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# Board 357: Pilot Study of the Impacts of a Robotics Curriculum on Student's Subject-Related Identities and Understanding of Engineering

**Prof. Holly M Golecki, University of Illinois, Urbana Champaign**

Dr. Holly Golecki (she/her) is a Teaching Assistant Professor in Bioengineering at the University of Illinois Urbana-Champaign and an Associate in the John A Paulson School of Engineering and Applied Sciences at Harvard University. She holds an appointment at the Carle-Illinois College of Medicine in the Department of Biomedical and Translational Sciences. She is also a core faculty member at the Institute for Inclusion, Diversity, Equity, and Access in the College of Engineering. Holly studies biomaterials and soft robotics and their applications in the university classroom, in undergraduate research and in engaging K12 students in STEM. Holly received her BS/MS in Materials Science and Engineering from Drexel University and her PhD in Engineering Sciences from Harvard University.

**Ms. Elizabeth Ann McNeela, University of Illinois, Urbana Champaign**

Bioengineering undergraduate student interested in the effects of outreach programs and curriculums on engineering enrollment.

**Thomas Tran, University of Illinois, Urbana-Champaign**
**Dr. Karin Jensen, University of Michigan**

Karin Jensen, Ph.D. (she/her) is an assistant professor in biomedical engineering and engineering education research at the University of Michigan. Her research interests include student mental health and wellness, engineering student career pathways, and engagement of engineering faculty in engineering education research.

# Pilot Study of the Impacts of a Robotics Curriculum on Student's Subject-related Identities and Understanding of Engineering

## Abstract

Participation in educational robotics, tinkering, and making are common precursors to enrollment in engineering majors. Negative perceptions of robotics can inhibit some students from participating and later, pursuing engineering studies. Additionally, gender disparities persist across many engineering disciplines and are particularly high in mechanical engineering and electrical engineering, with less than 20% of undergraduate degrees being awarded to women (ASEE By the Numbers 2021). K12 robotics programs have shown potential in increasing a student's likelihood of enrolling in a mechanical or electrical majors. By broadening the applications of robotics to human-centered designs and highlighting soft and biomaterials used in building robots, the field of soft robotics may be a platform to engage a diversity of students in K12 robotics and later, engineering majors. This paper presents a pilot study aimed at answering the research question: *Can a soft robotics curriculum impact high school students' attitudes and self-beliefs, and serve as a strategy to recruit women students to engineering majors traditionally dominated by men?*

To answer this research question, a soft material robotics curriculum and quantitative survey were piloted at a public high school in a class of 20 students. The class was composed students of whom 50% identify as girls and 50% identify as boys. The pilot curriculum was delivered over four days. Students participated in pre- and post-surveys, having parental consent in accordance with Institutional Review Board requirements. Students collaboratively worked in pairs to complete the builds using elastomer and textile materials, building robotic components while being introduced to engineering terms, concepts, and design process workflow. Pre- and post-surveys were distributed to students, measuring changes in STEM identities, engineering agency beliefs, and career interest.

The results of this small pilot informed changes to the curriculum and quantitative survey tools for future use. Survey data analysis highlighted an increase in familiarity with soft robotics concepts, such as the material makeup being composed of "soft" materials for "human medical use." There was also an increased understanding of specific engineering majors rather than the broader discipline. When asked to identify which major an individual may study to work on soft robots, participant answers exhibited a broader understanding of specific career paths after the curriculum. Preliminary analysis of the pilot study indicates our curriculum's potential to introduce students to engineering and its related career paths. The pilot also provided insight to the method of surveying used and justified for us the use of a retrospective survey in a full scale planned study. This program may serve as a pathway to engage a diversity of students in robotics and engineering leveraging new materials and applications.

## Introduction

Gender disparities persist across engineering disciplines. This is especially true in traditional disciplines such as mechanical engineering (MechE) and electrical engineering (EE) [1]. Nationwide, ~15% and ~14% of undergraduate MechE and EE degrees are awarded to women, respectively [2]. Alternatively, bioengineering and biomedical engineering (BME) programs graduate ~40% women students each year [2]. Successful pathways to majoring in BIOE are well studied, while strategies to attract women students to traditional disciplines are less successful in changing national trends. Literature suggests that this disparity in engineering major preference persists from perceptions formed prior to entering college [3]–[5]. In addition, because of cited difficulties in changing majors once in college, it is critical to attract students to these majors during high school [4]. The current gendered landscape in engineering led us to ask, what can be done in the pre-college curricula to change students' perceptions of traditional engineering majors?

Pre-college robotics programs are common precursors to joining MechE and EE majors [6]. Girls, however, are not participating in pre-college robotics at the same rate as boys [7]. An analysis of pre-college extracurricular activities and their mapping to engineering majors showed that traditional disciplines, such as MechE and EE, had more students tinkering with electrical or mechanical components outside of school prior to entering college[8]. When girls are not part of extracurricular robotics programs, they miss vital opportunities to develop tinkering self-efficacy. If we can attract more girls to participate in pre-college robotics, we may open a pathway for these students to develop attitudes and self-beliefs that lead them to join majors with lower representation of women [6].

Critical Engineering Agency (CEA) is a theoretical framework adapted from the earlier Critical Science Agency framework. CEA is used to understand students' subject-related identities and agency beliefs, precursors to developing an interest in engineering [9]. Engineering agency beliefs define how students perceive their ability to positively impact the world through an engineering career. For women students, math and physics recognition as well as agency beliefs were positive predictors of choosing engineering majors [9]. The CEA framework has been used to understand how identities and agency beliefs of women enrolled in engineering majors were strengthened by hands-on projects early in college through a Community of Practice for participants [10]. We asked if a similar approach, engaging girls in hands-on human-centered design projects within a robotics curriculum, may be an effective method to engage pre-college girls in robotics and engineering and hence strengthen subject and engineering identities as well as engineering agency beliefs. We believe an opportunity exists to embed hands-on fabrication, fundamentals of mechanical engineering and human-centered design into robotics to increase girls' interest in traditional engineering disciplines.

Soft robotics is an emerging subfield of robotics inherently linked to human-centered design, healthcare applications, and hence engineering agency beliefs. Soft robots interface with humans by replacing hard components with mechanically programmed polymers and flexible electronics. The field of soft robotics [11] emerged as a result of robotic devices being deployed as bioinspired machines [12], grippers of delicate objects in manufacturing [13] or the ocean [14], as exoskeletons [15], or implantable devices [16]. Soft robotics represents a new field, combining traditional principles with soft materials for human-centered applications. Previous work hypothesized that soft robotics may appeal to women because of its use of chemistry, biology and materials science, disciplines [17]. However, we believe that soft robotics will appeal to students' pre-existing agency beliefs, and through investment in the design objectives, students can gain skills and confidence in robotics, and in turn engineering majors where women are traditionally underrepresented.

## Methods

Previously, we implemented soft robotics curricula in a variety of K12 contexts [18]–[20]. In this pilot study, we (1) delivered a four-day curriculum that focuses on representing engineers from a broad range of identities in course materials and (2) piloted an Institutional Review Board (IRB) approved quantitative survey of subject related identities and demographic data. The goal of this pilot was to evaluate our experimental methods for ease and clarity of implementation.

*Implementation* The goal of this study is to broaden students' definitions of who can do robotics. To that end, we revised our introductory curriculum, being mindful of the individuals in the field that we highlight by giving examples of women and individuals from other underrepresented groups in introductory slides. Figure 1 shows the outline of the planned hands-on curriculum delivered during a four-day short course at a publicly funded, competitive enrollment high school.

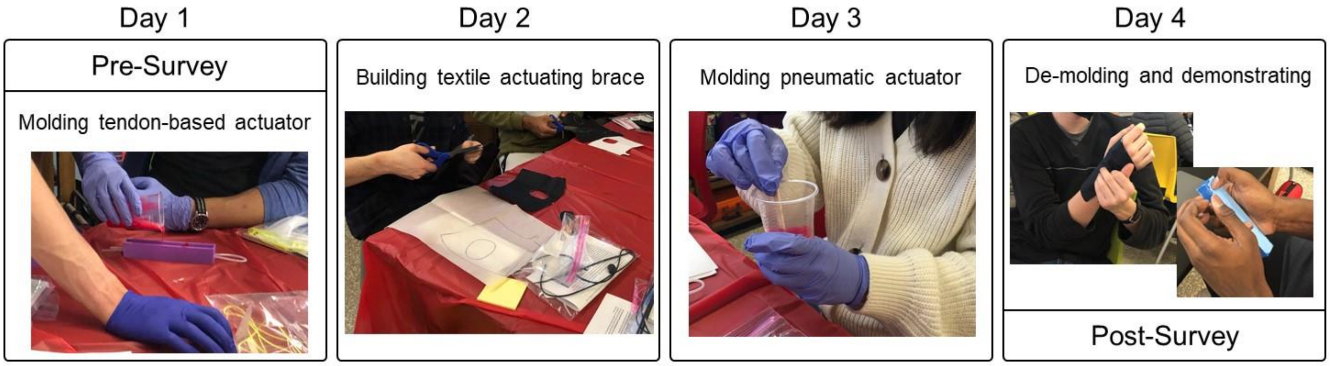


**Figure 1**. Outline of planned hands-on activities during the soft robotics curriculum and quantitative survey.

*Survey* The quantitative survey was designed using existing quantitative measures, combined with open-ended response questions. Surveys were delivered pre and post classroom implementation. The quantitative measures used in this pilot are as follows:

*Identity measures*: Survey items include the Persistence Research in Science and Engineering study [21]. These items include math identity, physics identity, and engineering identity. Each identity item includes: (1) two items measuring interest, (2) six items measuring performance/competence beliefs, (3) two items measuring recognition.
*Engineering career interest*: Engineering career choice is measured with a question that asks students to "Rate the likelihood of choosing a career in the following" including STEM related careers and eight specific engineering disciplines [9].
*Agency beliefs*: Five items that measure students' perceptions of their ability to think critically about engineering and use engineering to do good in the world will be included [9].

**Survey Results**

In total, 20 students participated in the class. Of those students, 10 students had signed parental consent and were present for all four days and completed both the pre- and post- survey. The last two questions of the survey asked gender identity and age. Gender identity options included (a) man, (b) woman, (c) non-binary, (d) prefer not to answer, and a write in option. Students participating identified as 50% men and 50% women. Average age of the student respondents was 16.8 ± 1.5 years.

*Definitions of a soft robot* In the free response section of the survey, participants were asked "What is a soft robot?". Overall, students had reasonable ideas about what soft robots were and their unique features compared to traditional robots. Table 1 shows a summary of pre- and post- survey responses for this question. While in the post survey, no one answered "I don't know", it is important to note that 4/10 students responded with a definition that explains what soft robots *are not* ("not made of metal"). In the larger study, we will focus on giving students the vocabulary to describe the new materials soft robots are made from (e.g. elastomers, silicones, low modulus materials, soft, flexible, compliant materials).

**Table 1**. Pilot survey responses to “What is a soft robot?”

| *Theme* | *Occurrence Pre-survey* | *Occurrence Post-survey* |
|---|---|---|
| Made from soft or flexible materials | 4 | 5 |
| Not made from hard or rigid materials | 0 | 4 |
| A robot that is intended to help people | 1 | 1 |
| Bioinspired robot | 1 | 0 |
| I don't know | 4 | 0 |

*College majors to work in soft robotics field* A second free-response question asked, “What college major does someone who works on robotics study?” Figure 2 shows the results of this question (a) overall and (b) by gender identity. The combined data shows a trend in students answering those majors traditionally associated with robotics: mechanical (60%), electrical (50%) and Computer Science (CS) (30%) in the pre-survey. However, in the post-survey there is a shift to include more engineering disciplines and “Engineering” more generally (50%). When broken out by gender, trends are less discernable, likely given the small numbers of responses. However, based observations from the combined responses, we will look for similar trends in the planned future larger study.

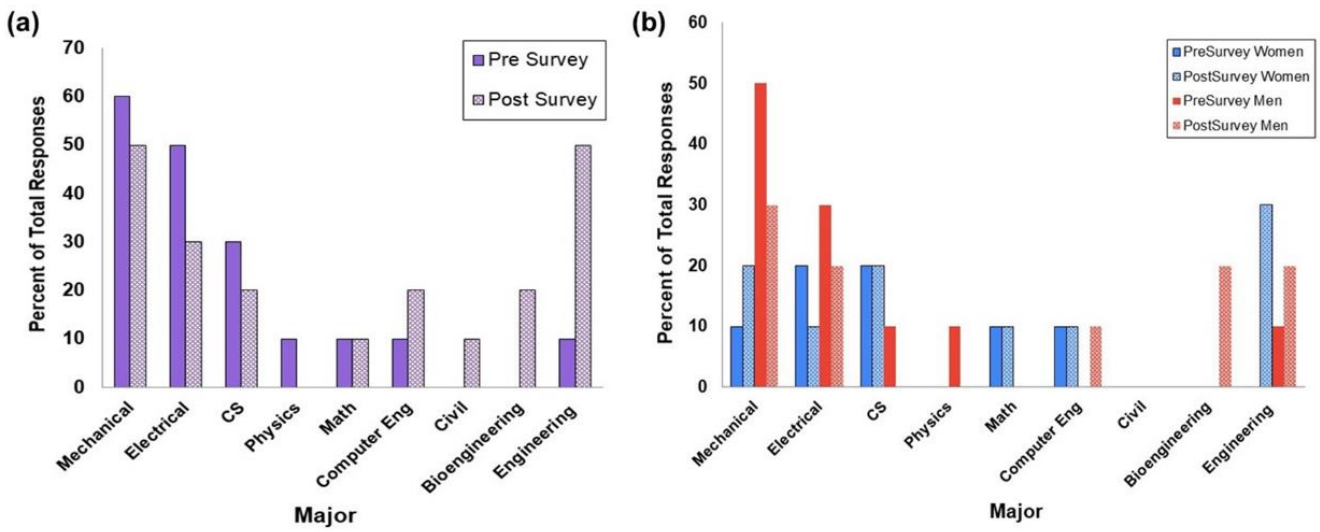


**Figure 2.** Responses to open ended question regarding college major required to work in the field of robotics reported (a) overall, all genders combined, and (b) responses divided by gender.

*Subject related identities and engineering agency beliefs* We also used the validated measures described above to understand students subject related identities and engineering agency beliefs. Although this pilot consisted of a small sample size ($n$ = 10), we were able to make judgements about the format of the survey given the short duration of the curriculum (four days). Figure 3 shows changes in these measures pre- and post- implementation.

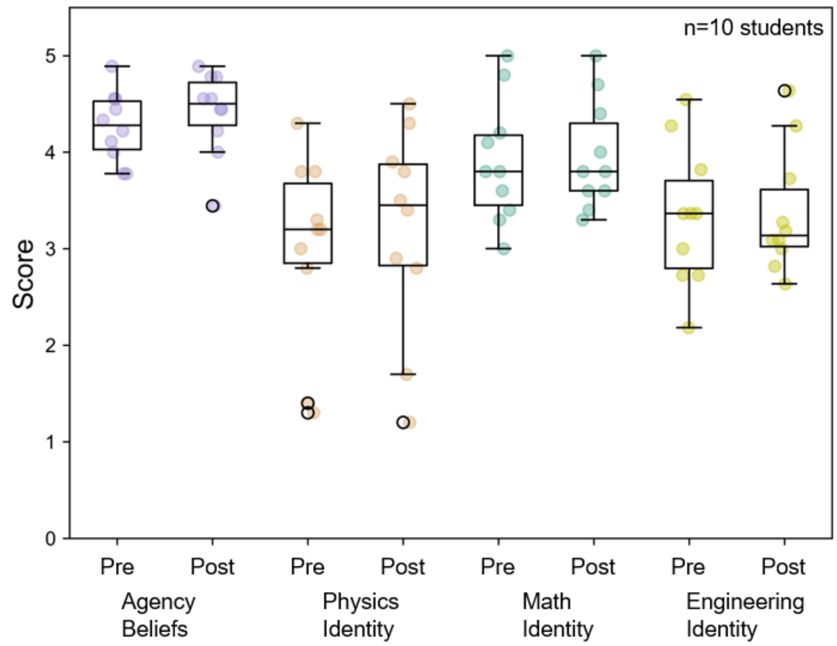


**Figure 3.** Pilot data collected on day 1 and day 4 of a soft robotics implementation (n=10 students).

**Reflections on Pilot Study, Changes**

*Implementation* Student participants were focused and engaged in the activities. We received feedback on the survey in a prompt asking, "Is there anything else you'd like to tell us?". One student commented, *"I really enjoyed all of the activities from the week. They were very engaging and informative."* Another student noted the desire for similar activities at their school, saying, *"I really enjoyed the class, we really need something like this at [school name]."* In addition to students generally being interested in the activities, we wanted to ensure that students could be successful in completing the activities in short (40-minute working plus 10-minute cleaning up and transitioning) class periods. In the pilot used a heat-sealable fabric-based activity in which students create a pneumatic wrist brace (Activity adapted from Soft Robotics Toolkit Resources for Educators). This activity was accompanied by discussion of textile-based wearable robots. While students generally appreciated the varied materials and accessible supplies (irons), very few students were successful in fabricating an air-tight design and none were successful on their first attempt. Students were resourceful, using duct tape to repair their designs (Figure 4) however, we decided to explore alternative textile-based designs for the next study. In future implementations, students will build a McKibbens muscle actuator. We also plan to pilot this activity with a class before the next implementation, but generally with undergraduates new to the field, students can complete the McKibbens activity in ~20 minutes with a very high success rate.

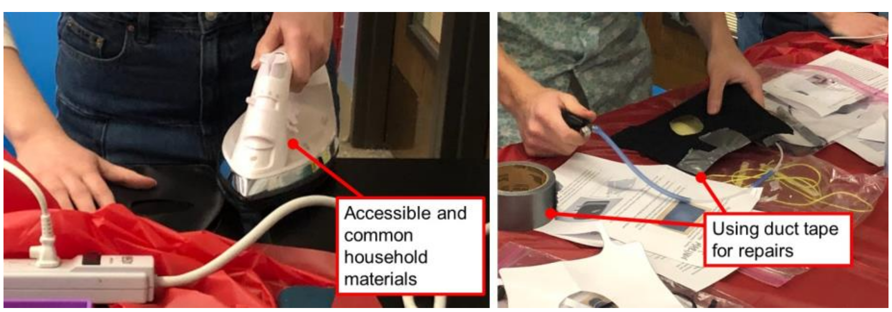


**Figure 4.** Images show students building the pneumatic wrist brace design using common household materials (left) and repairing leaky designs with duct tape (right).

*Retrospective Survey* Based on pilot results and in consultation with project advisory board members, we plan to explore the use of a retrospective survey in the next phase of this work. A retrospective test is administered at the end of an implementation and asks participants to reflect on psychological factors and report their current perceptions for each measure [22]. In this case, after the soft robotics implementation, students will be asked to report perceptions for the measures reported above (engineering agency beliefs, physics, math and engineering identity, Figure 3) "after" finishing the soft robotics curriculum. Next, they will be asked to report their perceptions for the same measures "before" starting the soft robotics curriculum. The difference between present (after) and retrospective (before) responses can be used to calculate gain scores for each measure. Retrospective tests account for response-shift bias [22] or the Dunning-Kruger effect [23] that might exist after participation in the soft robotics curriculum in which participants overestimate their initial perceptions, which are then adjusted after exposure to the topic [24]. This may be a possible explanation for the decrease in average engineering identity survey responses in our pre- post- design. When compared to "physics identity" and "math identity", which students have an exposure to in their high school setting, engineering is not a course offered at this school. This lack of exposure may lead to overestimation of skills or interest in the pre-survey design. Altogether the small sample size limits the conclusions that can be drawn about survey measures from this pilot. A limitation of the retrospective approach is that the "before" self-reported perceptions in a retrospective test are influenced by the participants' experience with the curriculum and results may not match a traditional pre-survey response. However, Drennan and Hyde report these relative perception reports are "a better indicator of change" [25] and may be more significant when evaluating the soft robot design experience that is completely new to students. Additionally, this retrospective design has been used before in a similar context, allowing for comparison to previously published results [17].

## Conclusions

The pilot study presented here was designed to test our planned study protocol and procedures. Adapting research to an outreach setting presents challenges with student success and timing. Based upon this survey we decided to revise one textile-based actuator activity. Overall, we received positive feedback from students about the activities and anticipate success in a large-scale implementation. As discussed, based on pilot implementation, we will design a retrospective survey for quantitative data collection in the next phase of the project that will also be supported with qualitative data collection. Pilot work shows that a soft robotics curriculum can shift student perceptions about who can do engineering, majors used to enter the field and expose students to new applications of engineering.

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