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Community-Engaged Learning, Prototypes and Requirement Development*

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A challenge facing many institutions is how to bring "real" design experiences into the curriculum. Industry-inspired projects are often used in design classes, but the community can offer a plethora of compelling projects that challenge students in many ways and offer opportunities for students to make an impact in their local and global communities. One engineering engagement program has used community-engaged learning to create a human-centered design learning experience that benefits students and creates tangible benefits to community organizations. This paper explores two interrelated elements of this design learning experience: how students use prototypes in the design process, and how students perceive project specifications and use those specifications in the evaluation of prototypes. Prototyping is emphasized through the design process and different ways that prototypes are used are described. Examples are provided to demonstrate the breadth of projects and the roles of prototyping within the program. The understanding of the Specification Development phase of the design is explored with three different interventions to enhance student awareness of requirements. Representations of the design process created by students showed inconclusive results for the interventions. The representations pointed to the dominance of the learning in the actual design experience and implies that interventions would be more effective within the context of their specific designs.

Keywords: human-centered design; community; prototyping

1. Introduction

Design is a core practice of engineering and of great importance to engineering education [1]. A challenge facing many institutions is how to bring "real" design experiences into the curriculum. Such experiences offer opportunities to apply the technical skills learned in engineering courses, as well as developing the broader professional skills needed in today's competitive global economy, including teamwork and leadership skills [2]. Industry-inspired projects are often used in design classes, but the community can offer a plethora of compelling projects that challenge students in many ways and offer opportunities for students to make an impact in their local and global communities. Community-engaged learning or service-learning is a pedagogy that has gained more acceptance within engineering education over the last two decades. It offers opportunities to introduce design experiences that by their nature integrate human, cultural, environmental and community issues into the design contexts.

The pedagogy of community-engaged learning has shown to have many benefits in engineering education. The context aligns with research on diversity and evidence points to an increase in diversity, especially regarding gender [3] and is supported by the observation that many EWB-USA chapter are nearly gender balanced [4]. Many programs use community engagement to enhance the undergraduate experience [5] with benefits that include enhanced academic performance, motivation, ability to work with others, leadership, overall satisfaction, aspiration for advanced degrees, and preparation for work [6–9]. Experiences in the first years can benefit retention [10, 11, 13]. Community-engaged experiences have also been posited as playing a significant role in the preparation of the core skills for practicing engineering. As Bielefeldt et al have claimed "[project-based learning] and [project-based service-learning] are both effective pedagogies to achieve a broad array of core knowledge and skills that are critical for engineers" [5, p. 542].

Community-engaged learning shares the values and components of human-centered design approaches as it involves real users and stakeholders integrating academic learning with service to local, regional, or global communities. In our teaching and research, we focus on human-centered design. In human-centered design and community-engaged learning there is a balance between design as a process with benefits to students, partners, and relationships as well as the final product or deliverable. Prior work suggests that a human-centered design process leads to innovative design, but perhaps more fundamentally we believe that it is important for undergraduate engineering students to learn that design is situated within a social context, i.e., that design impacts people, and that as designers we have an ethical responsibility to be concerned about the people that our design work impacts. At the same time, human-centered design

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can be powerful when students design products and/or processes that meet real human needs. It has been shown to be most effective on student development when the design teams can interact with real users within an authentic context [9]. Evidence suggests that an extended experience in practicing real design would offer students the opportunity to engage in a fuller range of design skills and thinking [9, 13].

Prototypes are an important part of the communication and development process. The use of prototypes early in the design process allows student teams to gather important information about the stakeholders, requirements, and work to a final useful deliverable. In community-engaged learning, this is especially important as the final designs are intended to be deployed to the community partners and actually used. Communication throughout the process is a key element and prototypes are an important tool in the communication and design strategy. Specifications and requirements are particularly important working with prototypes as these are what the successes and corrections are based upon. Prototyping with users can also lead to the discovery of new requirements that were not manifest earlier in the design process. A previous study that explored how students perceived the design process [14] noted that students often lacked an explicit understanding of the importance of requirements. This paper explores the ways that prototypes are used across a wide range of design projects and explores interventions to enhance the students' understanding of the importance of requirements and their connection to prototyping, thereby diminishing the impact of the prototypes. While the interventions were inconclusive, the investigation provided insights to guide future research and program development pointing to efforts that are more closely linked to the active design project.

2. Context

The context for this study is the EPICS program at Purdue University [15, 16]. EPICS offers design courses that can be taken by any student in the university at any year. The courses can be used as a substitute for other courses within the curriculum of most majors in the university. Engineering students may use EPICS as a substitute for the first-year design course and later in the program for one or two technical electives. Some majors allow EPICS to also count as a capstone design course with departmental permission. All EPICS projects are developed within community partnerships that are local, regional, or global. The intent is that all successful projects are delivered and used by their community partner(s). Teams of undergraduate students partner with a not-for-profit or community organization to define, design, build, test, deploy, and support engineering-centered projects that significantly improve the organization's ability to serve the community. The experience integrates highly mentored, long-term, large-scale, team-based, multidisciplinary design projects into the undergraduate engineering curriculum. Students can participate multiple semesters; teams typically have a mix of returning and new students on the team. Students take on different roles, such as design lead, project manager, and project partner liaison. The core of the EPICS courses is the design work with their community partner and it is supplemented with required professional development hours outside of the regular class period that are selected for many offerings from the program. EPICS has grown at Purdue to 45 divisions with over 1100 students participating each year representing more than 30 majors from all colleges within the university. Students include first-year students to seniors with each taking the course for different types of credit within their respective degree program. Each section has a theme of a common community partner or technology having an average of 15 students with 2–4 project teams within each section. The large section size helps insure some returning students each semester for continuity of projects across semesters. Community partners are engaged with a minimum commitment of five years and most partnerships continuing for more than a decade. In the spring of 2019, 42% of the participants were female, while 43% of the participants were non-Caucasian. First-year students participate through the EPICS Learning Community, which has averaged 43% female over the last six years. Data from the EPICS shows that graduates are prepared for professional practice and report being promoted at faster rates than their peers.[17]

EPICS leads a university consortium that has engaged more than 50 other institutions globally in developing similar course structures as well as a K12 Program that brings EPICS projects in more than 100 middle and high schools in 17 states within the U.S.

Purdue University moved all classes online after spring break in March 2020. The data for the specification study was collected in the fall semester of 2019 when classes were all in person. In the fall semester 2020, classes resumed on campus but with significant restrictions. Students were also allowed to participate virtually so teams had a mix of on campus and virtual students [18]. The prototype cases discussed below are from both prior to the pandemic and during the return to classes.

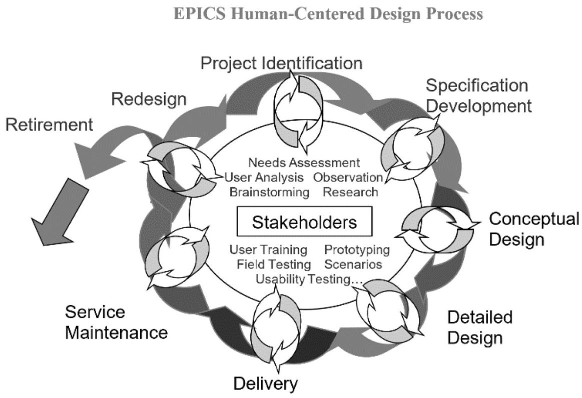

Fig. 1. EPICS Design Process.

2.1 EPICS Design Process

Recognizing there is not a single model for design; EPICS did not initially teach a specific design process. Students learned different approaches for design processes in different majors. Early in the program students were asked to use the ones they knew and were comfortable with. The reality, however, was that students had different levels of understanding of design. Not all students were actually learning any design process model. The result was that most teams were not using a formal design process in the development of the projects.

As the program grew and processes were changed to allow for scale, the variation of design approaches presented challenges to support the large number of approaches. Evaluation of their work was also challenging with the variability.

A change was made to teach a single design process that would be applicable for community-based designs. The EPICS design process was developed to reflect a human-centered approach where stakeholders are at the heart of the EPICS design process (Fig. 1). The process integrated ideas of human-centered design and the values of community-engaged learning. Stakeholders encompass all of those who are impacted by the project including the direct users, the community partner organization, secondary users such as teachers, therapists, and people who maintain the project, parents and family members, as well as the broader communities that each of these stakeholders represent. The EPICS design process begins with understanding the needs of the stakeholders and involves them throughout the design process. It is iterative and advocates the use of prototypes and empirical evaluation to make design decisions. It also includes attention to the delivery, service, and maintenance aspects of the project.

Although the overall goal is to move through the phases, sometimes the project team gains 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, advisors, 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.

The move to a common design process was very positive. The results of students being more aware of design is noted in the programmatic assessment section later in this paper. A common model across all teams has also made design reviews more uniform. Industry volunteers review each team's designs twice per semester and these volunteers often review over multiple teams. A common design process has facilitated effective critiques across teams [16].

3. Prototypes

Prototyping is emphasized through the EPICS design process. The projects in EPICS span a very diverse set of design experiences including software, mechanical, electrical, water, agriculture and international development projects. The use of prototypes varies significantly across the different contexts for the designs. Examples of how prototypes are used in different types of projects and at different phases of the design process are provided to demonstrate the breadth of projects and the roles of prototyping within the program.

Early in the design process, low fidelity prototypes are often used to insure that the partner's requirements are being met and to explore physical dimensions and constraints. Commonly, the partner may provide requirements and the team will explore initial ideas and could interact with the partner to insure that the team understood the partner's requirements.

Low fidelity prototypes are also used for global partners. A team working with a Haitian school explored ideas for a hydroponics system. A physical prototype allowed the team to begin to understand how the system would function and to scale aspects of the ideas and is shown in Fig. 2. A local representative could interact with the design idea for feedback and the model was shown to the school officials. The concept was communicated to the partners and feedback was integrated into the design. The team was able to explore aspects of the design including piping and spaces for plants. While not to scale, it did allow students to make

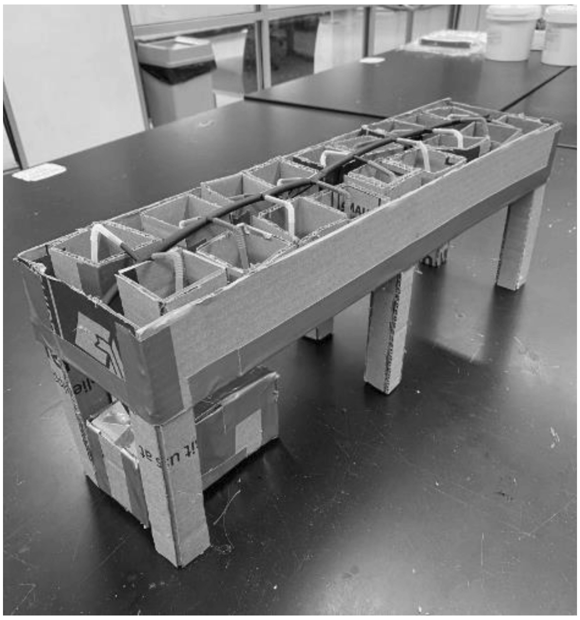

Fig. 2. Hydroponics System for Haitian School.

Fig. 3. Mobility Chair for Veteran.

decisions on the size to be appropriate for the children in the classroom.

Sometimes low fidelity prototypes are built later in the design process as decisions are being made or iteraction is needed. A design concept was in detailed design when the ideas was determined infeasible due to modificaitons needed for the building. The concept was a lift mechanism for bicycles and construction materials in a storage building for a local non-profit. The flaw in the original design was discovered early in the semester and at the mid-semester design review the team needed a new path. They created five different concepts that had different attributes and they were able to demonstrate each idea and compare the ideas in real time with the partners and the industry mentors. At the end of the design review a new concept was agreed upon and the team moved to implement the new concept.

Teams can use cardboard and other materials to quickly change their ideas early in the design process. One team working with a local veteran with limited mobility worked on a chair design and used pvc pipe to be able to explore different ideas quickly (Fig. 3). The structure of the pvc pipe allowed students to simulate the use of the chair. The team could make a full scale model that was tested in the classroom and used in role playing based on the user needs. The concepts were iterated and the design ideas narrowed. The concept was shown to the user for feedback during the design and recommendations implemented before the final design was fabricated and delivered.

Prototypes done early in the design process do not have to be low fidelity. One set of teams has been paired with a family with a child with a physical disability where he has no use of his arms. The team has worked on mechanisms to allow him to feed himself, highlight on a page, dress himself and fish. The team used CAD models and 3D printed the ideas. Fig. 4 shows models for holding a highlighter and two concepts to hold an eating utensil and a straw. These were tested in the labs and then taken to the family for the child to try. The team could see how the ideas worked and where to improve. Feedback was given immediately by the parents and child for improvement and the next iteration was produced. The cylces have continued until an acceptable design is achieved and the team moves on to the next need to address.

Sometimes prototypes are used to solve technial issues with the design. Fig. 5 shows an early prototype for a mechanism that would allow a child with a severe disablity to steer a sailboat. The user interface was set by the partner that was a summer camp for children with disabilities. The interface was a joy stick that would plug into the box that held the mechanism. The design challenges was meeting the requirements and fitting it onto the sailboat itself. The team had to design the electronics and the mechanisms that would provide the needed force to turn the boat. A boat was brought into the lab for the team to test the fit and perform simple tests and then the team moved to an actual

Fig. 4. Early prototypes 3D printed for writing and eating.

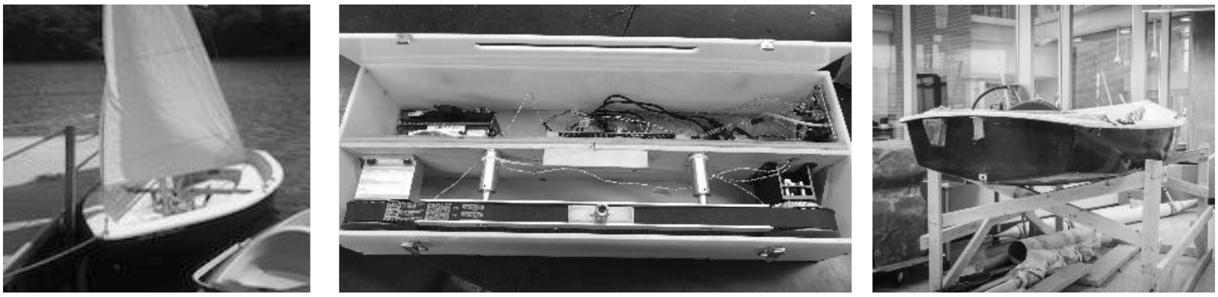

Fig. 5. Sailboat steering prototype.

boat on the water. The team was successful in their delivery.

Global projects present challenges with the actual users so far away from the design teams. Travel is infrequent and design ideas need to be tested. A full scale and functional prototype is used by a team working on air quality in African kitchens in Fig. 6. To be able to test the ideas, a model had to be built that would simulate functionally the environment of the actual kitchen. Safety is paramount and the prototype incorporates safety features as well as functional aspects of the actual kitchen environment. The prototype needed to have additional constraints, such as being able to be heated in the midwestern winter, that the actual African kitchen did not have in order for the students to continue to develop their design concepts. The test environment allows the students to develop and test full scale ideas for the actual design.

Prototypes are used in a variety of ways across the program to engage the users in design decisions, allow students to explore ideas and to test concepts. The program emphasizes early prototyping and provides an easily accessible array of materials. The labs are designed to facilitate a wide range of projects from construction, mechanical, electrical, and software projects. More than 140 projects are being developed simulataneously for more than 50 partners. Since the projects can span semesters, there are projects at every phase of the design process at any point in the semester. Success in

Fig. 6. Model Kenyan Kitchen.

completing and delivering the product to the community partner requires keen attention to the user needs and thorough testing of the concepts. Prototyping is a key element of this process.

4. Prototyping and Specification

Prototyping with purpose is a theme within the program. Prototypes are used to identify requirements and to test ideas against the requirements. An earlier study of students' understanding of design showed a lack of inclusion of the requirements in the design process [14]. Because specifications and requirements are so important in the evaluation of prototypes and the development of authentic design, an intervention was designed to increase awareness, understanding, and use of specifications in the design study. Using prototypes with community partners is intended to evaluate the design concepts with respect to the specifications as well as to refine, clarify, or even identify new requirements. It was hypothesized that students' awareness and use of specifications could be raised with interventions that could extend across the design teams.

4.1 Specification Intervention

Three different interventions were examined across eight course divisions. The interventions were designed, so that they could be used across course divisions and if successful implemented across the entire program. They included an assigned reading, a web-based video lecture, and an in-class design exercise. Two different instructors implemented the interventions, and each had four divisions, which allowed one of their divisions to act as a control group with no intervention. The students in each course division were asked to sketch or diagram the design process as they understood it during the second or third week of the semester as an initial baseline. The interventions were then performed during the fourth week of the semester, and finally the students were asked to repeat the design process sketching activity during the 16th, and final, week of the semester. This assessment method followed the procedure in the prior study [14]. The artifacts generated during the design process sketching activities were coded and evaluated in accordance with the predicate study, assessing whether the student referred to each phase of the design process, as well as whether they indicated an awareness of the stakeholders or iteration in the process. The assessments of the students' sketches were compared between the early and late semester artifacts to determine whether the interventions affected the students' perceptions of the design process, including the Specification Development phase.

4.2 EPICS Study Participants

Eight of the EPICS divisions were chosen to participate in the study. Per Table 1, all eight were taught by one of two instructors to provide some control over variability of instruction. Each division had one or more community partners that worked with the students on the designs and would ultimately receive the final product once it was complete. Access to the partners varied by distance and accessibility. Five of the divisions had local community partners that could be reached easily. Three of the teams have partners within the state or adjacent states that were far away enough that a trip could not be done during class times. That limited the number of trips per semester. A final team had global partners where students could only communicate remotely. Each of the partners had access to the teams via web-based communication, texts, calls and emails, as well as in-person visits where possible.

4.3 Draw Your Process Task

Students from the eight EPICS divisions were asked to draw the design process that they were using and not to simply redraw the EPICS design process graphic. Any representation using pictures and/or words would suffice. They were also told that their responses would not be part of the materials that were graded in the semester. The students were given instructions on paper with the specific task at the start of the semester (T1), in weeks 2 or 3, and in the final week of the semester, week 15 (T2).

Eight divisions participated with 112 students

Table 1. Circumstances of each division in the study

Division	Instructor	**Local partners** (Able to visit and return within class session)	**Regional partners** (Unable to visit and return within class session)	**Global partners** (Visits impractical, remote contact only)
1	A		x	
2	B	x		
3	B			x
4	A	x		
5	A		x	
6	B	x	x	
7	A	x		
8	B	x		

Table 2. Group composition

Group and Intervention	Divisions	Number of New Students in Group	Number of Returning Students in Group
A – Control	1, 6	20	10
B – Role Play	5, 8	21	10
C – Reading	2, 7	18	6
D – Skill Session	3, 4	20	7

total. 33 students had been in the class prior and were returning to the teams and 79 were new to EPICS. The eight divisions were divided into four groups and the distribution of new and returning students in each group is shown in Table 2. Two of the co-authors teach four divisions each, and each instructor had one division in each group, to minimize instructor bias. The groups are described below.

The groups included:

- Group A (Control) had the standard experience with no additional interventions.
- Group B (Role Play) used a modified version of the Stanford D School's wallet exercise during one of the lab sessions in weeks 3–6. This activity involved role playing with each student alternating as a designer and a user. Since most students do not use traditional wallets, another product was substituted in each division (recommendations were a portable hydration system or a backpack). The exercise developed up to the point where user needs were identified and then students were asked to identify a list of specifications. The lists were then compared between teams as a summative exercise and a brief oral reflection was on the experience, importance of specifications and how they applied to their current projects.
- Group C (Reading) was assigned in weeks 3–6 to read the chapter on Technical Requirements Definitions from the NASA Systems Engineering Handbook [20] and answer a short quiz to verify that they had read the chapter.
- Group D (Skill Session) watched the EPICS 'Specification Development' video [21] during lab in weeks 4 or 5. After the video, the students met with their project teams and reviewed and revised the section on specification development as needed in the Design Document that has been carried over from the previous semester.

In the final week of the semester, week 15, students were given the same exercise again without seeing their original work. These design representations were collected and coded along with those from the start of the semester.

4.4 Analysis Approach

The analysis of the data was done to categorize features of the student artifacts. The four-person research team, co-authors, identified the phases of the EPICS design process described earlier ('Specification Development' being one of those phases) as categories to code the data against. In addition, the researchers included 'Iterations' and 'Feedback/People' (e.g., interaction or communications with users, stakeholders, and community partners) as important elements of the design process to code. The researchers coded several cases together to calibrate the process including cases that were identified as challenging. Once the calibration was complete, the data was coded by three co-authors individually and shared with the rest of the team. None of the instructors coded their own divisions and each coder did not know which division had which treatment.

4.5 Findings and Trends

Fig. 7 shows the results for the codes for specifica-

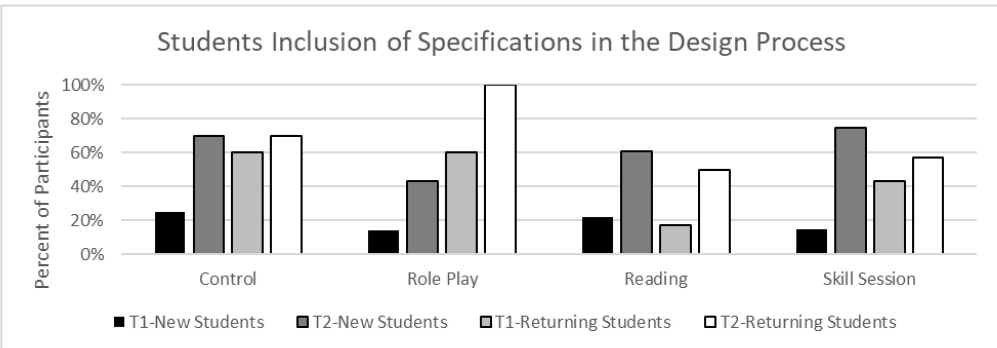

Fig. 7. Student Representations of the Design that Included Specifications by Treatment Group.

tions in the data for the four groups for the new and returning students respectively. For the students who are new to EPICS the awareness of specifications or requirements is low and below $\frac{1}{4}$ of the respondents for each group. Each treatment shows an increase as well as the control group. All the groups participated in a full semester of design work and each team had a partner. The additional assignments and exercises did not appear to have a significantly different impact on their perceptions of the requirements in the design process.

The students who had been in EPICS in Fig. 7 showed a highly varied inclusion of requirements in the initial design process drawing activity (T1) with two of the groups showing 60% of the participants including requirements from the beginning, including the control group. The previous semesters, nothing was done to explicitly address requirements and recall that the same two instructors taught across the divisions. It is interesting that the role play group showed an increase and 100% of the returning students included requirements in their end of semester design process. This may be because they were experienced with the projects already and could relate the exercise to their projects while the new students were still learning. While the reading and skill session showed modest gains, it is unclear if these were from the assignments or a function of what they learned during the semester in their design experiences since their gains were like the control group.

While the supplemental activities were targeted at increasing awareness of requirements and specifications in the design process, the other elements of the design process were also examined. Nearly all the respondents included problem identification and conceptual design in their representations at both time one and two. The data was coded for iteration for all of the participants and the results are shown in Fig. 8. It was surprising that for three of the four groupings in both new and returning students had fewer elements of iteration at time two compared to time one. The groups that increased were the new students in the role play group along with the returning students for the reading group. Oddly, at time one for the returning students there were no representations showing iteration at time one.

A similar phenomenon is seen when considering the attributes of interacting with people and feedback as shown in Fig. 9. The role play cohort saw an increase across both groups but the others saw small increases or decreases. For new students, it was expected that interacting with real users during the exercise would draw out their understanding of human-centered design.

The foundation of the EPICS learning experience is the project work and it appears that the project

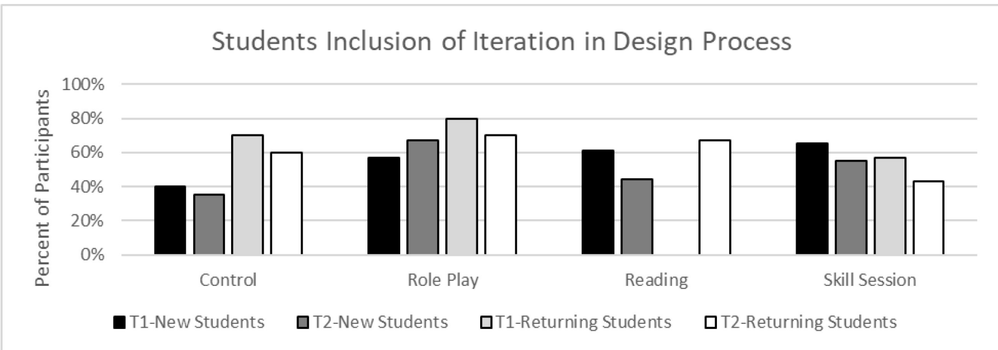

Fig. 8. Student Representations of the Design that Included Iteration by Treatment Group.

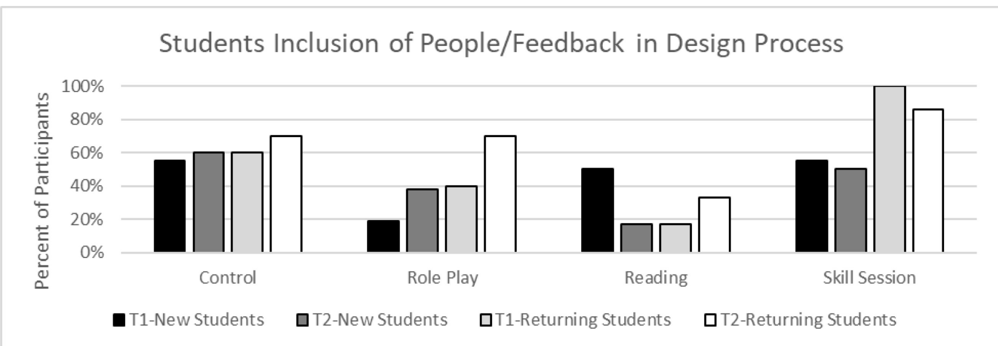

Fig. 9. Student Representations of the Design that Included People and Feedback by Treatment Group.

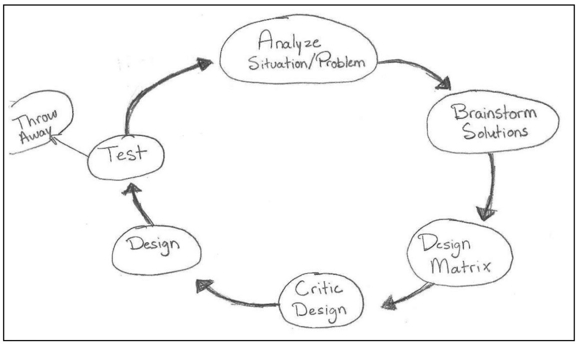

Fig. 10. Representation at Time 2 – General Process.

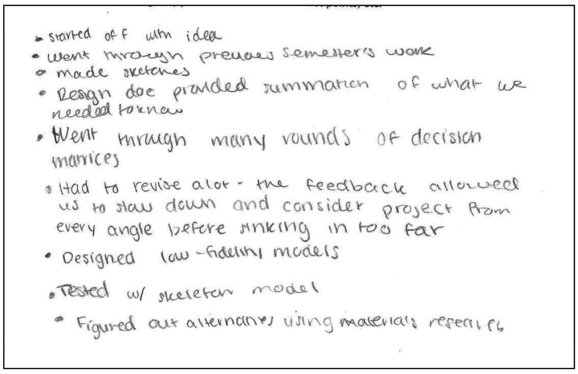

Fig. 11. List as Design Representation.

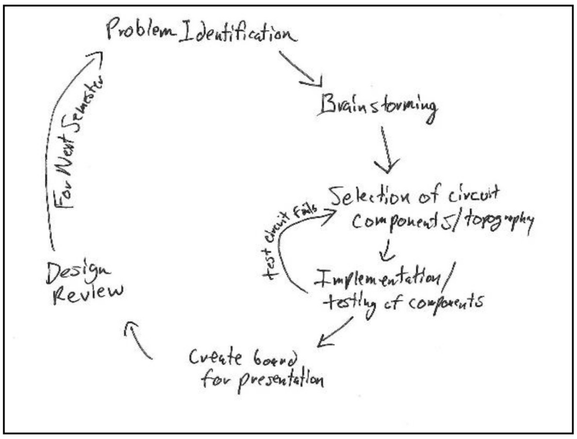

Fig. 12. Graphics for Time 2.

itself and the weekly work and experience that the students gain matters more than the any exercise or activity done in the semester. Examination of the student representations shows that the project and experience in that semester was a significant factor. Many of the representations of the design process included attributes that are specific to their current design or interaction pattern with their community partner. Some of the representations were more generic and showed a generalized process using some form of diagram. For example, Fig. 10 shows a cyclic process that is more generic. While the overall process is a cycle, it does not show iteration or interruptions within the process. It also lacks any explicit mention of feedback or people. It does include a station for test and two paths with one going to a "throw away" and the other starts the process over. No mention is made of any specifications or requirements either.

More common were representations that showed more of what the students did the semester under study that related to their design and partner interaction. Fig. 11 shows a representation that is a list of the main activities that the student did over the last semester. It is a list that seems linear without iteration and is missing and requirements. However, decision matrices are included and discussed and these require some criteria to be evaluated. These are typically the requirements so they may be implied but not explicitly called out and therefore not coded. As one can see, the list is very specific to what they did that semester.

Similarly, Fig. 12 shows another representation that is specific to what they did over the semester under study. This representation shows iteration and shows the end of the semester and the beginning of the work for the next class. It was noted in the instructions to not use the generic design process that is taught but to reflect on what you used. The students seem to have taken this part of the instructions to heart and tried to recreate what they did for the semester. This representation includes iteration and testing. It implies that there are requirements that the test needs to pass but does not call them out explicitly

5. Discussion

Community-engaged design experiences require students to gather information from users and stakeholders to develop designs that will be used by their partners. The survey of projects showed a wide array of prototypes being developed and used. They included low fidelity prototypes that were used to develop understanding by the design teams as well as mechanisms to convey ideas to their partners. Prototypes were also used the test technology and concepts. These prototypes were assumed to be guided by or used to gather information that would be compared to the specifications for the designs. The EPICS design process includes an explicit phase for requirement development. An earlier study of student representation of the design process showed a low inclusion rate of specification or requirement development. The potential to increase the awareness of requirements inspired three pilot interventions that supplemented the work on the project itself. The only substantial increase in requirements awareness were from returning students that participated in role playing. For the other cases there was inconclusive improvement when compared to the control group with no intervention.

Examination of the design process representation showed an overwhelming connection to their specific projects and represented the design phases that they experienced that semester. The interventions that were explored were done outside of the actual design and used common content across course divisions for consistency. While this was done in the hope that a successful intervention could be scaled and used throughout the program, it disconnected the activity from the development of their own design and reduced the effectiveness. The exception was the role-playing exercise where the connection was made more explicit. This is the one case where the returning students showed significant gains between time one and two. It can be posited that the students who were able to connect the exercise with their project based on their prior knowledge and experience carried that connection through the semester and showed the result in the time two data. The new students in that section were still learning about the design and could not make the connection.

It was evident from the representations created by the students that they envisioned the design process as it related to their specific project. This suggests that interventions to enhance the understanding of the design process need to be clearly mapped to the students' project work. An approach may be to imbed the supplemental learnings into the context of their current designs more explicitly. This could be done by modifying their reflection activities to connect their work with the design process broadly and with specification development specifically. Ash and Clayton [20] discussed models for reflection and approaches to making learning visible which could personalize their experiences and learning while they are using prototypes or conducting other design activities. Activities related to their prototype development and use linked to reflections may offer more impact across divisions.

6. Conclusions

Students demonstrated a wide array of prototypes that were used in a variety of ways within the design process. The prototypes were used by students to explore options and communicate ideas to the partner and receive feedback on the design options related to their design specification. However, when asked to create a representation of their design process, most students did not include requirements and specifications. A series of interventions used across multiple course divisions to enhance the visibility and understanding of requirement development within the design process showed inconclusive results compared to the control populations. Instead, students' representation of the design process identified the design process that reflected their experience during the semester under study. Evidence that students are using requirements with their prototypes and testing are visible in the representations but not explicitly called out any more than the control groups. Elements of iteration and user-feedback were also included as it related to the semester under study. Therefore, activities to enhance understanding and applications of specifications may be more effective when connected directly to their actual design rather than the common tasks used across course sections to demonstrate the design steps and processes. As researchers, we were able to consider how course structures across the program and within divisions may be impacting students' perceptions of design, using their representations of their design processes. We believe the interventions as a design process activity has promise, but future research efforts might include modifications, to support students in reflecting on how they go about their design and to address specific elements within their project.

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