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University/Community Partnership through Senior Design Projects

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Abstract

The College of Applied Science (CAS) at the University of Cincinnati (UC) offers a range of engineering technology degrees at the baccalaureate level. Seniors are required to enroll in a capstone curriculum entitled "Senior Design." Working individually or in small groups, they experience the project management process in its entirety—from concept development and design analysis to prototype fabrication and testing.

The senior design sequence typically extends over three quarter terms. The public demonstration of "Senior Design" outcomes takes place annually, at the college's Tech Expo, through poster presentations that give students the opportunity to display and defend their project work.

Typically, CAS seniors identify their design problems from one of two broad areas of experience: 1) their own industrial experience through work as co-op students, entrepreneurs, service managers, trouble-shooters, etc., or 2) their personal experience as students, volunteers, parents, homeowners, renters, racing enthusiasts, hobbyists, sports participants or coaches. Within this personal experience area, a few students have chosen design problems connected to adaptive equipment needs or direct service needs of non-profit organizations within the community.

Recent faculty efforts have increased the number and scope of community-based projects. These projects have yielded redesigns of wheelchairs, computer mouse controls and exercise equipment, along with prototypic control systems for unique user profiles and environments.

This paper lays out the rationale and implementation of community-based projects and compares them to the more traditional projects drawn from students' industrial or personal experience. On several measures of learning objectives, community-based projects appear to offer intensified challenges and rewards similar to projects sponsored by industry. Since the design solutions for community-based problems are not likely to be viable for private investment, they seem all the more appropriate for the investment of public university resources. Enlarging the scope of design problems via community-based projects should enrich the capstone experience for all involved.

Introduction

Within the University of Cincinnati, the College of Applied Science (CAS) provides engineering technology programs for a student body of approximately 1400. In its 175th year of operation, CAS honors its founders' vision—the vision of the Ohio Mechanics Institute (OMI)—that the opportunity to learn should be available to all who are able and willing to participate; that liberal learning in the arts and sciences should form the academic core of technical education; that learning is applied, and designs are functional; and, that technology responds to societal needs and promotes societal well-being.

In 2003, learning at the College of Applied Science remains hands-on and applied. Academic programs lead their students from hands-on introductions to the tools and technical methods of the majors to a senior capstone experience that tests their ability to define technical problems, develop appropriate solutions, and build and test prototypes that best address the users' needs.[1] The learning goal is "to provide the knowledge and skills necessary for graduates to be successfully employed in business and industry, worldwide, and to be contributing members of their communities."[2]

Since the inception of baccalaureate programs, CAS has required its seniors to pass the capstone sequence in order to graduate. With some regularity, small numbers of seniors find themselves delaying their graduation in order to successfully complete the capstone curriculum, even though all course and credit hour requirements have been fulfilled. Twenty years of capstone projects offers ample evidence of the appropriateness and rigor of this summative assessment of student learning. In retrospect, the archive of project reports filed by CAS graduates to document their senior projects also validates the educational mission of the college.

The archive of senior project reports reveals the development of academic programs, the emergence of new technologies, the character of student achievement, and the continuous improvement of teaching/learning. Over time, the details come and go. The definition of technical problems, design of optimal solutions, and testing of prototypes may be given more or less weight by major programs (and, therefore, by students). Similarly, required methods of design analysis shift and develop in line with concurrent trends in research and practice. Yet, along the way, the essence of the learning experience emerges. While any one senior's project provides a snapshot of the individual and the program in its current environment, the collection of project reports over two decades and across academic programs reveals what is constant.

At the core of all senior projects is the mandatory connection between academic study and professional practice—the creative application of new knowledge to solve ill-defined, real-world problems.[3, 4] To successfully complete the capstone curriculum, all candidates for graduation must identify and develop this connection for themselves and for the end-users of their potential solutions.

The Capstone Curriculum and Learning Assessment

Regardless of the variance in details from program to program, the capstone curriculum, known informally as "Senior Design," brings faculty and students together for an in-depth and extended learning assessment. Students may work individually or in groups, and occasionally a group may include members from more than one academic program. While specific learning objectives vary throughout the major programs, all students must demonstrate their accomplishment of "reflective practice" in their technical disciplines, [3] using higher-order thinking skills and academic competencies achieved and applied across disciplines.

One example of this reflective practice may be seen in a variety of "laboratory" projects. Students in Electrical and Computer Engineering Technology (ECET) and Mechanical Engineering Technology (MET) often design and build prototypes for actual laboratory apparatus that is fully instrumented and used by faculty in subsequent years. These "Senior Design" products result from students evaluating their own laboratory learning experiences, identifying gaps in the learning sequence, and using their capstone projects to address current student needs and develop future learning opportunities.[1]

Many direct learning measures characterize the CAS capstone curriculum. The faculty advisors give ongoing, portfolio-style assessment of students' work as it evolves. Learning objectives across academic programs focus students and faculty alike on the development of appropriate research plans, on technical work plans including budget and scheduling dimensions, on the development of drawings and analytical procedures, and on test plans logically related to their research questions and design problems.[2]

In addition to this ongoing, developmental evaluation, capstone project review occurs through a number of oral presentations for internal and external, academic and industrial audiences. Written feedback from these evaluators may be shared immediately with students and faculty advisors and used to strengthen the project's outcomes. A valuable result of these assessments is the evolution of new roles in the learning process for both students and faculty. On the one hand, projects demand that students take on the role of "expert," able to uncover and use pertinent research data, to design and carry out their own laboratory and field work, to access appropriate human and material resources (since, even though projects may be carried out by individual students, no student succeeds alone), and to manage all project dimensions toward measurable performance outcomes. On the other hand, as students take on this expert status, they also find themselves working in new ways with their faculty advisors. Project reviews place students and advisors together, on the same side of the playing field, and working toward a mutual "win" through the responses from internal and external project reviewers.[2]

The capstone curriculum leads to the annual Tech Expo, the college's public exhibition of senior projects. At the exposition, projects are reviewed by industry representatives, alumni, professional organizations such as the Institute of Electrical and Electronic Engineering (IEEE) and the Society of Mechanical Engineering (SME), and by high school student visitors. Project ratings are reviewed by departments, and individual project awards are announced at the close of the exposition. Students consistently report that this public evaluation of their work yields a qualitative leap in their ability to think through and articulate its rationale and value—and to identify appropriate recommendations for further development.

The final products of the capstone curriculum are comprehensive technical reports, often evaluated by English faculty in addition to faculty in the major program, and by industry representatives in cases where students have external project advisors.[5] Archived reports in the college library provide faculty with a cumulative inventory of the products of their program development, and, at the same time, provide students with real evidence of their learning achievement.

The Selection of "Senior Design" Problems

The first term of the "Senior Design" sequence requires students to investigate and choose their design problems, identify their faculty advisors, and write project proposals. The key to success at this stage is creative thinking. Engineering technology students, like most of us, prefer to follow clear road maps to their academic destinations. In this case, however, even the destination itself must be chosen by the student-designer. Year after year, students—and faculty—identify the work of the first term as the most difficult, and defining the problem as the daunting challenge. Nonetheless, CAS faculty members have not yielded to the more typical practice of presenting students with lists of already defined problems. Instead they share with students their current professional interests and their own research and teaching challenges so as to entice them to respond and, through the dialogue, to generate their own problem definitions.

On the whole, students develop their design problems from one of two broad areas of experience: 1) their own industrial experience through work as co-op students, entrepreneurs, service managers, trouble-shooters, etc., or 2) their personal experience as students, volunteers, parents, homeowners, renters, racing enthusiasts, hobbyists, sports participants or coaches.

Drawing upon their personal experience, a smattering of students are able to perceive quality-of-life needs beyond their own, and the problems identified by these student-designers shape the projects that are the focus of this report.

The Rationale for Community-based Projects

The mission of the college clarifies both the purpose of technology—to respond to societal needs and promote societal well-being—and the role of a technical education—to apply learning in the arts and sciences so that designs are functional and society is well-served. What better way to reinforce and test this mission than through the direct application of student learning to community needs identified by the students?

No doubt, "traditional" projects that are sparked by personal interests or sponsored by industry yield numerous benefits for both the students and the academic programs. The steady supply of industrial sponsors and frequent patent filings attest to these mutual benefits. On the other hand, community-based projects are likely to involve constituencies that often go unnoticed and unheard.[6] The needs of these constituencies may lead to solutions outside the scope of more typical end-users. Project pay-offs are likely to be longer term and of undetermined value—not viable for private investment—and, thus, all the more appropriate for the investment of public university resources.

Community-based projects should in no way diminish the challenges and opportunities associated with more traditional project choices. These projects are not for everyone. Yet, if a richer landscape of "Senior Design" problems is achieved through the development of community-based projects, the bar should be raised for all faculty and students involved.

Developing Community-based Projects

Implementing community-based projects as a viable option within a capstone curriculum depends upon several critical process dynamics. They are identified here as, 1) Raising Awareness, 2) Understanding Opportunities and Constraints, 3) Connecting and Supporting All Participants, and 4) Building Networks of Relationships. In turn, each process step depends upon the three essential parties to any community-based project, as illustrated in Figure 1, below.

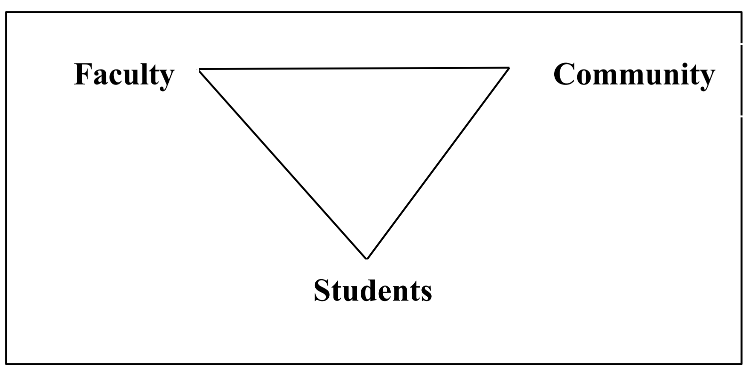

Figure 1, The Three Parties to Community-based Projects

Raising Awareness. To begin, faculty and community members need to learn from one another. As they share their own work, possibilities for partnership emerge. These possibilities should be thoroughly explored in order to begin to identify potential opportunities and constraints within both the academic system and the community organization. Only then should the conversation expand to include students, the third essential partner.

Understanding Opportunities and Constraints. Before committing to an initial project, all three parties need to share their specific project perspectives in as much detail as is feasible. The purpose of this exchange is to sort out real opportunities from unreal expectations. All three parties need to identify their own constraints (For example, when are exams, vacations, board meeting reports, budget proposals, and faculty leaves scheduled?). To prevent any one party from feeling abandoned by the others, special attention must be paid to funding and scheduling needs that could potentially derail the management of the project.

Connecting and Supporting All Participants. Throughout the duration of the project, communication among all those involved remains essential to achieving the expected outcomes. Students may be charged to take the lead on this front within their responsibilities as project managers. Nonetheless, faculty members must be especially attentive to the community partner's feedback, making sure that all three parties are sharing the same information among themselves and with others who may be indirectly involved.

Building Networks of Relationships. Each community-based project, even the smallest in scope, will advance or diminish long-term relationships among academic and community partners. The overriding challenge of developing community-based projects is sustaining the most promising ones. This challenge, too, generally falls to one or more faculty members who care enough to build a network of continuing relationships from which new and stronger partnerships may emerge. Essential to success over time is faculty leadership. Students need to see key faculty members choosing to devote some of their research and professional work to community needs, and community members respond to university faculty who are involved citizens.

Comparing Community-based Projects to Other Project Types

When measured on a number of specific learning objectives within the capstone curriculum, community-based projects appear very similar to industry-sponsored projects. In contrast to both community-based and industry-sponsored projects are those projects based solely upon the personal interests of the student-designer. While these "personal projects" offer a more predictable—and therefore comfortable—learning environment, they also appear to offer less complexity and, subsequently, fewer process challenges and potential rewards.

Table 1 displays comparisons of personal projects, industry-sponsored projects, and community-based projects according to six specific learning objectives.

Table 1, Comparisons of Project Characteristics by Project Type

Learning Objectives	Personal Projects	Industry Projects	Community Projects
Defining the Technical Problem	Very Challenging	Very Challenging	Very Challenging
Surveying Potential Users	Available input by a relatively small number of users.	Complicated by the number, types and organizational roles of users.	Complicated by characteristics of specific users.
Evaluating User Needs and Desires	Feasible based upon adequacy of the available user input.	Complicated by the number and variety of users within the organizational structure.	Complicated by unique users, operators and organizational structure.
Defining the Technical Solution	Relatively straightforward.	Complex in its varied dimensions.	Complex in its varied dimensions.
Testing the Optimal Solution	Feasible based upon adequacy of the available user input.	Complicated by the number and variety of users within the organizational structure.	Complicated by unique users, operators and organizational structure.
Recommendations for Further Development	Tend to be restricted upon the designer's insights and a few respondents' views.	Tend to be based upon direct responses from a variety of users.	Tend to be based upon direct responses from a variety of users.

Comparisons within Table 1 illustrate how industry-sponsored and community-based projects may intensify both the project's demands and its potential rewards for the student designer. Since the design process itself challenges everyone, the less talented or mature students are likely to learn more effectively if they focus on immediate problems within the scope of their personal interest and experience— without the additional complexities of industry or community contexts. On the other hand, managing the design process within these broader contexts adds not only complexity, but also new opportunities to learn.[5, 6]

Students who have chosen to carry out community-based projects confirm their increased demands and rewards. One senior, who chose to redesign a standard wheelchair, did so in order to tackle the problem of making medical office exams possible for individuals with no ability to leave their chairs. Her redesigned wheelchair allowed a single operator to recline its backrest to 26 degrees off of the horizontal plane, and to elevate the entire chair to 24.5 inches (the height of a typical exam table). The wheelchair user had no ability to provide user feedback during the design process, and only her body language could convey usability and comfort during the testing of the prototype. The student-designer had to rely upon operators and a range of health care service providers for both design needs and testing data. Her research skills were taxed far beyond what is normally expected, and her working prototype attracted the interest of a physician/inventor at last year's Tech Expo.[7]

Another senior, who used infrared technology to create a remote device for elevator access, observed residents living with spinal cord injuries and multiple sclerosis in a facility named Beechwood. In his words, "The elevator was an obvious challenge for many residents. Working together, we came up with the idea." In the words of one of the residents, "Elevators are extremely difficult for someone like me because I have a hard time reaching the buttons. A remote control would make things a lot easier." An infrared remote control was the student-designer's affordable solution.[8]

Community partners respond with enthusiasm. Beechwood's Newsletter, summer 2002, included this summary statement in an article that profiled two seniors' projects. "If their achievements are any indication, the future of adaptive devices for the disabled looks very promising. All of us at Beechwood applaud their achievements and look forward to participating in the design and testing of future projects." One year later, Beechwood is working to budget funds for installation of the remote control for elevator access throughout their facility. A Beechwood administrator says simply, "The residents keep asking for it."

Conclusion

While community-based projects should be carefully initiated and maintained, they can yield opportunities and rewards comparable to those we expect from industry-sponsored projects. Initiation and maintenance depend upon at least four critical process dynamics: 1) raising awareness, 2) understanding opportunities and constraints, 3) connecting and supporting all participants, and 4) building networks of relationships.

If these process dynamics are achieved and sustained, then both academic and community partners are strengthened by sharing their unique resources. Above all, the students gain. They are able to see their own work within its broader community context; they learn to manage projects within complex structures and systems beyond their control; and, they acquire first-hand experience contributing their technical skills to serve community needs.

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