

## **AC 2010-1404: TEACHING HUMAN-CENTERED DESIGN WITH SERVICE-LEARNING**

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# Teaching Human-Centered Design with Service-Learning

## Abstract

Effectively teaching human-centered design can pose challenges within the undergraduate curriculum as it requires access to users and stakeholders. Service-learning, a growing pedagogy within engineering, offers many synergistic opportunities to create a human-centered design experience. In service-learning, students are paired with a real user in a real community and asked to address a real need. This paper presents the implementation of a human-centered design approach using service-learning at Purdue University. The approach is multidisciplinary with participation from students within and outside of engineering. The design process and curricular structure is discussed along with example projects that illustrate the approach from the perspectives including mechanical, electrical and software design. Successes and challenges are also discussed.

## Introduction

Design has long been a core function of engineers. Recently it has been argued that there is a paradigm shift occurring in design from a “technology-centered design” to “human-centered design” approach<sup>1</sup>. IDEO defines human-centered design as “a process and a set of techniques used to create new solutions for the world. Solutions include products, services, environments, organizations, and modes of interaction. The reason this process is called “human-centered” is because it starts with the people we are designing for.”<sup>2</sup> The human-centered approach to design is a recognized contributor to innovations in engineering design<sup>3</sup>. This approach also helps students to develop skills in creativity, practical ingenuity, and communication necessary for the Engineer of 2020<sup>4</sup>. It provides competitive advantage to engineers in a global workplace<sup>5</sup>, and help engineers address the Grand Challenges identified by the National Academy of Engineering<sup>6</sup>. Utilizing human-centered design processes have been shown to increase productivity, improve quality, reduce errors, reduce training and support costs, improve people's acceptance of new products, enhance companies' reputations, increase user satisfaction and reduce development costs.<sup>7,8</sup>

There are many examples cited in the literature that point to the lack of understanding of the user, or an understanding of the way in which the product would be used, that contributed to its failure<sup>8,9,10</sup>. “Without effective user involvement in all stages of planning and design the organization is simply storing up problems for the future. When the problems emerge post-implementation they are likely to be serious and more intractable because system changes become more expensive as the design progresses and ‘hardens.’”<sup>8</sup> Effectively teaching human-centered design can pose challenges within the undergraduate curriculum as it requires access to users and stakeholders. Service-learning, a growing pedagogy within engineering, offers many synergistic opportunities to create a human-centered design experience.

## **Service-Learning**

Service-learning is a pedagogy characterized by both learning for the students and service to the community. It has been formally defined as “a credit-bearing educational experience in which students participate in an organized service activity in such a way as to gain further understanding of the course content, a broader appreciation of the discipline, and an enhanced sense of civic responsibility.”<sup>11</sup> The “learning” in service-learning is tied to academic learning outcomes, content and standards. It encourages engagement in the community by involving participants to help determine and meet real needs in the community, especially needs of those who are under-served. It is reciprocal in nature, valuing the partnership and recognizing the expertise brought by the community partner. It also includes reflection, which has been shown to enhance learning across academic subjects<sup>12</sup>. Giles and Eyler (1999)<sup>13</sup> found that the majority of students surveyed reported they learned more, understood more, and were motivated in service-learning courses.

While engineering has been slower to adopt service-learning than many other disciplines, there is significant and growing increase in service-learning within engineering. Curricular models of service-learning, such as the EPICS Program, have been adopted at several universities as well as extra-curricular models such as Engineers Without Borders, Engineers for a Sustainable World and Engineers for World Health. Research on service-learning in engineering includes a joint study conducted at the University of Massachusetts-Lowell and the Massachusetts Institute of Technology that showed that students’ participants increased their connection between engineering and community needs<sup>14</sup>.

In service-learning, students are paired with a real user in a real community and asked to address a real need. This user(s) is often different from the students which requires the students to learn about their user and other stakeholders, the context and the need they are addressing. The context of the projects provides a rich environment for participation from disciplines from outside of engineering and the activities in human-centered design offer ways for many students to participate in the design process. Service-learning also provides additional opportunities to meet ABET requirements, promote the broader skill set that is called for the Engineer of 2020<sup>4</sup> and attributes that have been associated with diversifying the population of engineering students.

Teaching human-centered design within a service-learning context provides mutual benefits for both aspects. Scott (2008)<sup>15</sup> found that by using a service-learning context to teach usability in his technical writing class, that the “Students also appeared to value user-centered design more highly by the end of the projects.” There is also benefit for facilitating user-engagement within the service-learning context by incorporating human-centered design. Scott (2008)<sup>15</sup> argued that “As a number of writing scholars have argued, reciprocal, responsive service-learning requires the engagement of users a “partner in inquiry” (Flower, 1997) rather than just clients (see also Deans, 2000; Dubinsky, 2002; Scott, 2006), and user-centered design can provide a methodology for such engagement throughout a project.”

## **EPICS**

EPICS, a program in Purdue University’s College of Engineering, is an innovative service-learning approach to teaching design where multidisciplinary teams of students partner with local

community organizations to identify, design, build, and deliver solutions to meet the community organization's needs.

The goal of EPICS is to meet a critical educational need of providing hands-on engineering and technical design opportunities to a broad group of students, especially females and underrepresented minorities. The program also meets vital needs within the communities they serve by providing not-for-profit organizations—such as community service agencies, schools, museums, and local government offices—the creation, implementation, and delivery of technology resources needed to significantly improve the organization's ability to serve the community. Each team is constituted for several years, from initial project definition through final deployment allowing multi-year projects of significant design complexity and high potential impact in the community to be completed. The designs that are produced by the EPICS teams address compelling issues in the local community that often have potential applications in other communities through dissemination or commercialization.

Quantitative and qualitative student evaluations have shown that EPICS is effectively teaching communication, leadership, teamwork, and design skills that are required for success in today's global economy. Qualitative assessments have also shown that participation in EPICS enhanced their desire to continue within engineering.<sup>16,17</sup> EPICS has shown the ability to attract women at higher rates within engineering which is consistent with other engineering service-learning programs<sup>14</sup>. In-depth interviews are exploring female student perceptions.

### **EPICS Human-Centered Design Process**

The EPICS Design Process was developed to specifically support students in their service-learning design projects. Although frequent interactions with the users and other stakeholders in the design were included in the previous version of the design process, it was not emphasized or the center of the design process as reflected in human-centered design. Therefore, we have modified the design process to explicitly include interactions throughout the design process. In addition, the design process now emphasizes using mock-ups and prototypes as a way to better understand the need, explore possibility solutions, and define the specifications. The EPICS Design Process consists of the following phases as shown in Figure 1:

- Project Identification
- Specification Development
- Conceptual Design
- Detailed Design
- Delivery
- Service and Maintenance
- (Retirement)

The EPICS Design Process model is not intended to be a recipe for design, or simply an exercise that the students need to complete and check off. It is a heuristic (general principle or “rule of thumb”) for design and is intended guide them through the design process. The center portion of the graphic indicates a number of tasks that can be completed throughout the design process, such as brainstorming, prototyping, and usability testing. There are iteration cycles in each step

with the stakeholders (the customer, user, client, etc.) that represent the involvement of the stakeholder in the development of the solution continuously throughout the design process. Although the overall goal is to move through the phases, sometimes the students gain new knowledge about the requirements, constraints, users, context, usability and/or capabilities of technologies being used that make it necessary to iterate, or go back to previous phase and complete it again. However, there are a couple of points in the design process that are “go vs. no-go” decision points that require an agreement from the project partner, instructors, and/or EPICS administration to go forward with the design. They are indicated as “Gates” in the design process. The use of “Gates” is very common in industry, where meeting certain criteria is required to gain additional resources in the development of the product.

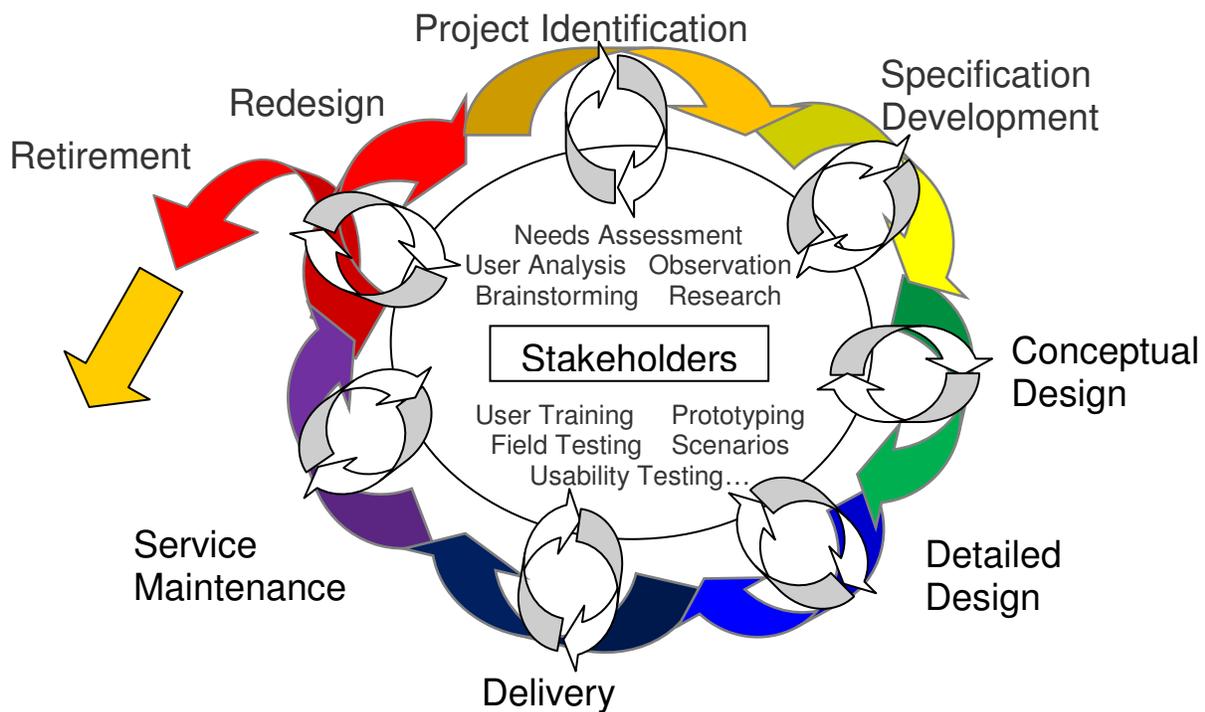


Figure 1. Human-Centered Design Process

The following is a list of activities that typically occur during each phase of the design process:

**Project Identification Phase:** Goal is to identify a specific, compelling need to be addressed

Common tasks	<ul style="list-style-type: none"> <li>• Conduct needs assessment (if need not already defined)</li> <li>• Identify stakeholders (customer, users, person maintaining project, etc.)</li> <li>• Define basic stakeholder requirements (objectives or goals of projects and constraints)</li> <li>• Determine time constraints of the project</li> </ul>
<b>Gate 1: Continue if have identified appropriate EPICS project that meets a compelling need</b>	
<b>Specification Development Phase:</b> Goal is to understand “what” is needed by understanding the context, stakeholders, requirements of the project, and why current solutions don’t meet need, and to develop measurable criteria in which design concepts can be evaluated.	
Common tasks	<ul style="list-style-type: none"> <li>• Understand and describe context (current situation and environment)</li> <li>• Create stakeholder profiles</li> <li>• Create mock-ups and simple prototypes: quick, low-cost, multiple cycles incorporating feedback</li> <li>• Develop a task analysis and define how users will interact with project (user scenarios)</li> <li>• Compare to benchmark products (prior art)</li> <li>• Develop customer specifications and evaluation criteria; get project partner approval</li> </ul>
<b>Gate 2: Continue if project partner and advisor agree that have identified the “right” need, and if no existing commercial products meet design specifications.</b>	
<b>Conceptual Design Phase:</b> Goal is to expand the design space to include as many solutions as possible. Evaluate different approaches and selecting “best” one to move forward. Exploring “how”.	
Common tasks	<ul style="list-style-type: none"> <li>• Conduct Functional Decomposition</li> <li>• Brainstorm several possible solutions</li> <li>• Create prototypes of multiple concepts, get feedback from users, refine specifications</li> <li>• Evaluate feasibility of potential solutions (proof-of-concept prototypes); select one to move forward</li> </ul>
<b>Gate 3: Continue if project partner and advisor agree that solution space has been appropriately explored and the best solution has been chosen.</b>	
<b>Detailed Design Phase:</b> Goal is to design working prototype which meets functional specifications.	
Common tasks	<ul style="list-style-type: none"> <li>• Design/analysis/evaluation of project, sub-modules and/or components (freeze interfaces)</li> <li>• Complete DFMEA analysis of project</li> <li>• Prototyping of project, sub-modules and/or components</li> <li>• Field test prototype/usability testing</li> </ul>
<b>Gate 4: Continue if can demonstrate feasibility of solution (is there a working prototype?). Project Partner and advisor approval required.</b>	
<b>Delivery Phase:</b> Goal is to refine detailed design so as to produce a product that is ready to be delivered! In addition, the goal is to develop user manuals and training materials.	
Common tasks: Complete user manuals/training material Complete usability and reliability testing Complete delivery review	
<b>Gate 5: Continue if Project Partner, Advisor and Admin agree that project is ready for delivery!</b>	
<b>Service/Maintenance Phase</b>	
Common tasks: Evaluate performance of fielded project Determine what resources are necessary to support and maintain the project	
<b>Gate 6: Project Partner and Advisor approve continued fielding of project. If not, retire or redesign.</b>	
<b>Retirement or Redesign</b>	

## **Capitalizing on Human-Centered Design**

We have found that although the service-learning experience offers tremendous opportunity for students to learn about broader concepts, such as human-centered design, that learning must be scaffolded in order for students to obtain the most benefit from the experience. We have introduced a number of curricular pieces to scaffold their learning of human-centered design.

The Human-centered Design Process is taught in the initial lectures of the course which allows us to have a common language with which to talk about design. Supplemental lectures are available for students to get a more in depth understanding of how to explore the users' needs, social context, etc. Because students work on teams, we have always included a team building activity in the class early in the semester. In the team building activity, students are given a scenario and asked to produce prototypes that they believe will be effective in eliciting information from their project partner, who is being played by their instructor. The exercise gives the team an opportunity to discuss including the customer, user and other stakeholders in the design. It also gives an opportunity to discuss effective ways of gathering information about your customer/user, the need, and the context such as using prototypes.

## **Examples and Curricular Observations**

To illustrate how human-centered design has been incorporated, three examples are given that demonstrate a mechanical, electrical and computing example of students' projects.

### ***Soap-box Derby Car***

An example of human-centered design is the design and development of a Soap-box Derby car that can be used to provide children with a disability the opportunity to participate in a derby-like experience of "racing" down a hill. Local Soap-box Derby representatives approached EPICS with the need to develop a better two-seat car where children with disabilities could ride along with a driver. Currently, dual seat cars exist in two models. One kind allows the children with a disability to steer but has a system where the driver can compensate. Another design does not have a working steering system for the children with disabilities so they cannot really steer but they can turn a steering wheel that is not connect to the wheels of the actual car. The other challenge was to design an inexpensive car that could be made by other towns across the country.

To gain insight into what the car needed to be, the team volunteered to be part of a day-long race for children with disabilities on a track in Indianapolis. This race used cars that were adapted from midget racing cars. They had two seats with the drivers in the rear and a steering system that had a 1:1 gear ratio between the drivers and the children in the front. The experience at the event taught the students many things. As can be seen from the pictures, they got experience how the cars were towed up the hill and how they were released. At the event this year, they also saw the potential dangers of the current steering systems when one of the older students overpowered the driver and rammed the car adjacent to him.



Figure 2 Current Soap-box Derby Cars

The students came up with a steering design that empowered the children with the ability to steer if they were able but used a slip clutch to insure that the driver could overpower the front driver for safety. The new design is shown below in Figure 3. The team looked at the experience of the children and wanted to simulate more of a Soap-box Derby car than a motorized race car. The more open design also allowed easier access in and out of the cars. When their prototype was taken to the race in Indianapolis, a few families who could not get their children into the race car designs came over to the EPICS car and let their children sit in it. The team found that for larger children (e.g. tall teenagers) they could not fit into the modified midget cars. Also, for children with severe disabilities that limited their mobility, the midget cars did not allow parents and volunteers to get them in and out. The modified design was more open and would allow more children to participate.



Figure 3 Testing of New Design

The design team came away from the experience realizing that they could not design an effective car without spending time at an event where the kinds of users, in this case children with disabilities, their families and the drives, were in action. This gave them an understanding of their design constraints and a broader view of the impact their design could have.

### ***IPAAC (Interactive Programmable Alternative Augmentative Communication) Project***

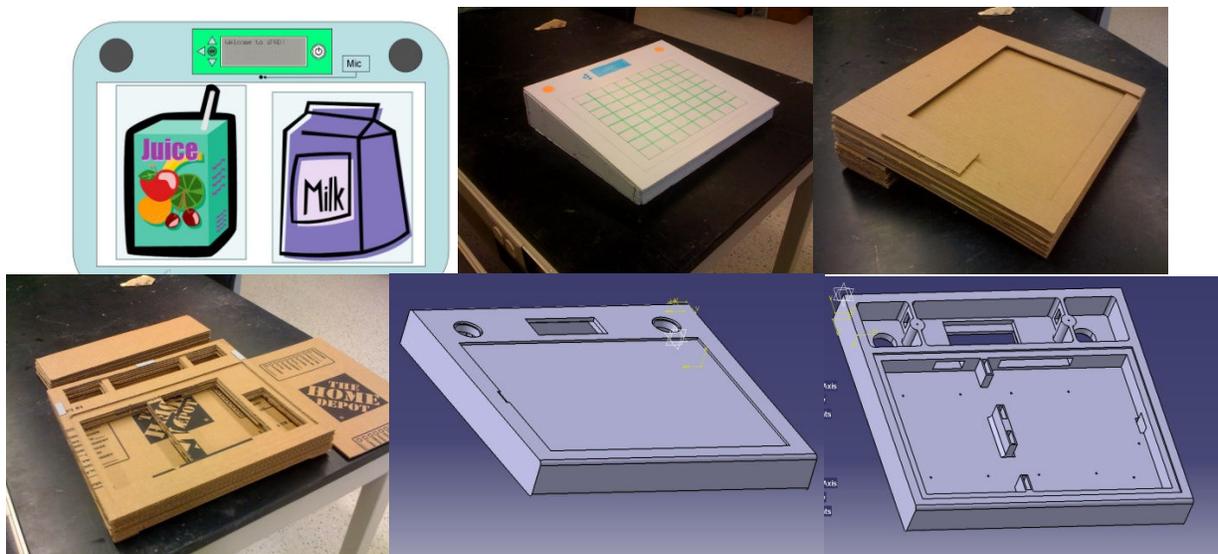
Another example of how the human-centered design process is being employed is the IPAAC project. The IPAAC is an augmentative communication device that is being designed to assist children with communication and cognitive difficulties by providing them with a technology that's intuitive and easy to use. The teacher of the special education room of a local junior/senior high school serves as the project partner (customer) of the project, while the students in her

classroom will be the ultimate users. As part of the process, the team has visited the classroom to observe the students in general and specifically to interact with the technology they are currently using. This also enabled them to gain a better understanding of the complexity of the need. For example, the Purdue student designers at first thought that the communication device would be used simply as an educational tool that would allow the teacher to “test” the students in the class. However, by observing and participating in the design, they came to understand that many of the users of the device (the students in the special education class) did not even understand the power of communication and their ability to make their needs known through communication. This is reflected in their project documentation:

This project will not just help the student with his/her communication difficulties but also enable them to express their needs and desires by themselves more efficiently, thus making them more independent and increasing their ability to form sentences, recognize sights and sounds, and in general result in an increased appreciation and satisfaction from their use of language.

The project partner was very involved in the development of the specifications for the device. In addition, the student designers spent a significant amount of time interacting with current technology to understand its functionality and the way in which the users (teachers and students with disabilities) interact with the device. This enabled them to design a device that fits with the “mental model” of how the teacher and students expect to interact with a device.

Another aspect of the design that has especially utilized human-centered design concepts is the casing for the device. The Purdue students have developed several iterations of pictorial and physical prototypes that have been brought to the project partner for feedback and subsequent revisions. Some of the changes that have resulted from these revisions are the inclusion of gripping area on the sides of the device so it can be easily carried, the removal of guides for the buttons, and removing unneeded material to reduce the weight of the device.



(graphical rendering of user interface, foam core model, cardboard model front, cardboard model rear, catia model front, catia model rear)

## *Software Projects*

In software projects, the EPICS Human Centered Design Process fits with current software tools and best practices. The process was utilized in the fall, 2009 semester by one Purdue University EPICS project to develop a system for scheduling volunteers for a crisis center. Following the methodology, the team worked with their project partner, who was himself the person who now does this job by hand. The students watched and documented how he does it, after many years of running the scheduling operation, making allowances for unique situations such as preferences of the individual volunteers. Students also had to estimate, realistically, how much more a computerized system could do, and how much to build the project partner's expectations for early releases.

To help resolve both concerns, they created prototypes and demonstrated these back to the user. He is now also able to try using their current this himself, so as to give more extended feedback.

A challenge of this system is that some of the "user" role will be done online by the volunteers themselves, instead of by the project partner. This will create an additional challenge for the students, to prototype this in a way that models various sub-groups, such as new volunteers versus experienced ones. They are only part way through the task of understanding how their user base will interact with this new system.

The project partner's main goal was to decrease the amount of time he spends creating a monthly schedule. He would like to spend more time finding volunteers for the center. At the same time, however, his center will have a more interactive public presence, through the interface that the system provides to current and potential volunteers; so it also will play a recruitment role. It is very likely that expectations will increase as the project partner and volunteers gain experience using the system, and the students are aware of this issue because they are sensitive to seeing their system through other eyes. For example, at present the project partner is happy with a system which will replicate his own monthly scheduling. However, it is very likely that he will realize how much more convenient it would be for the volunteers if they came away from a real-time interaction with the system, knowing their next schedule, regardless of when they did this.

The students also have worked with Purdue researchers on scheduling, and they know some of the potential hazards of systems like this. Rescheduling is difficult, for example. Applying optimizations like trying to make the schedule "equitable" adds a layer of complexity. These are areas where they now have sufficient theoretical knowledge to understand what kind of a system to try for, for this particular project partner. As a team, they represent a focal point of expertise, combining the practical experience they've learned from their user, with the computational limitations of scheduling systems.

They have worked with their project partner to decide how to deliver such a system. Initially, there should be a parallel operation, with a comparison made between volunteer schedules made by the new system and schedules the project partner himself does. This mode of acceptance testing will let the project partner decide if the system really is "as good" as he is, before trusting it to do his monthly schedules. In essence, this delivered system will be their "final prototype."

The students made various levels of prototypes as they progressed through the early stages of this development. They created pictures of the system in operation, to describe generally how they thought the system worked, in terms the project partner would understand. For instance, they showed visually how their algorithm would deal with different sizes of volunteer "availability pools" for different shifts, to see if the system's intended actions fit the way the project partner handled these. They were able to show even visually such details as how their "schedule mutator" would operate to improve on first tries at monthly schedules.

The team then used software that enables rapid prototyping so that they quickly could transition to showing him screens with various data and interactions, and get his feedback. They used a different but compatible tool to prototype scheduling algorithms, so that they could model different kinds of results and get his feedback on those.

Overall, this project team used prototyping to make visible the invisible properties of the software they planned to build, so that their non-technical client was able to grasp, in his terms, what they meant and provide practical advice. The system is still in creation, but it surely will be one which provides few surprises when it is delivered.

## **Conclusions**

Designers in the current global economy must have an ability to understand users of their designs to be effective. Teaching human- or user-centered design can be a challenge in traditional design classes. Service-learning offers a compelling way to blend providing meaningful service to those of need and educating the next generation of designers in modern methods of design. Designing to meet human needs offers the context to learn how important understanding users and the larger context of the design can be.

Experience shows that the setting of real users is not enough and that intentional activities and reflection is needed to move students to both understand users and to see how this information can and should be applied to their designs. By adding these experiences and reflective activities to the design experience, students can see how important knowledge of the users is and how it creates better designs.

It was also important to have explicit design process that emphasized prototyping, mock-ups and frequent interactions with users. These were ways that students could communicate more effectively with users and to gain the information they needed. These prototypes did not always work nor did they always meet their users' intent. Often it is in their failures that they truly appreciate and understand the mistakes and assumptions that they had made. However, trying to have a process with the frequent prototyping that allows those failures to occur at a micro-level (small iteration) versus large iteration reduces the impact on their failures, reduces their frustration and creates better designs.

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