Using Competitions as Capstone Engineering Design Projects

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The engineering senior design experience is now firmly entrenched in engineering curricula. However, as many faculty teaching senior capstone design recognize, the identification, screening, selection and financing of design projects remains at best a challenging task. As indicated in the literature, trends suggest that over time, more competitions are being included in the portfolio of capstone engineering projects. This article focuses specifically on guidelines for considering the use of competition projects in capstone design classes. In addition as reference, this article provides a sampling of over 30 national competition projects that are currently used by some universities as senior design projects in single or multidisciplinary capstone courses.

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Background

With over twenty years teaching multidisciplinary senior design courses in one form or another, I feel confident in saying that I have seen both the best and worst of capstone projects examples. Regardless of the sponsorship of the project, internal versus external, industry versus government, service or competition, there are advantages and disadvantages of adopting each option. One trend of note however is the increased sponsorship and availability of engineering competitions suitable for capstone projects.[1,2] Again here, there exist excellent competition experiences for students and alternatively potentially disastrous ones.[3,4]

At Roger Williams University, the primary objective of the two semester senior design class is to provide a forum for the synthesis and application of a student's knowledge and skills acquired over the course of his or her college career. The class provides opportunities for the application of these competencies in undertaking a design project sponsored by a client partner. Learning outcomes associated with the two semester senior design class include the following.

Students are expected to:

- Gain practical experience in a multidisciplinary design and development team.
- Understand and then transform a client's needs into a tangible project design.
- Apply the formal engineering design process with emphasis on concurrent engineering.
- Practice defined processes and effective team (and client) communication during conceptualization, production and delivery of a product or system.
- Develop proficiency in preparing, reviewing and validating all components (notes and writings, sketches and drawings; simulations and models; vendor relations; budgeting, economic analysis, materials selection, etc.) related to a completed project design.
- Synthesize information and develop effective communications explaining the results of the design process in informal and formal reports and presentations to technical and non-technical audiences.
- Recognize value in alternative ways to approaching issues, thinking critically, managing team members, and problem-solving.
- Experience the value of early starts, careful planning, team interaction, and positive interpersonal communications under tight deadlines.
- Participate in at least two external events where the successful project and research will be showcased.
- Create the foundation for a successful career or graduate studies.

These learning outcomes directly correlate with the Engineering Program's assessment framework that in turn supports accreditation requirements.

Qualifying a Senior Design Project

A competition project is no different than any other type of senior design project with respect to deliverables, meeting the needs of stakeholders[5], and value of experience for students.[6] Although there are a number of different approaches and formal methodologies for qualifying projects, a successful project outcome usually starts with a well defined problem statement and effective mentorship from the various sponsors.[7]

For the purposes of meeting course objectives and student learning outcomes, a qualifying external project must have an identified external client providing some degree of a developed problem statement. As known, problem statements may be presented in many different

forms. For example, an industry sponsored project may propose a simple one page statement requesting proof of concept for an idea still in development stages. Alternatively, an engineering competition project often includes over one hundred pages of rules, constraints and specifications that support the articulation of the design problem. In any case, (again for my classes) the final problem statement must be robust enough to provide a basis for identifying alternatives to answering the design question.

Furthermore, the nature of the competition problem statement should allow for the inclusion of students from at least three different majors or specializations.[8,9] Students should expect that the projects, even though competition focused, will parallel those commonly found in industry; projects defined by participation of cross-functional employees that share a range of specializations (e.g., various disciplines within engineering, writing, science, management and marketing). Although some engineering programs still deliver capstone courses to an audience of students from a single major, neither the design problems nor the team dynamics generated in these venues are realistic with respect to what a student encounters when entering the engineering profession. The opportunities for incorporating other majors from within and external to engineering only enriches the experience for all.[10,11,12]

Another requirement for qualifying the capstone competition project is that the problem statement should allow for students to physically create something, i.e. a prototype, working model or integrated system. Therefore, competition projects that involve only research into technological trends or innovative practices much like a thesis paper are not acceptable for my senior design classes.[13]

From the client perspective even though a competition, students still need to have identified experts to communicate with concerning technical questions, specifications, clarification of technical details and other. This available interaction is critical to student success whether face to face, through email, competition listserv, phone other channel. In addition to the design binder and my written class requirements, a competition design project must at minimum include a significant written technical paper suitable in whole or part for publication as well as the production of a poster, oral presentation and demonstration of the prototype or model.

Evaluating Competition Projects

There are a number of competitions that meet the aforementioned requirements. One example held annually in New Mexico is the Environmental Design Contest sponsored by WERC: A Consortium for Environmental Education and Technology Development. The competition, recently celebrating its 20th year, has demonstrated a solid track record of offering four to eight industry/government sponsored multidisciplinary design tasks each year.[14]

Each one of the tasks offered by the WERC competition is best accomplished with a team of engineers possessing different specializations. In addition to engineers, many schools enter the competition with members from computer science, environmental science, chemistry, technical writing, business and marketing. All of the tasks in this competition focus on some aspect of energy and/or the environment and require a comprehensive approach to solving one of the industry or government sponsored design problems. This is one of the few competitions that has historically provided teams traveling to New Mexico with travel stipends for offsetting costs.

Furthermore, this competition incorporates a significant written report, oral and poster presentation, prototype benchscale demonstration where as many as five different teams of industry judges evaluate individual benchscale presentations. The organization, supportive environment for students, and professionalism of the many staff members and industry participants running the contest each year over the course of the four day competition is a model for success.

Alternatively, I have had my students participate in some of the more popular discipline specific competitions with far less favorable results. National competitions that are run by student chapters of organizations or enlist new volunteer judges on a yearly basis rarely produce an optimal experience for students. In addition, design experiences that include only a competition event (such as a race) without the requirement of technical reports, oral presentations or interaction with judges and industry are also far less valuable to students. Furthermore, industry or government competitions in the early stages of development often don't have the infrastructure or financial support to allow an optimal result for the capstone design experience.

In a survey of the literature, one tool that I have never found in comprehensive form is a current reference list with links to potential capstone design competition projects for multidisciplinary courses. In Appendix A, I provide one based on the projects that I consider each year for senior design class. One of the challenges in constructing a tool such as this is the dynamic nature of the offering of engineering design competitions. However I believe it is a good start to documenting competition opportunities.

Conclusions

When participating in competition based senior design projects, many factors can ultimately impact the success of the student experience. In the end however, it is our responsibility as faculty in facilitating these experiences to provide a foundation that enables success. With proper screening and research, certain capstone competition projects can provide equal and in some cases superior outcomes to traditional industry or service based projects.

References

[1] L. Riley, "Integrating External, Client-Based Engineering Senior Design Projects into a Capstone Class," *Proceedings from 1st National Capstone Design Conference*, Boulder, Colorado: 2007.

[2] S. Howe and J. Wilbarger, "2005 National Survey of Engineering Capstone Design Courses," *Proceedings of the 2006 ASEE Annual Conference*, 2006, pp. 1-21.

[3] See also: W. Padgett, "Teaching Design Through Design Competitions," *Proceedings of the 27th Annual Frontiers in Education Conference*, Pittsburgh, PA: 1997, pp. 1477-1480.

[4] S. Kundu and M.W. Fowler, "Use of Engineering Design Competitions for Undergraduate and Capstone Projects," *Chemical Engineering Education*, Vol. 43, 2009, pp. 131-136.

[5] R. H. Todd and S.P. Magleby, "Elements of a successful capstone course considering the needs of stakeholders." *European Journal of Engineering Education*, 2005, Vol. 30, Issue 2, p. 203-214.

[6] J.A. Marin, J.E.J. Armstrong, and J.L. Kays, "Elements of an Optimal Capstone Design Experience." Journal of Engineering Education, Jan. 1999, p. 19-22.

[7] P. Little and J. King, "Selection criteria for cornerstone and capstone design projects." International Journal of Engineering Education, 2001, Vol. 17, Nos. 4 and 5, p. 406-409.

[8] Patricia Wojahn, Linda Ann Riley, and Young Ho Park, "Teaming Engineers and Technical Communicators in Interdisciplinary Classrooms: Working With and Against Compartmentalized Knowledge," *Proceedings of the IEEE IPCC Annual Conference*, 2004, Minneapolis, MN.

[9] Linda Ann Riley, Patti Wojahn and Young Ho Park "Multidisciplinary Courses: Facilitating Win-Win Opportunities Across Departments and Colleges" 2003 Science, Technology and Education Conference, published at: http://spacegrant.nmsu.edu/NMSU/2003/index.html, Las Cruces, NM.

[10] Young Ho Park, Linda Ann Riley and Patti Wojahn "Senior Design Classes: Teaming Engineers with Technical Documentation Specialists to Enhance Students' Learning Experiences" 2002 Science, Technology and Education Conference, published at: http://spacegrant.nmsu.edu/NMSU/2002/index.html, Las Cruces, NM.

[11] Patti Wojahn, Julie Dyke, Linda Ann Riley, Ed Hensel, Stuart Brown, "Blurring Boundaries between Technical Communication and Engineering: Challenges of a Multidisciplinary, Client-Based Pedagogy," *Technical Communication Quarterly*, 2001, Vol. 10, Issue 2, pages 129 – 148.

[12] Julie Dyke Ford and Linda Ann Riley, "Making Room for Communication in Engineering Education: Letting Past Research Inform Future Pedagogy," *Journal of Engineering Education*, October 2003, Vol. 92, no. 4.

[13] See also: C. Kaiser and W. Troxell, "Student Design Competitions in Undergraduate Engineering Education," *Proceedings of the 35th Annual Frontiers in Education Conference*, Indianapolis, IN: 2005, pp. S3J-S3J.

[14] See details of the WERC Annual Design Contest at: http://www.werc.net/contest/index.asp

Appendix A

Competition Name	Weblink – Note that some links provide access to multiple competitions
2010 ASEE Model Design Competition	http://www.tcc.edu/faculty/webpages/PGordy/ASEE/ASEE2010/index.html
2010 National Concrete Canoe Competition	http://content.asce.org/conferences/nccc2010/index.html
2010 Student Structural Design Competition	http://content.seinstitute.org/files/pdf/2010StudentStructralDesignCompetition-updatedMay2009.pdf
12th Annual International Underwater Autonomous Vehicle Competition	http://www.gorobotics.net/the-news/latest-news/12th-annual-international-autonomous-underwater-vehicle-competition/
AGCO National Student Design Competition	http://www.asabe.org/awards/competitions/National.html
SACHE Student Design Competition for Safety in Design	http://www.aiche.org/Students/Awards/SACHEAwards.aspx
FAA Airport Design Competitions	http://www.faa.gov/airports/runway_safety/design_competition/
American Institute of Aeronautics and Astronautics - Design Competitions	http://www.aiaa.org/content.cfm?pageid=210
ANS Student Design Competition	http://www.ans.org/honors/va-studesign
ASCE - AISC Student Steel Bridge Competitions	http://www.aisc.org/content.aspx?id=780
ASHRAE 2010 Student Design Project Competition	http://www.ashrae.org/students/page/1420
National Scholar Award for Workplace Innovation and Design	http://seniordesign.be.ucsd.edu/courses/BENG_187AD_Competition_Presentation.pdf
Bentley Student Design Competition	http://www.bentley.com/en-US/Community/Academic/Networking+and+Development/BE+Awards/Be+Awards.htm
Engineering World Health	http://ewh.org/index.php/programs/technology/competition/details
2010 International Aluminum Extrusion Design Competition	http://www.etfoundation.org/assets/pdf/ETF2010_Call4EntriesInfo.pdf
ASME Human Powered Vehicle	http://www.asme.org/Events/Contests/HPV/Human_Powered_Vehicle.cfm
ASME 2010 Earth Saver Student Design Competition Challenge	http://www.asme.org/Events/Contests/DesignContest/Student_Design_Competition.cfm
NASA - Portal Information Site for Various NASA Sponsored Competitions	http://www.aeronautics.nasa.gov/design_comp.htm
20th Annual WERC Design Contest	http://www.werc.net/contest/index.asp
2010 G. B. Gunlogson Student Environmental Design Competition	http://www.asabe.org/membership/students/OpenRules2010.pdf
EPA P3: People, Prosperity and the Planet Student Design Competition for Sustainability	http://www.epa.gov/P3/
PERI GmbH - Construction Exercise	http://www.peri.de/ww/en/news/con_exercise.cfm
SAE Collegiate Design Series Competitions	http://students.sae.org/competitions/
SolidWorks Student Design Competitions with SolidWorks 3D Software	http://www.solidworks.com/sw/education/student-design-competitions.htm
Precast/Prestressed Concrete Institute Student Design Competition	http://www.pci.org/education/big_beam/index.cfm
Student Manufacturing Design Competition - Manufacturing Engineering Division	http://divisions.asme.org/MED/Student_Manufacturing_Design.cfm
Undergraduate Seismic Design Competition	http://mceer.buffalo.edu/education/usdc/default.asp