ASCE/ Engineering Mechanics Institute	<a href="http://emipmc12.nd.edu/Competitions.html">http://emipmc12.nd.edu/Competitions.html</a> <a href="http://www.concrete.org/STUDENTS/ST_COMP ETITIONS.HTM">http://www.concrete.org/STUDENTS/ST_COMP ETITIONS.HTM</a>		x		x
FRC Bowling Ball Comp	2005	National	ACI	<a href="http://www.concrete.org/STUDENTS/ST_COMP ETITIONS.HTM">http://www.concrete.org/STUDENTS/ST_COMP ETITIONS.HTM</a>				
FRP Composites Comp.	1998	National	ACI	<a href="http://www.concrete.org/STUDENTS/ST_COMP ETITIONS.HTM">http://www.concrete.org/STUDENTS/ST_COMP ETITIONS.HTM</a> <a href="http://content.asce.org/conferences/geo-congress2012/student.html">http://content.asce.org/conferences/geo-congress2012/student.html</a>			x	x
GeoChallenge	2005	National	ASCE/ Geo Institute	<a href="http://content.asce.org/conferences/geo-congress2012/student.html">http://content.asce.org/conferences/geo-congress2012/student.html</a>		x	x	
Geotechnical- Determine Moisture Content	1985ish	Regional	SouthEast ASCE Regional	<a href="http://www.eng.fsu.edu/asce2012/competitions.php">http://www.eng.fsu.edu/asce2012/competitions.php</a> <a href="http://region3.ascweb.org/Competition/competition_rules_and_guidelines.htm">http://region3.ascweb.org/Competition/competition_rules_and_guidelines.htm</a>			x	
Heavy Civil	1997ish	Regional	Associated Schools of Construction (ASC)	<a href="http://region3.ascweb.org/Competition/competition_rules_and_guidelines.htm">http://region3.ascweb.org/Competition/competition_rules_and_guidelines.htm</a>				x
Hydraulic Rocket	2012	Regional	SouthEast ASCE Regional	<a href="http://www.eng.fsu.edu/asce2012/competitions.php">http://www.eng.fsu.edu/asce2012/competitions.php</a>			x	
ITE Traffic Bowl	2010	National	Institute of Transportation Engineers	<a href="http://www.ite.org/trafficbowl/default.asp">http://www.ite.org/trafficbowl/default.asp</a> <a href="http://www.concrete.org/STUDENTS/ST_COMP ETITIONS.HTM">http://www.concrete.org/STUDENTS/ST_COMP ETITIONS.HTM</a>			x	
James Institute Student Award for Research on NDT of Pervious Concrete Cylinder Comp.	2010	National	ACI	<a href="http://www.concrete.org/STUDENTS/ST_COMP ETITIONS.HTM">http://www.concrete.org/STUDENTS/ST_COMP ETITIONS.HTM</a>	x			
Plan Reading	2012	Regional	SouthEast ASCE Regional	<a href="http://www.eng.fsu.edu/asce2012/competitions.php">http://www.eng.fsu.edu/asce2012/competitions.php</a>			x	
Popsicle Bridge	1984	National	CSCE/SCGC	<a href="http://troitsky.ca/rulebook/">http://troitsky.ca/rulebook/</a>		x	x	x