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Engagement in Practice: A cornerstone design course fusing the engineering design process with community engagement in context-based design

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Abstract

Capstone engineering design projects aim to synthesize four years of college education into an authentic / context-based engineering design experience wherein student design teams work to balance objectives with constraints to produce a design that meets clients' needs. Assigning complex engineering design projects prior to the senior year can feel daunting because students haven't learned the technical engineering that they must apply to produce successful designs. But the engineering design process doesn't require the application of complex mathematical, scientific, or engineering theory; it can be taught, and students can apply it as early as their freshman year.

This paper will describe a framework for incorporating a context-based engineering design project into a first-year engineering curriculum. The project is part of a one credit course, first offered in spring 2022, and required for all undergraduate students in the Department of Civil and Systems Engineering at Johns Hopkins University. For the first three years of the course, students worked through the engineering design process as they collaborated in teams to develop proposals for vacant city lots. Community partners who had volunteered to steward the lots acted as the project clients, and at the end of the semester students presented their proposals to the community partners. In addition to presenting their work, students developed scaled drawings, cost estimates, and a list of potential funding sources for their clients. Incorporated as part of a larger curriculum redesign, there were three objectives for the course: (1) to improve students' design thinking skills, (2) to attract and retain students to the program, and (3) to engage students with the community in their adopted city.

Though the course enrollment has grown from 5 (2022) to 8 (2023 and 2024) to 14 students (2025), the relatively small numbers mean that formal data was not collected during the first three years the course was offered; rather, we've iterated the course design based on informal observations made each year by the course faculty. These iterations, observations, and future research questions will be discussed in this paper.

Background and Motivation

Much research has been done that points to the benefits of incorporating context-based engineering design projects into undergraduate engineering curricula through project-based learning [1] [2] [3]. A context-based engineering design project is one that requires students to "recognize the complexities of global and societal issues and respond to those issues with the solutions they develop" [1]. The authenticity of such projects improves students' design thinking skills, which according to Brown [4] include empathy, integrative thinking, optimism,

experimentalism, and collaboration. Unlocking these design thinking skills through contextualized design projects may be particularly important if we are to attract and retain a more diverse population of students to the engineering profession as underrepresented groups and females tend to be motivated by working with people and helping others [1] [5], two essential elements of engineering design, but elements that may be overlooked in undergraduate engineering design problems that are not contextualized.

ABET has long understood the necessity of including engineering design in undergraduate engineering programs and in effect it has required contextualization of design and professional issues through its student outcomes [6], specifically student outcomes (2) and (4) which require:

> an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors (Student Outcome 2)
>
> an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts (Student Outcome 4)

It is common practice for undergraduate engineering programs to use the senior capstone project to assess the abilities of students to meet these ABET student outcomes [7]. Considering the mid-twentieth century definition of engineering as "applied science", capstone projects are a logical place for students to synthesize the technical knowledge they have gained throughout their four years as undergraduate students into a solution for a design challenge. After all, what have students learned in their high school education or even their first semester in college to prepare them for engineering design? But if we put aside the engineering-as-applied science definition, the engineering design process may successfully be used to design any manner of solutions to society's problems, and as faculty we can cater the technical nature of the contextualized engineering challenge to the students tasked with designing a solution.

In 2020, the Department Civil and Systems Engineering at Johns Hopkins University, like many of its peers, had seen a decline in its enrollments which prompted an evaluation – and ultimately a redesign – of its undergraduate curriculum. At the same time, the engineering school was reevaluating its approach to undergraduate education in response to a university-driven effort leading to an increased emphasis on design, including plans for a new school-wide design center. Thus, in keeping with the mission of the University and to fulfill a multitude of our own objectives – e.g. attracting and retaining students by making them feel part of a community, integrating an authentic design experience early in the curriculum to build students' design thinking skills, and engaging students with the community in their adopted city – the program added a one-credit cornerstone design course to its new first-year curriculum. The course was designed to incorporate a project-based learning approach.

The City of Baltimore, where the university is located, has likewise had challenges to land use that are difficult to ignore and important for civil and systems engineering students to understand. Baltimore owns a staggering 20,000 vacant lots, most of which were at one time occupied by now-demolished row homes [8]. The city's Department of Housing and Community

Development maintains an online dashboard for identifying the lots and an Adopt-a-Lot program through which citizens can sign up to be stewards for vacant lots. Stewards are permitted to turn the lots into neighborhood green spaces whether those be places to grow fresh vegetables or even plant trees for the shade of an urban forest. The city's Green Pattern Book [9] is a resource for prospective stewards, providing examples of uses for vacant lots, guidance for necessary steps such as soil testing, and instructions for having water turned on at the site. Once a site has been well-maintained for at least five years, the steward can apply for their site to be transferred from Baltimore City to an environmental land trust [10]. This is an important resource for stewards because without the trust, the city could sell the land at any time to a developer.

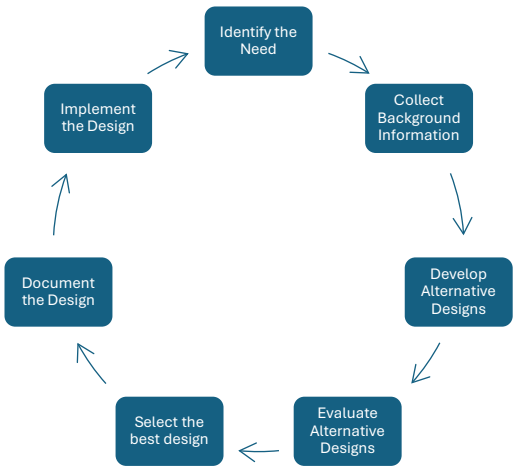
Course Description and Learning Objectives

First offered in its current form in spring 2022, the course has evolved in its details, but at its core has remained unchanged – and that is for students to learn the engineering design process through project-based learning, where the selected project exposes students to a challenge facing Baltimore City. Students spend the semester working through each step of the engineering design process and at the conclusion of the semester propose alternative solutions to a challenge posed by a community partner who is working to improve or develop a parcel of city-owned land. From 2022-2024, the project's community partners were stewards of city-owned community managed open spaces (i.e. adopted vacant lots), and the challenges were related to the lots under the stewards' management. In 2025, students worked with clients from Baltimore City and a volunteer organization that maintains and advocates for one of the city's parks.

While formalized models for the Engineering Design Process can vary, the one that we use consists of seven steps (see Figure 1). The nature of the project dictates that some steps can be completed quickly, and others take more time, but over the 13-week semester students work through the first six steps (see Figure 1). We consider the seventh step of the process, *Implement the Design*, to be fulfilled when the students present their proposals to the community partner. Included in their proposal presentations are design drawings for the site, a cost estimate for the elements in their proposals, a schedule for design implementation, and a list of suggested funding sources for the steward to pursue. We have tried to provide the community partner with at least two design alternatives, which has generally been feasible even with our small class size.

The course learning objectives are tied to the steps of the process and include:

- Describe the engineering design process
- Develop a conceptual design that meets client needs within a set of constraints
- Apply decision-making techniques to select a final design from alternative conceptual designs
- Work in teams to prepare supporting design documentation
- Communicate final designs to a broad audience



Class	Day	Date	Topic
1	Wed	24-Jan	**Identify the need** / Introduction to the Engineering Design Process
2	Wed	31-Jan	**Collect background information** / Visit Local Community Garden for inspiration
3	Sun	11-Feb	**Collect background information** / Visit selected lot, meet with garden steward, take measurements + photographs
4	Wed	14-Feb	**Develop alternative designs** / small group work
5	Wed	21-Feb	**Develop alternative designs** / small group work
6	Wed	28-Feb	**Develop alternative designs** / small group work, cost estimating
7	Wed	6-Mar	**Evaluate alternative designs** / poster proposal presentations
8	Wed	13-Mar	**Select the final design**
	Wed	20-Mar	No Class – Spring Break
9	Wed	27-Mar	**Document the design** / large group work
10	Wed	3-Apr	**Document the design** / large group work
11	Wed	10-Apr	**Document the design** / large group work
12	Wed	17-Apr	**Document the design** / large group work
13	Wed	24-Apr	**Implement the solution** / preliminary design presentations to clients
Final	Wed	1-May	**Final design presentations** as part of WSE Design Day

Figure 1. Engineering design process used in CaSE Cornerstone Design Project (left) and a sample 13-week schedule for the class (right)

Discussion

In the first year the course was offered (2022), students developed plans for the use of real vacant lots selected through Baltimore City's Adopt-a-Lot program. The class visited the site (Figure 2), took measurements and photographs, and together brainstormed what the needs of the community stakeholders might be, but students did not have real community partners who could truly speak to those needs and with whom they could engage. While the project was contextualized, the lack of a community partner limited the students' abilities to authentically learn about the challenges facing communities with blight, which in turn may have limited their ability to develop empathy for Baltimore communities, an important design thinking skill [2].

In 2023, students reviewed several vacant lots and selected one for redevelopment as a Community Managed Open Space (CMOS). While they did not have a steward as a community partner, they were able to connect with a community garden manager unaffiliated with their project to see an established CMOS that had recently been transferred to an environmental land trust. Though the garden was long-past the conceptual design stage, the stewards were having challenges with stormwater drainage at the site and invited the class to see the problem and try to solve it if they could (Figure 2). So, while the students developed design proposals for a vacant lot in one area of Baltimore City, they had the opportunity to volunteer at a nearby established site and learn from a vacant lot steward who had been through the full process. This opportunity offered a glimpse into the positive benefits of partnering with community members.

One of those benefits was building a network and in 2024, the garden manager we had met in 2023 introduced us to a steward just getting started on their plans for developing a vacant lot. This became the most fruitful community partnership of all, as the steward wanted exactly the service we were offering: to develop proposals for their newly adopted lot (Figure 2). Though outcomes were not formally measured, 2024 was without a doubt the year when students demonstrated the greatest motivation for the project and developed the most realistic plans for

the site, indicating a greater sense of responsibility to the community. The community partner's engagement with both the project and the students demonstrated just how important community partnerships are for adding authentic context to a design project.

Figure 2. Clockwise from top left: Student sketching the project site in 2022; Students volunteering to dig drainage ditches at an established and protected community garden in 2023; Students taking measurements at the project site in 2024; students and community partners at the end-of-year poster presentation in 2025

While the vacant lot projects are an excellent opportunity for first-year engineering students because their solutions require little technical engineering knowledge, with the realization of the importance of community partners, we considered alternate opportunities for projects in 2025. One promising partnership emerged, and that was with the Friends of Gwynns Falls Leakin Park (FOGFLP), a volunteer organization that helps maintain and advocates for Baltimore's largest public park, and Baltimore City Department of Recreation and Parks (BCRP), the owner of Gwynns Falls Leakin park.

The park has sustained damage to a portion of its trail and the two partner organizations wanted an engineered solution that would be more resilient to similar damage in the future. Students were tasked with developing proposals, including design drawings, cost estimates, and material quantities. They recently presented their proposals to FOGFLP and BCRP.

Lessons Learned

The first four years of the cornerstone design project have been rewarding for both students and faculty but have also presented challenges and thus offered numerous opportunities for continuous improvement. Significant challenges may be summarized as: (1) identifying community partners, (2) identifying projects that allow students to practice the engineering design process with minimal engineering technical knowledge, and (3) managing complex projects in short timeframes without overburdening students.

Community Partnerships are critical. Students are more invested in the project when they can engage with a real community partner and feel that their work is truly impactful to a community. This was observed in 2024 when we were fortunate enough to get connected to a community partner to form a mutually beneficial relationship. Unfortunately, connecting with community partners is challenging. Identifying partners relies on making connections and building relationships, neither of which is guaranteed to happen in any given year. Our success in 2023 and 2024 may have been attributed in part to persistence, but in truth it was a lot of luck. Cold emails sent to volunteers at several local community gardens yielded few responses, and of those, resulted in one very good opportunity as discussed in the previous section.

Technical Knowledge can be taught using a "just in time" approach. Because this course is taken by first-year students, it is important to identify projects that require limited technical engineering knowledge. That said, it is possible to incorporate enough technical instruction in some cases for students to develop reasonable solutions. In 2025, the students were effectively asked to design wood bridges without any knowledge of statics or mechanics of materials. Without digging into beam theory, it was possible to show them the equations they needed to know to ensure the span lengths they selected for decking and joists did not overstress the members or cause excessive deflection. The students picked up the necessary knowledge quickly which may be because as first-year students they are highly motivated to do some actual engineering, but it may also be a result of wanting to produce workable designs for their community partners.

Time Management is hard. There is rarely enough class time to do everything we want to do as teachers, but time was a particular challenge in this course which only meets once a week for 50 minutes (in accordance with university guidance for a one credit course). This makes site visits difficult because we need to find an alternative time to meet (50 minutes would be too short, even if the site was close to campus). We can see some evidence that enrollments are increasing, and that is good news, but it also means that finding time outside of class when all students are available to visit a site will become increasingly complicated.

Future Directions and Research Questions

The demonstrated importance of having real community partners in this first-year contextualized design course led us to pivot in spring 2025 from projects related to vacant lots to urban parks. Urban parks in Baltimore are plentiful and most are managed by long-standing volunteer organizations (i.e. friends groups) that partner with the city to maintain the parks as natural and cultural resources. Building relationships with these community partner organizations may be more sustainable as the work required to maintain the parks is plentiful and the volunteer organizations are motivated to engage with new audiences to increase awareness of these resources.

While partnering with the parks may be a more sustainable option for the class, the flip side is that more well-resourced organizations (i.e. friends groups) may result in smaller benefits to students / student engagement if they sense that there is less of a need for their services. While collecting data to help answer this research question would be complicated, it would be interesting, especially considering recent research studying the nuances of contextualized design projects [2].

In addition, as the course concludes its fourth year in a well-established state, it would be worthwhile to evaluate whether the course's implementation has improved students' design thinking skills and/or successfully attracted and retained students to the program, two of the three objectives for originally requiring the course.

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