



Civil and Environmental Engineering Senior Capstone Design and UniverCity Year Partnership

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The senior design capstone course is an essential part of civil and environmental engineering (CEE) education at the University of Wisconsin-Madison (UW-Madison), offering students a chance to apply their accumulated knowledge to practical, real-world projects. However, finding a continuous stream of unique public works projects in various CEE sectors such as transportation, water resources, geotechnical engineering, construction, environmental engineering, and structural engineering to satisfy the needs of an expanding undergraduate program presents a significant challenge. This paper presents a novel approach to enhancing the senior design capstone course for CEE students, highlighting a successful, long-standing partnership with the UW-Madison UniverCity Year program and its associated communities. Central to this partnership is the enduring legacy of “The Wisconsin Idea.”

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Introduction

Senior Capstone Design is a required course for all students in the undergraduate civil engineering, environmental engineering, and geological engineering degree programs at the UW-Madison. It brings together practicing engineers, educators, community clients and stakeholders, and students to create solutions addressing a multitude of engineering challenges.

Senior capstone projects are proposed by real-world clients open to supporting students in gaining work experience with the civil engineering process. The projects are multidisciplinary and open-ended in nature and touch on a broad set of themes including general building design, transportation design, and environmental design. As students take on challenges through the process of creating and documenting designs for their capstone project, they are guided by a team of engineering faculty and practicing engineer mentors.

Incorporating community-driven projects into senior capstone provides students with valuable opportunities for real-world service-learning. Given the community-oriented nature of civil engineering careers, it's important that students take pride in their contributions to society.¹

It is noted that this structure is not exclusive to the University of Wisconsin-Madison. For example, Purdue University's Engineering Projects in Community Service (EPICS) is a service-learning design program where students collaborate in multidisciplinary, vertically

integrated teams with community not-for-profit organizations on long-term, large-scale projects. Key pedagogical and assessment elements, including structured reflection activities and genuine partnerships with community stakeholders, contribute to its success.²

This paper introduces a novel approach to service-learning project selection in a civil engineering senior design capstone course at UW-Madison. It highlights an established and successful partnership with the UW-Madison UniverCity Alliance, emphasizing the vital role of local community collaboration.

The Wisconsin Idea

The public service mission of higher education resonates strongly at the University of Wisconsin-Madison, a land-grant institution. In addition to the Extension mission that was established at all land-grant universities, two enterprising chancellors coined the phrase the “Wisconsin Idea” to explain what they hoped would be distinct about the university's contribution to the overall development of the state.³ The “Idea” it refers to is how the university can help legislators make policy, how research and teaching at UW-Madison can benefit all residents of the state, how the university can help local governments improve their ability to respond to citizen concerns, and generally how accessible the university is to the public.

The “Wisconsin Idea” embodies the spirit of community engagement and outreach at UW-Madison.

This philosophy serves as a broad framework, guiding a diverse range of activities from local to international public projects. It inspires faculty, staff, and students to engage in public work, ranging from brief consultations to deep partnerships with community members. The “Wisconsin Idea” also provides a platform to showcase valuable insights from practitioners in various fields. These insights, often not found in textbooks, enrich students’ learning by offering real-world perspectives that complement their academic studies.

UniverCity Year: Community Relationships

The “Wisconsin Idea” motivates the university to get involved in the community, but if a community partner wants to initiate a partnership with the university, the process can be challenging to navigate. Universities often have multiple entry points for nonprofit partners (e.g. Centers for Civic or Community Engagement, Public Service Institute), for-profit partners (e.g. Offices for Business/Corporate Engagement, Small Business Development Centers, commercializable research or technology transfer offices), and federal and state governments (e.g. Offices of State and Federal Relations).

However, there are not as many entry points for local governments (e.g. cities, counties, towns, and villages). Given that many civil and environmental engineering projects are funded and implemented at the local government level, it makes sense for civil and environmental engineering departments to have more opportunities to interact with these local governments.

That is where UniverCity Alliance comes in. UniverCity Alliance is a network of faculty and staff at UW-Madison, whose goal is to make the university more accessible to local governments across the state.⁴

The Alliance has created a program called the UniverCity Year that does targeted outreach to localities across Wisconsin to understand their needs and challenges. It is a structured program where these communities apply (through a formal application process) with a list of their most pressing challenges, and the staff of UniverCity Alliance scope out those projects in a way that makes it easy for a faculty member or instructor to adopt the projects into academic course work. UniverCity Alliance staff act as “matchmakers” between the stated needs/priorities of local governments and courses on campus eager to work with real-world clients.

The model seeks to connect university stakeholders who desire practical projects anchored in the world of practice (so students can gain more workforce skills) with localities who desire access to expertise gained through the existing university infrastructure (e.g. credit-bearing experiences like courses, internships, or field placements).

Professors of Practice: Industry Relationships

Industry practitioners who possess distinguished professional achievements are appointed as adjunct faculty in the Department of Civil and Environmental and are recognized with the title of “Professor of Practice.”

Professors of Practice (PoPs) possess extensive practical knowledge and experience in one or more fields related to civil and environmental engineering practice. This includes the economic and financial analyses related to alternative selection and implementation, as well as evaluation of the extensive non-monetary factors essential to the goals of engineering business endeavors. Further, PoPs possess engineering management skills in systems thinking, project management, leadership and team building, risk assessment, and informed decision-making.

By partnering with department faculty, Professors of Practice enhance the department’s ability to prepare aspiring engineers for professional practice, helping make the transition from college to industry.

The extensive conceptualizing, designing, funding, and management experience of the PoPs also helps the department satisfy the accreditation requirements for the ABET Engineering Accreditation Commission (EAC). This approach is consistent with new models for engineering education fostered by, among others, the National Academy of Engineering⁵ and the American Society of Civil Engineers.⁶

Out of the 31 Professors of Practice in the department, 19 (61%) were engaged in senior capstone design educational activities including lecturing, mentoring, and serving as presentation judges in 2023.

The Capstone/UniverCity Year Partnership

Each candidate capstone project is required to meet several fundamental criteria:

1. It must encompass multiple disciplines, including at least four of the following:
 - Construction engineering
 - Environmental engineering
 - Geotechnical engineering
 - Geospatial engineering
 - Hydrologic engineering
 - Structural engineering
 - Transportation engineering
 - Hydraulic engineering
2. It must include all the following:
 - Adherence to design criteria
 - Exploration of three alternatives
 - Recommendation of a preferred alternative
 - Development of construction documents

There is a reciprocal benefit between CEE and UniverCity Year: while the capstone course requires community partners, UniverCity Year provides access to these partners who, in turn, seek the specialized expertise of our students.

Each semester, UniverCity Year staff meets with CEE capstone instructors to identify projects that align with course learning objectives. UniverCity Year staff consistently manage community relationships pre-course, during, and post-course, enhancing the community partner experience. Simultaneously, this ensures that the CEE faculty receive well-defined, appropriately scaled projects for their capstone courses.

The partnership began with one project in one community in Fall 2016. Since then, the program has grown to include 17 community groups with a total of 27 projects, including parks, buildings, roads, developments, stormwater and wastewater systems, watershed restoration, and alternative energy systems.

The partnership structure is depicted in Figure 1.

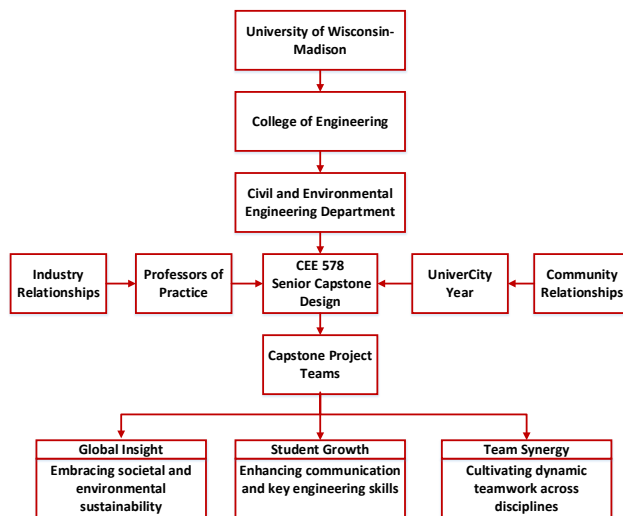


Figure 1: The CEE/UniverCity Year Capstone Partnership

This structural arrangement fosters three principal learning outcomes:

- Integrating global insights into all community-based capstone project designs,
- Promoting student development in competencies crucial for success in civil engineering careers, and
- Harnessing team synergy to accomplish projects beyond the scope of individual civil engineers.

Client Community Value

Student teams craft a comprehensive proposal tailored to a client’s RFP. Emulating real-world scenarios, each

team formulates a business proposal aimed at offering services that meet the client’s needs. With the understanding that they are vying for the client’s attention amidst competition from other firms, students are tasked with creating proposals that stand out. The proposals include the following components:

- Statement of interest
- Proposed work plan
- Presentation of preliminary project ideas
- Statement of qualifications
- Project schedule
- Invoicing methodology
- Team resumes

Teams have a twelve-day window between receiving the RFP to submitting their proposals and participating in a project team selection interview. After being awarded the project, the team contacts the owner to request available site-specific information (such as boring logs, topography, utilities, etc.). Each team is assigned two experienced engineers (or architects) as mentors to guide them through the project delivery process.

Teams look at several alternatives in a preliminary engineering report and presentation, recommending one alternative as the best option prior to beginning detailed engineering analyses. After obtaining input from the client community representative, the team confirms the selected alternative for the final design. Subsequently, they produce abbreviated plans and specifications, leading to a final presentation.

While the student products are conceptual in nature and are accompanied by a student work disclaimer, the value to community clients has been estimated to be in the range of \$13,000 to \$20,000.

Example Partnership Projects

During the 2023 academic year, student engineering teams embarked on several projects as part of UniverCity Year initiatives. This section offers additional insights into two of these projects and recounts the learning outcomes as reported by the student teams at the Fall semester’s end.

1. Cottage Grove, Wisconsin HWY BB Road Revisioning

Community-Based Project Description: The Village of Cottage Grove wanted to better understand what options might be available to change the character of West Cottage Grove Road (CTH BB) by way of revisioning the traffic lanes, adding bike and pedestrian infrastructure and enhancements, consideration for parking, safety, traffic calming, potential for future transit, aesthetic streetscape, and opportunities for “placemaking” along the corridor. The goal was to better manage traffic,

reduce vehicular crashes, make the space more accessible and inviting for pedestrians and bicyclists and encourage economic activity and redevelopment along the commercial corridor.

Student Learning Outcomes: The student learning outcomes of this project included gaining experience in several geometric design standards and roadway design software platforms. The team learned to navigate the WisDOT Facilities Development Manual to provide design solutions meeting standards for transportation, geotech, hydrologic, construction, and environmental criteria. The team worked with various traffic engineering software to analyze expected traffic volumes in the construction year and design year. The team also worked with Civil 3D to create drawings and plans for construction of an appropriate solution. By project completion, the team gained increased familiarity with the software and gained experience with technical standards, communication, and positive team dynamics. The team learned to present design study results professionally through two presentations and to respond to presentation questions from audience judges in a professional manner.

2. Eau Claire County, Wisconsin River Erosion Control

Community-Based Project Description: Eau Claire County needed an economical and sustainable solution to control Eau Claire River streambank erosion and sediment accumulation in Altoona Lake. The project consisted of a detailed review of the sediment problem and proposed creative solutions to reduce the sand bed load to Altoona Lake, such that dredging costs could be reduced. Technologies for riverbank stabilization and sediment control/removal prior reaching Altoona Lake were analyzed, and capital and operation/maintenance costs were determined. One alternative included a patented Streamside Technology Systems sediment collection and removal system (acquired by the County), which needed to be engineered to fit the site. When implemented, the system would sit in the riverbed and collect sediment for discharge as a slurry to truck for disposal or sale.

Student Learning Outcomes: During the design phase, the team honed skills in various software applications, drawing/scaling, code referencing, and comprehending the engineering project design process. Solutions for the sediment control project encompassed the fields of hydrologic, hydraulic, coastal, geospatial, construction, and environmental engineering. Integration of AutoCAD, Civil 3D, and GPS software expanded plan visualization and configuration possibilities. Continuous adherence to Wisconsin Department of Natural

Resources regulations and Wisconsin Department of Transportation manuals facilitated acceptable solution development. Exposure to authentic engineering documentation and engagement with mentors, clients, and technical presenters enriched the team's engineering project knowledge. Effective team management encouraged collaboration, fostering distinct skill development across various engineering disciplines.

Conclusion

Rooted in the "Wisconsin Idea," the UniverCity Year Program bridges the UW-Madison with local governments to foster collaborative partnerships. Complementing this, the UW-Madison CEE department PoPs significantly enrich the curriculum by integrating real-world expertise into the senior capstone design course.

The synergistic partnership between UniverCity Year, the PoPs, and the CEE senior design capstone course not only equips students with invaluable practical project experience but also delivers cost-effective civil engineering solutions to our partner communities.

Through our collaboration, a key insight emerged: centralizing project ideas and requirements from municipalities is essential for seamless integration with suitable capstone classes. The establishment of a single point of contact at UniverCity Year has proven invaluable for both Wisconsin municipalities and the UW senior capstone design course.

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