Five Years of Capstone Winners: Analysis of NCEES Engineering Awards 2009-2013

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The National Council of Examiners for Engineering and Surveying has conferred Engineering Awards to 25 capstone design projects, representing 15 capstone design courses. Most projects (92%) were local and "one off." Nearly all projects (98%) were sponsored by a civil engineering department or school. Most projects were multi-discipline, with the most common engineering disciplines being structures and civil-site (76% and 64%, respectively), followed by hydrology, hydraulics, and geotechnical. Most projects were open-ended and required preliminary design (80% and 60%, respectively). Common non-engineering instruction included project management (68% of projects), team management (40%), and communication, ethics, and sustainability (28% each). Common deliverables (assignments) were drawings, presentations, and reports (84%, 80%, and 76% of projects, respectively), and cost estimates and proposals (60% each). The number of teams per project varied widely; 48% had one team but 16% had six to 10 teams. Most projects (68%) had teams of six or fewer. The multi-disciplinary nature of the projects appears to be related to the involvement of practitioners. These two characteristics plus team-based design and non-technical instruction indicate that the capstone projects relied on experiential learning.

Keywords: Capstone, civil engineering, multi-discipline, teams

NCEES Engineering Award

Since 2009 the National Council of Examiners for Engineering and Surveying (NCEES) has conferred 31 Engineering Awards for Connecting Professional Practice and Education to mostly engineering capstone projects that engage "students in collaborative projects with licensed professional engineers."[1] Twenty-five mainly undergraduate capstone design projects represent 15 capstone design courses at 15 universities in the United States, as listed in Table 1 in the appendix.

Each winning project (and some course structure) is described in an award-program entry document and, briefly, in an annual award booklet, all of which are posted on the NCEES web site.[2]

Method of Analysis

Information in the entry documents was culled and categorized according to salient project or course characteristics. The annual booklets provided a small amount of additional information. Some limited information also was inferred from the entry documents.

The analysis generally considered the 25 capstone projects, but some of the analysis instead considered the 15 capstone courses that subsume the projects, since some courses (universities) had more than one winning project. The six winning projects that were not capstone projects were not included in the analysis.

Project and Course Basics

Twenty-three (92%) of the capstone projects were local and "one-off." Two projects were international (Ethiopia and Haiti). One project was multiple-use; another extended over more than one course.

Of the 15 capstone courses, six (40%) were taught over two semesters, one (7%) over three quarters, one (7%) over two terms, one (7%) over two quarters, and three (20%) were taught over one semester. The duration of three courses (20%) is unknown.

Engineering Instruction

All of the 25 capstone projects except one (98%) were sponsored by a civil engineering department or school, of which 12 (48% total) also included environmental engineering. Other named department disciplines were construction management, engineering mechanics, geomatics, and mechanical engineering (one each). The one department (and project) that was not civil engineering was electrical and computer engineering.

Eighteen projects (72%) were multi-discipline. Seven projects (28%) involved a degree program other than civil engineering, such as construction management, landscape architecture, and electrical, environmental, industrial, and mechanical engineering.

The most common engineering disciplines used or taught in the capstone projects were structures and civil-

site (land development), as shown in Figure 1 at 76% and 64%, respectively. Hydrology, hydraulics, and geotechnical engineering each were used in about half the projects. Environmental and transportation engineering each were used in about a third of the projects. Other disciplines used were architecture, landscape architecture, surveying, and computer, electrical, industrial, mechanical, and wastewater engineering.

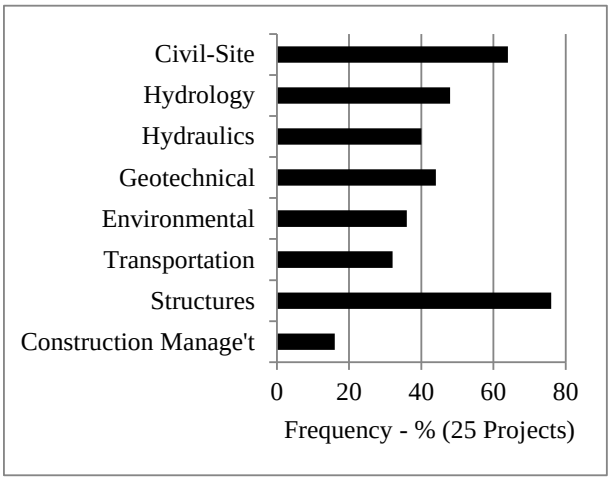

Figure 1: Engineering discipline used in the capstone design projects.

Figure 2 shows the engineering components used in the projects, where component may be just that, such as a bridge, or it may be a type of engineering task, such as traffic analysis.

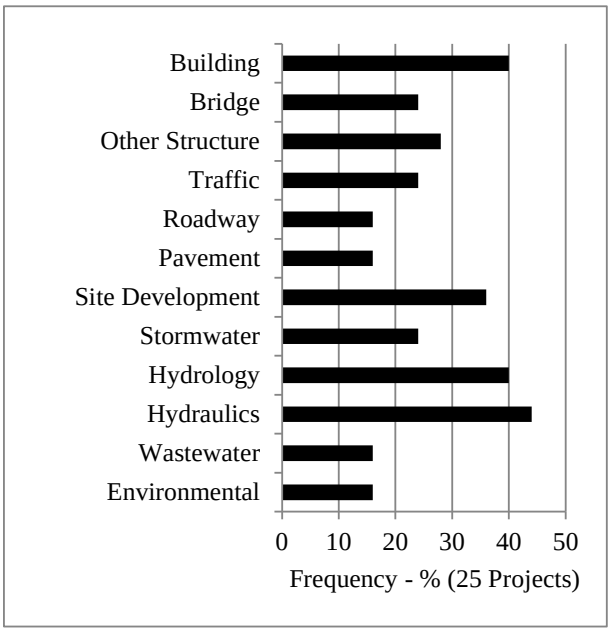

Figure 2: Engineering component used in the capstone design projects.

Structures (building, bridge, and many other smaller structures) were used in 92% of the projects. Hydrology and hydraulics components (such as a canal, channel, culvert, floodplain, lift station, and reservoir) each were used in about 40% of the projects. Site development components were used in 36% of the projects. Other engineering components used in the projects were stormwater and traffic (24% each), and roadway, pavement, wastewater, and environmental (16% each). The environmental classification included brownfields, Phase 1 studies, and soil remediation.

Other components were domestic water, load testing, surveying, and a haptic interface (for the one project that was not civil engineering).

The component frequency roughly matches the discipline frequency shown in Figure 1. One notable exception is that, although Figure 2 does not show any geotechnical component, geotechnical engineering was involved in many structures, hydraulics, and hydrology components.

Twenty projects (80%) were open ended, four (16%) were defined, and the level of definition for one project is unknown. Five projects (20%) required conceptual design, fifteen projects (60%) required preliminary design, and five projects (20%) required final design.

Most local projects included site visits. In three projects (12%), the site visits were intensive class working sessions. One project included a class at a fabricator's plant.

All projects but one (96%) involved mentoring by practicing professionals, who, often as volunteers, frequently also provided the instruction in engineering and non-engineering topics.

Non-Engineering Instruction

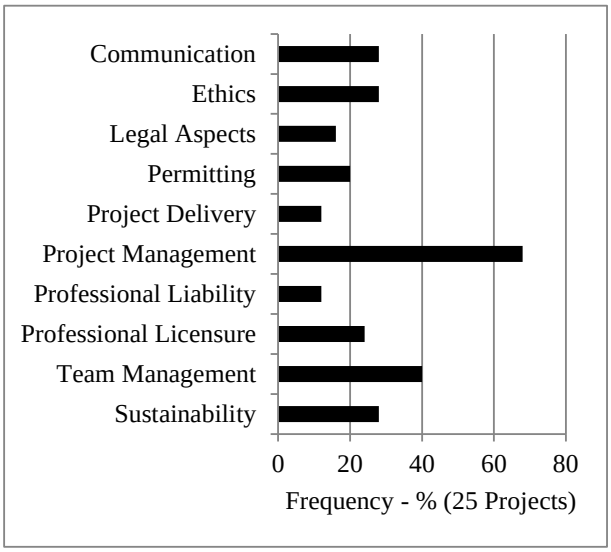

Figure 3: Non-engineering instruction in the capstone design projects.

The most common non-engineering instruction was project management, which was given in 68% of the projects, as shown in Figure 3. This was followed by instruction in team management (40%); communication, ethics, and sustainability (28% each); professional licensure (24%); and permitting, legal aspects, project delivery, and professional liability.

Other non-engineering instruction included aesthetics, continuing education, drawings, and public meetings.

Deliverables

The most common project deliverables (assignments) were drawings, presentations, and reports, each required on more than three-quarters of the projects (84%, 80%, and 76%, respectively), as shown in Figure 4. Cost estimates and proposals or statements of qualifications were required on 60% of the projects. A few projects required schedules, specifications, posters, or memoranda as main deliverables.

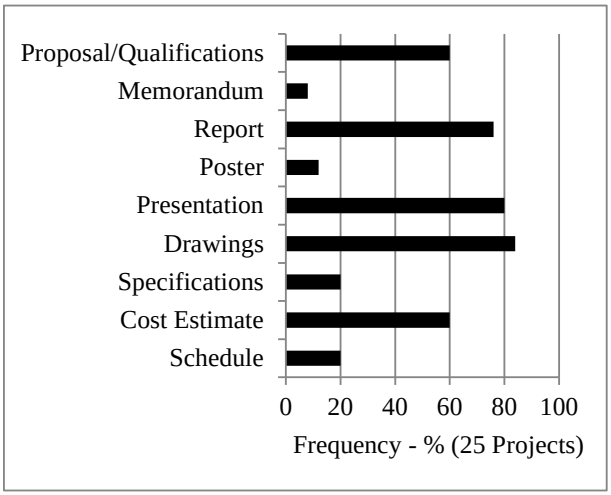

Figure 4: Deliverables (assignments) required in the capstone design projects.

Infrequent deliverables included a decision matrix, cost benefit analysis, design charrette, and LEED documentation.

Participant Set-up

Twelve projects (48%) had a single team, 16% had two to five teams, 16% had six to 10 teams, and one project (4%) had more than 10 teams. The number of teams for four projects (16%) is unknown.

Seventeen projects (68%) had teams of six students or fewer, three projects (12%) had teams of seven to 10, one project had teams of 11 to 20, and two projects (8%) had teams of more than 20 students. The number of students per team is unknown for two projects (8%). The number of students per project is listed in Table 1.

Thirteen of the 25 projects (52%) had five or fewer students per teacher. Fifteen of the 25 project (60%) had a student-practitioner ratio of two or less.

Conclusion and Discussion

The typical NCEES Engineering Award capstone course may be characterized as having a local, multi-discipline, open-ended, civil engineering project that required the preliminary design of a structure, site, or water-resource component, often in combination, by a small number of small teams. In addition to engineering, students received instruction in project and team management, plus communications, ethics, and sustainability. Practitioners usually provided the instruction, in addition to mentoring, under low student-teacher ratios.

The multi-disciplinary nature of the projects would seem to be related closely to the involvement of practitioners, since most "real world" engagements in civil engineering usually do require the efforts of several disciplines. The involvement of practitioners in the analyzed projects is not surprising given the basis of the award program. Cause and effect, however, are not clear. Did practitioners steer the projects toward multi-disciplinary scopes? Or were practitioners brought aboard because the institutions desired multi-disciplinary projects? Allusive language in the source documents suggests some of both and some combinations of both.

The multi-disciplinary nature of the projects, the intense involvement of practitioners, the team-based execution of design, and the instruction in non-technical topics all suggest that these capstone projects (and courses) generally relied on and promoted experiential learning. Descriptions in the entry documents of "hands on" work by the students and testimonials in the annual award booklets speak loudly to the emphasis on and benefits of experiential learning, especially under the mentoring of practicing professionals.

That all but one of the 25 capstone projects, and all but one of the 15 capstone courses, are in civil engineering may be a consequence of the award program seeking to recognize the involvement of "licensed professionals" in engineering education, a laudable outgrowth of the NCEES mission. Civil engineering projects nearly always must be executed under the supervision of a licensed engineer.

References

1. http://ncees.org/licensure/ncees-engineering-award/
2. http://ncees.org/licensure/ncees-engineering-award/. Also, the entry documents for the 25 capstone projects (and other document – and other projects and courses) may be found at https://sites.google.com/site/engineeringcapstone/.

Appendix – Table 1: NCEES Engineering Award Projects

NCEES Engineering Award, Winning Projects, 2009-2013					
University	Engineering Department	Award Year	Course Type	Duration	Number Students
California Polytechnic State University San Luis Obispo	Civil & Environmental	2010	Capstone	T2	160
California State University Los Angeles	Civil	2011	Capstone	Q2	39
California State University Los Angeles	Civil	2010	Capstone	Q2	23
Clemson University	Electrical & Computer	2010	Capstone	S1	16
Florida A&M University - Florida State University	Civil & Environmental	2009	Capstone	S2	36
Florida Atlantic University	Civil, Environmental & Geomatics	2012	Capstone	S2	8
Lawrence Technological University	Civil	2011	Capstone	S2	32
Oklahoma State University	Civil & Environmental	2012	Capstone	u	10
Seattle University	Civil & Environmental	2013	Capstone	Q3	4
Seattle University	Civil & Environmental	2013	Capstone	Q3	4
Seattle University	Civil & Environmental	2012	Capstone	Q3	4
Seattle University	Civil & Environmental	2012	Capstone	Q3	4
Seattle University	Civil & Environmental	2011	Capstone	Q3	4
Seattle University	Civil & Environmental	2011	Capstone	Q3	5
Seattle University	Civil & Environmental	2009	Capstone	Q3	4
University of Arizona	Civil & Engineering Mechanics	2009	Capstone	S2	u
University of Delaware	Civil & Environmental	2010	Capstone	S2	78
University of Missouri Kansas City	Civil & Mechanical	2009	Capstone	u	u
University of Nevada Reno	Civil & Environmental	2013	Capstone	S1	31
University of New Mexico	Civil	2011	Capstone	S1	22
University of New Mexico	Civil	2010	Capstone	S1	6
University of Tennessee Chattanooga	Civil	2009	Capstone	S2	8
University of Texas El Paso	Civil	2013	Capstone*	S3	40g
University of Texas El Paso	Civil	2012	Capstone*	S2	47g
University of Texas El Paso	Civil	2011	Capstone*	u	14g
Non-Capstone Projects (not included in analysis)					
Cleveland State University	Civil & Environmental	2013	Service	Y4	34g
Northern Arizona University	Civil, Const Manage't & Environmental	2013	Other	u	6
University of Iowa	Civil & Environmental	2009	Service	S1	u
University of Maryland	Civil & Environmental	2010	EWB	Y1*	30
Valparaiso University	Engineering College	2012	EWB	u	9
Virginia Tech	Civil & Environmental	2009	Program	S1	u

"*" (asterisk) indicates inferred information. "EWB" signifies Engineers Without Borders.
"g" indicates that student number includes graduate students. "u" indicates unknown.
For Duration, first character indicates Quarter, Semester, Term, or Year; second character is the number of same.