Redcone Civil Design Group: A Practitioner-Centric Capstone Experience

ABSTRACT

A partnership between a municipality, a civil engineering department and professional practitioners created the opportunity for a civil engineering capstone class (Redcone) to provide *pro bono* engineering services on public projects which will be constructed according to the students' design. Care is taken by the practitioners and the faculty to select right-sized projects which will be challenging and meaningful to the students. Throughout the process, the students are expected to understand that the ethical, professional, and design decisions they make affect public health and safety. The class provides a transition between school and the workplace, with marked increase in the professionalism of the students. The practitioners, students, faculty and client share responsibilities and benefits which gain respect in the broader engineering community and ensure Redcone's continuation as a viable civil engineering capstone experience.

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Introduction

Redcone Civil Design Group is the civil engineering capstone course at a University which partners with a City and professional practitioners to prepare students to work on real, constructible, and needed projects.[1] The design projects are typically traffic-bearing bridges (culverts) over water which include environmental, traffic, site, hydraulic, and property design constraints. Integral to the success of the year-long program is the collaboration among the students, the faculty, and the practitioner partners.

The City has agreed to construct the Redcone projects according to the students' plans, contingent on the supervision of the practitioners. The students are reminded from the beginning that their design is serious and has consequences in the community. The gravity of the City's commitment to honor the students' design brings an atmosphere of professionalism to the class experience that would be difficult to create if the designs had no importance beyond grades.

A well-scoped project is imperative in implementing a successful program and creating a long-term relationship among the client, practitioner, and university. Projects excessively broad in scope can lead to disorganization and frustration at all levels. By way of comparison, projects markedly small in scope may not offer an adequate amount of complexity nor provide a sense of accomplishment for the students.

The Redcone project reinforces personal, professional responsibility and the consequences of engineering actions. The class frequently and spontaneously engages in discussions and analysis of registration and ethics. The practitioners and faculty are quite transparent about their opinions, experience and limitations.

Conventional Civil Engineering Capstone Approaches

Civil engineering projects are typically large and complex, making design difficult for a University senior capstone class. Past projects at the University were usually either retrospective/paper designs or were of such great scope that the students seldom got a sense of completion from the work: "projects have to be scoped to the right size or level of involvement as to guard against being unmanageably large or so narrowly focused that they do not provide enough challenge or latitude for the students".[2] Another author shares an analysis of traditional CE capstone classes:

> Capstone courses offered by civil engineering departments are generally simulation-type courses. Paper designs or economic evaluations are often the desired final product in such courses. Construction is usually impossible since large structures and systems are involved.[3]

Students at another university designed pedestrian bridges for a small, rural community. While the project included an interface with the client on small, right-sized projects, the town only used the designs to scope their construction budgets for the bridges' design and construction.[4] A similar capstone design project involved practitioners and multiple design constraints, but differed from the Redcone course described herein because the students chose their own fictitious projects for analysis and design.[5]

Successful collaboration of faculty, students, and professional practitioners

Faculty/University

The faculty's role is to provide continuity, help resolve conflicts between students and practitioners, train the practitioner on education-related issues, and conduct educational assessments. The nature of the Redcone course has made it easy to assess ABET[6] student outcomes because the projects require some of the soft engineering skills to create a successful design, as shown below.

ABET Outcomes	Definition	Student activity
d	An ability to function on multi-disciplinary teams	Design team and interaction with other engineering/permitting professionals; Team peer evaluations
f	an understanding of professional and ethical responsibility	Participate in ASCE ethics workshop and complete analysis of NIEE* cases
h	the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	Design culvert or trail to meet budget constraints; Design culvert water crossings to minimize environmental impact within USCOE† 404 permitting guidelines; Design culvert to complement neighborhood; adhere to ADA‡ standards if applicable.
i	a recognition of the need for, and an ability to engage in life-long learning	Complete a two-part survey on the need for life-long learning and document independent learning
j	a knowledge of contemporary issues	Attend a public meeting for an engineering project and complete a brief report
k	an ability to use the …modern engineering tools necessary for engineering practice	Produce a sheet using Microstation for the construction blueprint set and learn Microsoft Project (scheduling software)
ASCE Criterion 8	procurement of work; design & construction interaction	Location study report presented to senior engineering staff at the City who chose design options; Design must be constructible for City staff – interact with City construction manager

The faculty in charge had no construction background, but was willing to rely upon the experience of the practitioner for technical design issues. A reciprocal relationship developed where the faculty was able to mentor the practitioners in leadership. This relationship and potential for additional development enhances the value of Redcone to the practitioner.

* National Institute for Engineering Ethics
† U.S. Army Corps of Engineers
‡ Americans with Disabilities Act

Student Team

The senior capstone class is ideally split into teams of approximately ten[7] to maintain involvement and ensure student accountability. The team size allows frequent oversight and mentoring by the practitioners. Careful division of teams, undertaken early in the process, is performed in an effort to ensure each team contains a well-balanced blend of civil engineering interests. The students are encouraged to represent their work on the Redcone project as *pro bono* work. An example of resume language for a student follows:

> *Redcone Civil Design Group, University, City. August 2003-May 2004. Bridge replacement of XX Drive over YY Creek. Responsible for 100-year flow computation based on APWA* design storm, and plan/profile drawing.*

The practitioners and faculty enter into the class with a predetermined timeline and an understanding of critical path items (location study complete two weeks before the end of the first semester, drawing set ready for outside review one month before the end of the second semester), but it is ultimately the responsibility of the students to identify intermediate project milestones. The practitioners have high expectations (writing, design, client needs) for the engineering products from the students and create opportunities to bring these younger students up to the high professional level that is needed.

Professional Practitioners

The role of the practitioner within the classroom is central to the success of the course. Ultimately, these individuals are responsible for keeping the students within scope, maintaining focus of the design group, ensuring quality, and providing professional mentorship. The practitioners act as mentors/coaches and do not teach in the traditional sense. In fact, when the practitioner is involved in too many aspects of the design, ownership of the project by the students is unlikely. Therefore, a hands-off approach within this studio environment is essential. The practitioner gives expertise to the university, student, client and the workforce. The ASCE Policy Statement 140[8] emphasizes the importance of integrating practitioners in civil engineering education:

> The involvement of practitioners in the formal education process will improve Civil Engineering education, while demonstrating the challenge and the satisfaction of Civil Engineering.
>
> Educators are expected to involve practicing professionals in the planning, design, and implementation of degree programs. Engineering faculties should include educators who are role models for aspiring practicing engineers and who can bring the current and future demands of engineering practice realistically into the classroom.

* American Public Works Association

Benefit to health, safety, and welfare of the public

Redcone fosters the growth of new engineering professionals who understand civil engineering projects. To achieve this, the students are charged with the development of construction documents that meet client design standards, cost, construction constraints, and the needs of the public. Accommodations for future planning efforts (bike trail, sidewalks, etc) are also considered.

One specific tool of the practitioner and the faculty in developing young professionals is the adherence to industry standards and realistic constraints. Redcone typically includes APWA* standards (hydrology), AASHTO† standards (road design), and economic (design within budget), environmental (USCOE‡ 404 permit application), social/political (easement/ROW§ requests), ethical (NIEE** case analysis), and constructability considerations.

Impact on raising social consciousness

Several specific tasks throughout the year-long course are specifically geared to educate the student on professionalism. During the course, the students are required to attend an engineering-related public meeting and report how the presenting engineers conducted themselves and what, if anything, the student would have done differently. The students complete a debriefing form which includes the following questions:

- Significant interested parties (e.g. government, neighborhoods, interest groups):
- What were the major issues?
- Describe the meeting dynamics (e.g. dominated by one person, apathetic, many people expressed their positions)
- Were any issues resolved in the meeting?
- How did the engineers handle the situations? Could you have handled the meeting?
- What training would be helpful to you in participating in these types of meetings in the future?
- If we had a public meeting on the XX project, what do you think would happen?
- Was an agenda distributed or made available?
- What was the meeting duration?

The practitioners and faculty throughout the year bring together ethics and decision-making processes in informal discussions that culminate in a formal ethics workshop.

The students learn about public interaction and perception from the municipality's right-of-way agent: a topic lacking in most CE curricula. The students must prepare an easement request to accompany their construction blueprints, so the workshop information is put to use to benefit the client.

* American Public Works Association
† American Association State Highway and Transportation Officials
‡ United States Army Corps of Engineers
§ Right-of-way
** National Institute for Engineering Ethics

Impact of partnering, coaching and practice

The nature of Redcone is partnering. The practitioner is responsible for keeping the students within scope, maintaining focus of the design group, ensuring quality, and providing professional mentorship. The practitioner provides a valuable linkage between the University and the client--promoting a lasting relationship. The practitioners' responsibilities extend beyond their duty to guide and mentor the students: their names and reputations are linked to Redcone and its reputation in the community.

Redcone is a significant recruiting tool for the University. High school seniors who aspire to engineering want to work on real problems with real responsibilities. Redcone has created a stir within the local engineering community; employers realize that these new graduates have the ability to "hit the ground running."

The faculty mentors the practitioners, who are middle-management-level engineers, which stretches their own mentoring skills and increases their business contacts. Multiple new connections between the University and industry have been made with the capstone course as the catalyst.

Multidiscipline and allied profession participation

The University and the professional practitioners understand the value brought to the experience by a multidisciplinary approach. Students experience the many different aspects of civil engineering. Some of the opportunities throughout the course of the year include:

- A two-hour workshop with the City's right-of-way agent to discuss easements, community perception, and overall project effects of land acquisition,
- Students partnered with the capstone class in graphic design to provide a logo and a brand for the CE course. This exercise culminated in interviews of three potential artists, twelve concept logos, and ultimately the selection of the Redcone logo seen in the header of the paper,
- Every year the students coordinate their design needs with both a survey crew as well as a geotechnical engineer. Students learn the difference between which data are ideal and what are required for design, and
- Students interview regulatory specialists to determine permitting requirements for their projects.

Knowledge or skills gained

Students

The students transition from a classroom setting to a design studio setting in the Redcone course. They adjust their work styles from homework (external deadlines) to self-management. The student become comfortable and competent as team members. The students make the first steps toward managing uncertainty on these projects. Their homework and well-defined design projects in earlier classes are in the past. They now must deal with a real topographic site and calculate a 100-year flow for culvert capacity. Students deal with incomplete or conflicting data and make a design recommendation based on these data by a deadline. They must choose one preferred design option from their analyzed options, but the preferred option must be selected wisely, not capriciously. These transitions are difficult but essential for

the students. Both the faculty and practitioner must give the students room to struggle with the issues and find their own resolutions.

The students begin building their engineering reputations. They must grapple with conflicting design constraints, site limitations, and easements. Their design drawings are reviewed by, and they present their design to senior City engineering staff at City Hall. They use Redcone as *pro bono* engineering experience in job interviews.

The Redcone model can easily be replicated at other universities. A review of the civil engineering ABET programs shows 70% of CE programs are close to a large city which may be able to provide properly-scoped projects for a civil engineering capstone course. Additionally, 100% of CE programs at U.S. schools have collaborative opportunities with their state Departments of Transportation.

Public/client

For the client, the benefit of new engineering professionals who understand civil engineering projects is invaluable. Students graduate from the University with an understanding of how a civil engineer works within a public works department and how the interaction between the municipality and its citizens is crucial to a successful project. They experience the demands of permitting, bureaucracy, and drawing standards in an academic environment. The clients' project is designed for construction under budget. The Redcone work products are well-known in the broader civil engineering community. Engineers unconnected with the University respect the work that the students complete, and enthusiastically hire our graduates.

Practitioner

The practitioner benefits from the experience beyond the altruistic goal of giving back to the profession. They are encouraged to explore their pedagogical skills and talents which include mentoring and leadership. They often find the time spent at the university as a respite from stressful work situations. The uniqueness of the Redcone experience has provided the opportunity for the practitioners and professor to collaborate on five national conference presentations, two national magazine articles, and an invited, peer-reviewed journal article.

Professional leadership

At the onset of the course, students elect a project manager. This project manager is held accountable for performance of the team. The project managers work with their practitioners to develop their leadership skills and participate in a Student Leadership Practices Inventory[9] (LPI) eight weeks into the course. All team members, including the team's practitioner, complete peer evaluation forms for the LPI. The results and interpretation of the LPI gives the student their first insight into their own management strengths and deficiencies. The project managers value the opportunity to improve their leadership, communication, and team effectiveness.

At the close of the first semester, the students are required to present their findings to the City. They deliver their location study report as well as a formal oral presentation at City Hall. This formal presentation is well-attended by City staff and is treated like a standard client-consultant engineering presentation. For the

student, they are taken out of the academic environment and forced to defend their own design decisions in front of seasoned engineers, practitioners, and faculty.

Viability of technology used in the project

All students had completed a course in basic computer-aided drafting, but the need to produce construction blueprints require them to learn Bentley Microstation with GeoPak during the senior design class. The students utilize GIS* for potential planning concerns and initial detour and traffic design. They complete a tutorial in Microsoft Project, which they use for their project's construction schedule. For the hydrologic and hydraulic portion of the project, the students have used a wide variety of software including HEC-HMS, TR-55, PondPack, HEC-RAS, and Geopak Drainage.

Closing Remarks

The success of the Redcone design experience depends on a balanced relationship between practitioners, University, and public/client. Managing this organic collegiality requires high expectations from all parties, consequences to all parties, and a desire from all parties to advance the engineering profession and train able engineers. The University has been fortunate to have practitioners who have enthusiasm to train students and a public/client who was willing to take a chance on a novel venture for small, civil engineering projects. The Redcone Civil Design studio has produced both capable graduates, as well as practitioners who have unusual insights into the educational process, through both the studio experiences and through their presentations to their peers in the literature and at conferences.

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* Geographical Information Systems