

ROXIE: Real Outreach eXperiences In Engineering First-Year Engineering Students Designing for Community Partners*

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This paper reports on the major undertaking of providing real problems with actual community partners as the basis of design projects for approximately 900 first-year engineering students. The initiative was dubbed the ROXIE project, 'Real Outreach eXperiences In Engineering'. The goal was to have engineering students work on real projects with actual clients rather than contrived less meaningful projects. Sustainability is a key element in three primary aspects of the ROXIE project. First, numerous projects for the community were directed at finding sustainable solutions to problems around their operation or economic viability. The second sustainability aspect for the ROXIE project involves identifying hands-on activities and associated materials for the once per week workshop sessions associated with the large lecture course. The third aspect of sustainability for the ROXIE project addresses issues of how to sustain and maintain the partnerships and instructional infrastructure of such a large undertaking for the long-term. This paper provides the motivation and greater detail of the background of ROXIE and then expands upon the three aspects of sustaining sustainable design highlighted above. Early results of integrating an area of social significance into design education have been very positive. Reflections from students, community partners and the instructional team are shared. Summary and future plans are also included.

Keywords: design education; first year design; service learning; student engagement; sustainable design; large engineering class

1. INTRODUCTION

EACH YEAR the instructors of the first-year course for engineering students, ENGE 1114: Exploration of Engineering Design, are faced with the challenge of providing a meaningful and valuable project experience that supports learning and fosters interest about engineering design. While past projects have been suitable for achieving basic learning outcomes, the contrived nature of these projects does not adequately provide an opportunity for students to learn about or gain experience with important design topics such as working with a customer, identifying customer requirements, framing an open-ended design problem, and most importantly, identifying their role as a responsible contributing engineer in the world at large. In the spring semester of 2008, all five instructors of ENGE 1114, who are also co-authors of this paper, looked to service-learning as a means of achieving these broader learning

objectives while still meeting the course learning outcomes for engineering design.

This paper reports on the major undertaking of providing real problems with actual community partners as the basis of design projects for approximately 900 first-year engineering students. The initiative was dubbed the ROXIE project, where ROXIE is derived from 'Real Outreach eXperiences In Engineering'. The mascot is a fish named Roxie. Our goal was to put the fish back into the water. This being our analogy of having engineering students work on real projects with actual clients rather than contrived less meaningful projects. As shown in the photo of Roxie (Fig. 1), there are treasures to be discovered with real problems and partners.

Initially, ROXIE was created to engage students and contribute to the community. Very quickly it became evident that sustainability was a critical central consideration for the long term viability of the ROXIE design projects, support activities, and infrastructure. Sustainability has been a key element in three primary aspects of the ROXIE

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Fig. 1. Roxie—putting the fish back in the water.

project almost from the beginning. First, numerous projects for the community were directed at finding solutions to problems around their operation or economic viability that involve working with limited resources, conserving the earth's resources, and minimizing environmental impact such as: living quarters for girl scout camps, water run-off control, outdoor amphitheater, landscape redesign, program for collection, refurbish and redistribution to the needy of retired computers, church kitchen redesign, wind diversion, student food pantry, dog shelters for humane society, alternative energy, and water pump system.

The second sustainability aspect for the ROXIE project involves identifying hands-on activities and associated materials for the once per week workshop sessions associated with the large lecture course. The approximately 900 students, who are enrolled in one of three 300-seat lecture sections (Fig. 2), are further divided into weekly 30-seat workshop sections. In the workshops, students apply concepts introduced in the lecture, reading and/or assignments to hands-on activities around learning engineering design process and methods, as well as teaming and project management skills. As one would imagine with large numbers, the challenge here was to identify activities that are enga-



Fig. 2. Large 300 seat lecture section.

ging, accomplish the learning objectives and make use of materials that are inexpensive, reusable, and in cases of disposal, are decomposable. These activities exposed students to sustainability through example rather than teaching or assessing student sustainability knowledge as this teaching and assessment was done in the preceding first semester course where the central theme is sustainability.

The third aspect of sustainability for the ROXIE project involves addressing issues of how to sustain and maintain the partnerships and instructional infrastructure of such a large undertaking for the long-term. We were all committed to the ROXIE project, knowing the growing body of research that supports the benefits of service-learning by having real projects and actual partners for student learning and engagement [1–3]. How would we design, implement and sustain the continued operation of this program with consideration of limited budget and reasonable time commitment of teaching faculty, graduate teaching assistants and our community partners?

This paper will provide the motivation and greater detail of the background to ROXIE and then expand upon the three aspects of sustaining sustainable design highlighted above: design projects focused on sustainability; sustainability and hands-on learning activities for large numbers; and sustaining community partnerships and instructional infrastructure for large-scale service learning focused design projects. Early results of integrating an area of social significance into design education have been very positive. The assertion that these projects are more meaningful for students is the subject of future research. However, students have welcomed both the hands-on and personal contribution aspects of their projects. Community partners have shared the significance of the results of the ROXIE project for their organizations and their continued commitment to participate. Reflections from students, community partners and the instructional team are shared. Conclusions and future plans are also included.

2. BACKGROUND AND RELATED LITERATURE

Important questions and statements about the preparation of students to think globally and about sustainability have been raised in a growing number of national publications. *The Engineer of 2020* published by the National Academy of Engineering (NAE) [4], questions: 'Do U.S. engineers understand enough culturally, for example, to respond to the needs of the multiple niches in a global market? Can we continue to expect everyone else to speak English?' A follow up report of the NAE [5] states the following about the U.S. Engineer of 2020 and beyond: 'It is expected that U.S. engineers will be based abroad, will have to travel (physically or virtually) around the world to

meet customers, and will have to converse proficiently in more than one language. Flexibility and respect for ways to life different from ours will be critical to professional success.' Further, numerous other quotes by respected academicians and CEOs highlight the importance of global education. For example: Frank Rhodes, President Emeritus, Cornell University states: 'The [New American University] .. will be international in its orientation and cosmopolitan in its character; study abroad will become a norm.' [6].

Equally concerning, is the preparation of the Engineer of 2020 to be socially conscious. This is clearly important preparation for engineers who are poised to apply their knowledge and skills for the betterment of humankind. At the same time, we also believe that opportunities for students to engage in projects and learning activities, such as human centered design projects, may also have a significant impact on the interest and learning of a more diverse student body, particularly for women students [7]. There is a growing body of research that suggests that by addressing gender differences in learning style and perceptions of technology and interests, a more equitable environment in engineering classes could be created by changing the primary activities used to introduce or reinforce concepts [8–13]. For instance, traditionally class projects in engineering/technology often focus on the artifacts of design such as engines, gears, robots, etc. rather than the motivation behind such devices such as the benefits to humankind. While their male counterparts may find the artifacts alone exciting, females often require a more holistic approach.

For students to think more holistically, there are three major skills that engineering students need to develop: 1. global/cultural competencies; 2. socially conscious/human-centered design; and 3. design for sustainability. Clearly, there is significant motivation and need for preparing holistic engineers. The sections that follow provide details on how Virginia Tech begins to address these needs through service-learning and human-centered design projects and activities for first-year engineering students.

3. SUSTAINABLE COMMUNITY PROJECTS

With the aid of VT ENGAGE and the Virginia Tech Service Learning Center, 185 teams composed of nominally five students each were paired with dozens of non-profit community organizations. The student teams acted as 'Systems Design Consultants' and were instructed to 'serve and improve' the community through engineering design. Specifically, the teams were tasked with (i) performing an act of service for the community organization, (ii) meeting with the community organization's leader to identify a design problem

that needed to be solved, and (iii) proposing a solution to the identified problem by following the design method taught in class. As expected, projects were quite varied and included tackling problems such as the redesign of recreational rooms for the volunteer Fire Department, designing the landscaping for local churches, and designing tip-proof feed bowls for the animal shelter. At the conclusion of the project, each team submitted a design solution to the community partner as well as a proposal for its implementation—the best proposals were considered for future funding [14]. Many of these projects dealt with sustainability issues that were discovered and negotiated with community partners in the course of carrying out the design project.

As participants in the ROXIE project, students serve as design consultants for non-profit community organizations. As such, they are not given a problem description; they are to visit the community partner and identify a need. To complete this task, the students proceed through the following five phases:

- *Perform service.* In order to identify opportunities for improvement, the students must first get first-hand experience with the community partner. In this first phase of the project which took a couple of days, students perform a small volunteer activity so they may better understand the needs and the mission of the organization with which they are partnered.
- *Identify a need.* Once the volunteer activity is complete, the students are asked to reflect on their experience and meet with the community partner liaison in order to identify an opportunity within the organization for improvement.
- *Propose a design project.* With a need identified, the student teams propose a formal design project for the course. This proposal is guided by three questions: 'is there an opportunity for improvement?', 'are there multiple objectives and constraints that must be met for a satisfactory solution?', and 'are there multiple alternatives for a successful solution to the problem?' The students are required to submit a written project proposal in which they describe why they are able to answer each question in the affirmative.
- *Propose a solution by following a systematic design process.* Once the problem is appropriately defined, the students begin to search for a design solution through the application of the systematic design process presented in the course.
- *Document and present their solutions to their class as well as their community partners.*

In Table 1, the design phases, deliverables, and project deadlines are shown in detail.

To provide a service-learning design experience on such a large scale, the instructional team implemented the ROXIE project in four primary steps:

Table 1. Design phases, deliverables and deadlines for the ROXIE projects

Design phase	Deliverable	Deadline (week of)
Phase 1: Identify problem	<ul style="list-style-type: none"> • Submit preference list of community service groups • Notes from meeting with community service group leaders(s) 	<ul style="list-style-type: none"> • February 4th • February 18th
Phase 2: Clarification of task	<ul style="list-style-type: none"> • Project proposal and problem description • Team code of cooperation • Work breakdown structure • Project plan, including Gantt Chart, roles etc. • List of design requirements 	<ul style="list-style-type: none"> • February 18th • February 25th • March 10th
Phase 3: Conceptual design	<ul style="list-style-type: none"> • Function structure • Alternatives • Selection of principal solution 	<ul style="list-style-type: none"> • March 10th
Phase 4: Preliminary design	<ul style="list-style-type: none"> • May include a variety of models 	
Phase 5: Documentation	<ul style="list-style-type: none"> • Project report • Project presentation • Individual log book • Reflection-based learning essay 	<ul style="list-style-type: none"> • March 17th

- *Establishing community partners.* Connections with community partners were established through the VT ENGAGE program of the Center for Student Engagement and Community Partnerships. An emerging trend across many campuses nationwide, campus/community outreach offices provide support for on-campus service-learning programs. A memo announcing the ROXIE project and its objectives was sent to community organizations as a means of soliciting potential partnerships. Ultimately 87 community partners were matched with 185 student design teams. Some partners had multiple teams working with them on a variety of projects.
- *Connecting students to the community organizations.* Students were given a choice as to which organization they would work with for their design project. An online signup method was used to provide students their choice of partner on a first-come, first-served basis. Contact information for the organization was provided upon a successful match. Multiple teams were assigned to some partners, with no more than four teams per partner. Each team focused on different projects.
- *Presenting design methodology content.* With students and community organizations paired, the instructional team presented four lectures on the structured design process. These lectures included project management, identifying design requirements, identifying functions, and generating, evaluating, and selecting design alternatives.
- *Assessment.* Students' design projects were assessed primarily through a written design report and formal oral presentations. In addition to faculty assessment, the oral presentations were peer reviewed. Students were also required to submit a personal essay with reflections on their project learning experience—a critical component of any service-learning effort. Finally, in addition to the design project deliverables, students' understanding of design process content was supported and evaluated by workshop quizzes, homework, and activities.

As one would expect, the details and extent of faculty and graduate student involvement have direct impact on the long term sustainability of the project. This will be discussed in Section 5 of this paper.

A small sampling of the 185 projects completed during the initial ROXIE implementation is provided in Table 2. As can be seen in the table, the projects are not centered in a single discipline. All of these however, had an aspect of sustainability. The projects are varied in that they require the students to use the design process to realize both products and processes, and solve a wide range of community needs.

Figure 3 is a photo of two students, reading a thank you note from the director of Beans & Rice, Inc. The students were part of the team that participated in the refurbishing of recycled computers for Beans & Rice, Inc. These refurbished computers assisted ten students completing their GEDs. The students are at their poster during the Outreach Expo which was an Expo of all the outreach and service-learning projects at Virginia Tech. As an indication of the contribution of the ROXIE design project to the outreach mission of Virginia Tech and the community, the ROXIE project had 40 of the 80 posters presented at the Expo.

4. SUSTAINABLE HANDS-ON ACTIVITIES AND MATERIALS

In addition to considerations of the sustainability of the ROXIE project, the authors have also investigated sustainability issues pertaining to the project's related in-class activities. Due to the large enrollment, the class workshop sections' hands-on activities must be carefully designed so that their required resources have a minimal environmental impact. Specifically, the instructors create activities that feature reusable materials, recyclable materials, and materials that are derived from sustainable resources.

Table 2. A sample of ROXIE design projects dealing with sustainability

Community organization	Design project description and impact
Beans & Rice, Inc.	Students designed a systematic process for volunteers to follow when refurbishing and recycling computers for this organization which provides students needing a computer for successfully completing their GEDs.
Boy Scouts	Redesign of an existing outdoor amphitheater. This included considerations of layout to prevent erosion, sustainable construction materials, and a means of anchoring seating to the hillside for long term use.
Food Bank	Design of a device that would assist volunteers with transporting canned food from the basement of the building to its distribution floor. This reduced physical stress and allowed elderly to volunteer.
Humane Society	Design of feeding bowls that could not be tipped by dogs thereby saving maintenance, water and cleanup as well as sustaining the health of the animals.
March of Dimes	Instructional materials and methods for the organizations' clients for future fundraising were designed.
Faith-based Organization	Design of a system to control water runoff from the building site; thereby reducing future erosion, maintenance, and aesthetic appeal of the landscaping.
Campus Rescue Squad	Students designed a custom workbench for the ambulance maintenance crew; thus reducing bending and fatigue for these critical and highly stressed workers. The bench would be built from sustainable and recycled materials.
Community Transit System	A team designed an efficient route and method for volunteers to follow when cleaning a large number of bus stops spread around the area after large events in town. This plan saved considerable consulting dollars by creating a plan to be used for all future cleanups.
Nursing Home	Students designed a flower/vegetable planting bed that was wheelchair accessible. In addition to the assistive technology value of this project to the residents, the ability of residents to plant and grow food to sustain themselves was greatly enhanced.

One example of how sustainability issues have shaped instructional design is in the creation of a mechanical dissection activity. Used as a means for providing students a physical context for the concepts of functional decomposition, mechanical dissection activities [15, 16] can be especially resource intensive for large enrollments. In the first implementation of a mechanical dissection activity in ENGE 1114, students dissected disposable toothbrushes. While the toothbrushes provided an appropriate mechanism for functional analysis, they were not reusable because of their sealed casings. In an effort to make the activity more sustainable, the authors have recently changed the activity to feature See-N-Say toys as the subject of dissection. These toys provide students a basis for understanding functional decomposition and, through comparison with



Fig. 3. Beans & rice ROXIE team at outreach expo.

older models of the toy, provide a means for students to observe how different means can achieve the same function. Since the act of dissecting a See-N-Say requires the removal of a total of only eight screws, these toys can be repeatedly dissected without fear of students damaging the components or of students being unable to reassemble the devices in working order.

Another example of the authors' incorporation of sustainability objectives into the design of in-class activities can be found in their design of a team-building activity. As ROXIE is a team-based design project, the instructors desired to create an activity that provided a structured opportunity for the student teams to form and that also provided them a time for reflection on their initial team interactions. As discussed in detail in [17], four different team-building activities were ideated and tested within the workshop sections as a means of investigating the potential tradeoffs between cost, environmental impact, engagement, and design and teaming learning objectives. These alternatives featured various levels of resource commitment: balloons and tape were used for a balloon tower-building activity; paper and tape were used for a paper tower-building activity (Fig. 4); TinkerToy™ kits were used for a TinkerToy™ tower building activity, and, finally, no resources were used for a discussion-based speculative survival scenario activity. Using Likert scale survey data and a systematic selection procedure, the instructional team was able to select an activity alternative which provided the best compromise to the multiple, conflicting objectives. The Paper tower provided the best compromise with the balloon and TinkerToy™ close behind.



Fig. 4. Team building paper tower in 30 seat workshop.

5. SUSTAINABLE INFRASTRUCTURE

As mentioned above, faculty and graduate student time and commitment are major factors in the sustainability of such a large and varied service learning project. The community partners' time and commitment are also critical to sustain such a project. Given that there are approximately 900 first-year engineering students participating in this project and only five faculty members and 10 graduate teaching assistants, the time for faculty to mentor graduate students who in turn mentor the 185 design teams is significant. While the value of the resulting design solutions and design reports for the community partners could be significant, the time commitments of community partners in planning, meeting with students to clarify their design requirements, and attend the student presentations is also significant. Hence, creating an environment to support these partnerships was also imperative to long term success. Truly, the successes of this initial project semester would not have been possible had it not been for the tireless efforts of the coordinator and co-author Karen Gilbert and staff of the VT ENGAGE program [18], committed student teams, GTAs, and faculty.

For the ROXIE Project to be sustainable, it required reflection and examination of the many aspects of the project. An initial idea that was not exercised in the spring 2008 offering was to have multiple teams working on the same project for a single client thereby reducing the number of different projects. The spring of 2009 saw an increase of enrollment to 1,064 students and a reduction of community partners. As a result, the instructional team (now expanded to six) chose to divide the 1,064 students into two groups. One group of roughly half of the students would work on ROXIE projects with actual clients and the other half of the students would work on assistive technology projects called HELP (Human-centered Engineering Learning Projects) the twenty projects available to students for HELP came from projects two of the authors had developed in the past [19–21]. The major difference for

these projects is that they did not have actual clients for students to interact with (although they may have had in the initial generation of these projects). This approach along with multiple teams working somewhat competitively on the same project moved the ROXIE project in a more sustainable direction (with 500 rather than roughly 1,000 students). This change has also provided the means of further research into the pros and cons of working with real projects with actual clients. This will be discussed further in the Future Work Section 7.

6. RESULTS

As mentioned in Section 3, each student must complete an individual reflection essay at the completion of the semester design project. The authors use excerpts from essays from the inaugural implementation of the ROXIE project as anecdotal support for, or counterpoints to, two important aspects of the ROXIE Project; Design Learning and Service-Learning. Excerpts are thematically presented in this section.

6.1 Design learning

Several students reflected on the manner in which the ROXIE project experience positively affected their understanding of the design process.

The ROXIE project . . . has greatly helped instill the principles of the design process in my mind. I have learned that there is a lot more to it than just writing down the problem, brainstorming, and experimenting.

Before this class, I would have probably been biased and chosen the coolest looking design. However, I learned to methodically progress through the steps and choose the best plan of action.

Many students discussed how their understanding of the engineering discipline had been shaped by the ROXIE project experience.

The ROXIE project was a unique experience that helped me to improve on my design abilities and also showed me what the future as an engineer would be like.

Before entering the ENG program at VT I was a submarine mechanic for the US Navy . . . Looking back at this period in my life I wish that I had some of the problem definition skills that I was taught during these beginning engineering courses.

Some students articulated their preference for ROXIE projects over other project types.

I fully believe that what we did was infinitely times more effective and educational than the 'pumpkin launcher' projects. I believe that the project made what we learned in the classroom more practical and easy to understand contrary to what I believe was meant to happen, where the classroom learning made the project easier to accomplish.

I thought I was going to design an object within a group and have competition with other groups. How-

ever (through ROXIE) I recognized design is more than that and it is a process of finding and solving these problems.

Of course, not all students' responses were positive. Some students expressed frustration in the requirement to use design methods, and questioned their general applicability.

I doubt that big engineering firms like Lockheed Martin would dedicate so much time trying to create graphs and charts—they would dedicate their time on brainstorming ideas and proposing solutions to their problems.

The process is not important. It is the solution that is the result of any process that is important. (Our partner) doesn't care if we (used) a Gantt Chart or even the way in which we analyzed different design solutions, all they care about is the final solution.

Other students were troubled by the course's focus in the design process, and desired projects that were more closely related to their perception of the engineering career.

(ROXIE) was not the best medium for learning about the design process . . . something more technical would have appealed to (students') interests in the field of engineering.

6.2 Service-Learning

In general, the large majority of students responded positively to the service-learning aspect of the ROXIE experience.

It is easy for students to struggle in finding a purpose for studying engineering during their freshmen year. ROXIE was an experience that allowed students to make their studies worthwhile, share their hard work with the community, and develop their engineering design skills and communication skills.

I really enjoyed being able to work with a community partner . . . I believe that the overall process was a positive experience.

Working with the community was very gratifying experience and helped me to realize how much people appreciate volunteering work.

I found it rather fulfilling. I have learned that doing what we did for the ROXIE project is something that I think I would enjoy doing for a living. . . . It really allows us to see what it is actually like to work as an engineer in the real world, and that experience is priceless.

The students' commitment to satisfying the needs of their community partner was strong, as evidenced by some students' concerns that the absence of actual realization made ROXIE lack true value.

The only thing that I think is wrong with this project is the fact that we are not able to deliver our design to our community partners. It feels like we are taunting them with a solution to a major problem of theirs without delivering the solution to them.

In addition to student reflections, the instructional team received considerable unsolicited positive feedback from the community partners through

e-mail and letters. Some community partner feedback included:

Just a quick note to say Thank You for developing the ROXIE project. We always enjoy exposing students, particularly Freshmen, to community service and helping them understand how their expertise and time can make a difference in the community. It was enjoyable, and impressive, listening to their presentations.

Executive Director, YMCA at Virginia Tech

I just wanted to express my thanks for the opportunity to work with your Engineering students. It was a pleasure to work with this group as they handled themselves in a very professional manner.

The plans that were submitted as part of their final report will most likely be implemented as soon as we are able to work out the logistics of the move. We had hoped to find a 'better' use of our space but with limited time and staff had not been able to look at what our options might be. What a great benefit to the museum this assignment was!

It is so good to see the University helping the community in these ways. Rest assured that as you send your students out, they are representing you well!

Executive Director, Montgomery Museum and Lewis Miller Regional Art Center

Thanks to the hard work of our ROXIE team, 28 young people working on their GED's already have a computer to help them with their studies, which will help ensure their success with passing this test.

Executive Director, Beans and Rice

We plan to implement as many projects as possible developed by our ROXIE teams. We are looking forward to a continued relationship with engineering students at Virginia Tech—possibly even working on more advanced projects as seniors.

Director, Girl Scouts of Virginia, Skyline Council

The instructional team also offered these reflections on the ROXIE Project via e-mail.

It has been a challenge having so many students enrolled in projects that are real problems for community partners. Yet, students are so much more devoted to doing a good job for their client than for just themselves. It's rewarding to see them dedicated and learning the many lessons that so often don't come until capstone design for seniors.

and

The ROXIE project was born from a desire to create more meaningful, realistic, and engaging design projects for our first-year students. The aspects of giving back to the community, working with actual clients and on real, ill defined problems were truly valuable and eye opening for many students.

and

In general, I was pleased with the ROXIE project. The service learning component fits perfectly under the Virginia Tech motto: *Ut Prosim* ('That I may serve'). I enjoyed seeing student presentations in class and at the university-wide service learning expo. It was clear that students were challenged by real world issues: differences in client and student expectations, limited

resources, open-ended problems, etc.; students seemed to understand that they were representing the engineering profession and the university and acted in accordance. I think three things that helped some teams be more successful were: (1) being paired with a responsive community partner that was easily accessible to the team through the project (2) understanding the links to engineering design even if a project did not seem engineering related on the surface and (3) understanding the limitations of the project deliverables to the community partner.

and

Initially, the ROXIE project was focused on engaging design projects for students, while contributing and giving back to the community, most of the projects dealt with sustainability issues. However, it became quickly evident that if sustainability was not a key consideration in all aspects of this program, then the ROXIE project would have a very short life.

7. CONCLUSIONS AND FUTURE WORK

This paper presented the motivation and background for the Real Outreach eXperiences In

Engineering (ROXIE) projects at Virginia Tech where first-year engineering students take on real problems with actual community partners. Three aspects of sustaining sustainable design are described. Reflections from students, community partners and the instructional team are shared. In addition to the continued improvement of the implementation of the ROXIE project, future work will focus on researching the effects of providing students with direct customer interaction. Specifically the authors will assess how first-year student interaction with a real customer can affect their motivation, self-efficacy, and design learning. In addition, the hypothesis that real projects with actual partners are more meaningful will be investigated. It is clear watching student presentations that the ROXIE Project presenters exhibit much more passion and ownership than the presenters of other projects. In the future, the authors will compare responses from students involved in the ROXIE project with those involved in the HELP projects (Human-centered Engineering Learning Projects without community partners) as a means of completing this research.

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