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Increasing Engineering Literacy among Non-Engineering Students

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Increasing Engineering Literacy among Non-engineering Students

Definitions of engineering literacy, as a concept, revolve around abilities and awarenesses those who are engineering literate have. From the National Assessment Governing Board (NAGB), engineering literacy is "the ability to solve problems and accomplish goals by applying the engineering design process."[1] Or, from John Heywood, it "requires that we understand how individual's [sic], organizations and society interact with technology, and this requires an appreciation of the values we bring to that understanding."[2] These definitions work together to provide a fuller notion of engineering literacy, as recognizing the fact of it as well as why it is necessary give us reason and means to becoming engineering literate.

Adapting from definitions of technological literacy, from Gramire and Pearson, engineering literacy is, at its core, a broad appreciation of what engineering is.[3] Though not an exhaustive comprehension, engineering literacy develops citizens through their participation in a culture and society that depends on engineering projects. Engineering literate persons function fully within such a society, participating in engineering projects not only insofar as engineering training is required, but also in recognition of the broader social impact of those projects.

In previous work in engineering literacy, we identified four major factors as significant in self-assessments of engineering literacy: Basic knowledge of engineers and engineering, Impacts of engineering on human life, Thinking and acting like an engineer, and Basic skills in the use of technology.[4] We used these factors to develop a survey that has measured students' perceptions of their own engineering literacy.

Our 2015 study in engineering literacy revealed that student perceptions of their own knowledge, skills, and perceptions of the impact of engineers and ways of thinking and acting, were relatively stable across dimensions of gender, ethnicity, degree progress, and curricular focus.[4] The survey used for the study resulted in several conclusions, which acknowledged little to no meaningful differences across these dimensions. The most significant conclusion drawn, though, was this absence of meaningful difference between students in engineering courses of study and students in non-engineering programs.

Despite these small differences, we believed that conversations with individual students could yield deeper insights into how students perceive their engineering literacy. We expanded our research through observing a course aimed, in part, at introducing and increasing students' information literacy, as well as interviewing the students in that course.

The rationale for engaging in a qualitative study was simple: though surveys reveal general trends and paint broad pictures with regards to a particular set of questions, interviews could provide more detail as to experiences and thought processes of individuals.

Aim of Study

The aim of this study, then, was to clarify how undergraduate students' engineering literacy developed over the course of a semester-long class called *Citizen Engineering*. While we

hoped to see improvements—an increase in student engineering literacy—we also understood that student perceptions of their own literacy would generally skew to higher levels. This was evident in the 2015 study, with most results rating at 4.5 or higher (on a scale of 6), and none rating below 3.[4]

With interviews, we allowed students to explain their own perceptions of their engineering literacy. We focused on several aspects that would measure how their literacy changed, namely, in what they anticipated when they enrolled in the course and how the course met their expectations. Through these questions—how they saw their own changes—we could approach something that might become a schema for improving engineering literacy through a classroom setting.

More, though, we wanted to see how students identified the importance of engineering literacy in their own lives. We asked about connections the class made between their broader academic experiences, their previous encounters with engineers and engineering, and their lives outside academia. We also inquired as to what these students thought were the central elements of engineering literacy, to get to some idea as to how an engineering literacy class might be better shaped for future course offerings.

Interview Format

The format of the interview was simple. A graduate research assistant arranged to meet with the students in the class, who had been given consent forms in advance. Meeting in a public, yet quiet, space at the university, the research assistant asked six primary questions, with room within the questions for additional, probing questions, with the given time frame between thirty minutes and one hour.

The questions asked were deliberately broad questions, allowing the interviewer to utilize the responses to formulate additional, probing questions. The core questions were as follows:

- Tell me why you enrolled in this course. What did you anticipate learning?
- How did you envision it connecting with your major, and with your general education?
- How have you found this course meeting those expectations?
- Describe your experiences with engineering before this course.
- How has your engineering literacy changed through this semester, especially regarding engineering knowledge, attitude, and abilities?
- How do you see engineering as a component of your life outside of academic circles?

We acknowledge that these questions have an inherent bias in them, focusing the respondent's attention to engineering literacy, and assuming the prominent place of engineering literacy in the students' academic lives. We also made every intention to distance these interviews from success in the course, with the research assistant being present in the course, though without any responsibility or influence over grading student assignments. These attempts were due diligence, an endeavor to minimize bias in student responses. Regardless of these efforts, students still saw the research assistant in the class, and the distance between interview and course success may not have been as clearly delineated in how they perceived the interviews.

Demographics

The interviews occurred over the course of three days. Of the six students enrolled in the class, five responded to the request for interviews. Despite the low number of students, the high percentage of response was encouraging. Certainly, the sample size left much to be desired. With a small sample size, it is difficult to extrapolate any far-reaching conclusions as to the benefits of a course such as this. However, this interview size allowed us to project *potential* benefits of the course, giving us ample ideas as to components of the course that ought to be changed, what students found beneficial in the course, and how they developed as students and as persons as a result of the course. Some might see this as little more than an extended course evaluation or final exam, and to some extent, this is true. But unlike a course evaluation or exam, the students were able to open up to lines of questions that could extract a wider variety of deeper self-analysis that a written evaluation or examination cannot.

All students were enrolled in the course *Citizen Engineering*. The course was an introduction to engineering for non-engineers, through practice, design thinking, analysis, and community engagement. Though limited to non-engineering majors, five of the students intended to enter engineering fields—three once they formally declare a major, and two once they enter graduate studies. Students in the course had some prior knowledge of engineering, in large part due to their enrollment at a university with a large engineering program. Many of them had classmates who were majoring in engineering, if they had not taken an engineering class themselves. They all had clear ideas as to what engineers are and do, sometimes delving into stereotypes. No engineering knowledge—understandings of engineering concepts or applications—was necessary to enrolling in the course, nor was it directly addressed in the course. Instead, the course explored the question "What could citizen engineering be?"—relating engineering to its broader impacts in the lives of citizens.

The demographics of the interviewed students revealed some variety, though not as wide a variety as is present university-wide. Two students were first-year students, both intending to major in engineering fields. (Note: These students enrolled as students in "University Studies," the catch-all major for those who have not formally declared a major course of study.) Three students were in their final, senior year, with one each majoring in Physics, Biology, and Mathematics and Statistics. Three of the students interviewed were male; two were female. We did not request identifying information regarding race/ethnicity.

Interview Summary

The interviews yield information that we sort broadly into three major categories: Experience in the course, Engineering literacy improvements, and Broader impact. Within these categories, we identified several similarities among the respondents, especially concerning characteristics of engineering literacy attained through the course. In summarizing the interviews, we have separated responses into the three broad categories, making some narrative that captures the breadth of the discussion had with the respondents. We have pseudonymised the respondents' names, in an effort to anonymize the students.

Experience in the Course

Interviews began with a request that the respondents describe why they initially enrolled in the course. Several, like Milburn, cited practical rationale, saying that his "advisor… pushed me toward this [course]…to, like, spark my interest more." Though an expected response, the notion that the course would spark a student's interest in engineering is encouraging for future iterations of the course, and how we can promote it to greater numbers of students.

In addition to the practical considerations for enrolling in such a course, students responded to the question with ideas and perspectives they hoped to learn through the course of the semester. Marley, who identified his novice status with "I did come in here pretty green," hoped that the course would provide a "new perspective on citizen engineering." Kameron "thought this class, like, I could probably apply some of my math skills in here, cause it is an engineering class." Reness thought she would be able to transfer some of the ideas and literacies more broadly, not limited to engineering: "I think that engineering literacy would definitely translate to scientific literacy in some instances. And like an appreciation on why research on things is important for people as well."

More broadly, some students saw the "Citizen" part of *Citizen Engineering* as an important component of their expectations in the course. Reness "wanted to be an informed citizen," looking at the intersections of engineers, engineering projects, and the broader society where those projects exist. Related, Rowena "wanted to understand a little bit more about the way they [engineers] think." By understanding how they think, she explained, we can better comprehend, as Marley also said, "how to use engineering to solve social problems."

When asked about how the course met their expectations, the students responded with a great deal of focus on how *Citizen Engineering* helped expand notions of engineering to include non-engineers' stakes in engineering projects. Marley was clear about this: "Learning about engineering, citizen engineering, will allow me to go into general engineering subjects with more of a mind toward citizens, not engineers and non experts. More of a willingness to cooperate with them directly on any local projects that directly affect them." Similarly, Kameron noted how the course was different from his expectations: "Pretty much my expectation for it, some baseline for engineering and like different engineering projects, participating in engineering projects… It was more like in citizens, rather than an individual perspective it's like the global and local perspectives, like the class developed into, like, case studies where the citizens actually were involved in engineering projects"

Students were appreciative of the variety of voices, and kinds of voices, presented through the course; one student simply said, "knowing different people's perspectives is really important." Others were surprised by the focus on different perspectives, as Marley said, "It changed my view as I said earlier even about like the moral aspect and the ethical aspect because I didn't really think it [engineering] was just about designing and building stuff, but that was what I kind of anticipated as like the main part." Design and construction, for Marley, were not the main part of engineering; rather, the moral and ethical considerations that accompany design and construction were a primary concern of engineering. Additionally, Reness saw that *Citizen Engineering* "exceeded my expectations on just learning about kind of, like, world issues."

The role of non-engineers in engineering projects was prominent in student responses. Milburn acknowledged their contribution to engineering literacy: "The impact of the general

public, on like, what they view and what they do about engineering, like, projects kind of. And also how people break [engineering] down." By including the broader public in their remarks, students demonstrated a broader, or perhaps a broadened, view of engineering. The course, Marley said, "taught me that maybe a local citizenry is someone who I should talk to more." Engineers are a part of the local citizenry, and also work in citizen action groups. Milburn added to this, "But it was them trying to fight up against a larger company that they believed was doing something that wasn't right for the community and right for the environment." Demonstrating an awareness of the multifaceted lives of engineers—that they work on engineering project but also live in communities—reveals students' divergent thinking and awarenesses gained through the course.

Two students in particular expressed application of what they learned through the class to their broader, future academic aspirations. Rowena said that she learned a great deal about the "iterative problem solving system," and Reness identified "learning about different peoples and their needs" as "a valuable skill for a science or engineering if you're doing a goal, product-oriented kind of task." In both cases, this application involved using their engineering literacy in other fields and other areas of their lives. It should also here be noted that both these students intend to apply to graduate programs in engineering after their undergraduate degrees.

What, exactly, had these students' experiences with engineers been? By developing some baseline for what an engineer is, and what students' interactions with engineers and engineering has been, we can extrapolate some ideas for implementing engineering literacy into a curriculum.

Common understandings of engineers and engineering often begin with stereotypes.[5,6] Students, when asked about their experiences with engineers and engineering, brought several stereotypes as their basis for examining those experiences. Rowena said, "I experienced a lot of that kind of like those stereotypical culture things about engineering, like, We have the hardest major,' or 'We're not social, and therefore, we're better than the other majors.'" She went on to describe an experience she had during an internship where she worked alongside engineers in a collaborative project that studied environmental engineering and nanoscience. She described the "collaboration with older, higher-up academic" as a "real...structured interaction," compared to "the beforehand social was again, kind of, just that stereotypical culture exposure."

Reness provided a lengthy discussion of what engineers are, and it is worth reproducing in full here due to its richness:

> I was almost an engineer, considering at one point. And I took an engineering course that professional development seminar for engineers. So that was, a lot of lectures by engineering professors, different disciplines, we had to do like a 'what is engineering to us' project and like presentation. And a little bit about the engineering design process, as well as we had to um, write a few like, learn how to write a cover letter, learn how to update your resume. It was very focused on how to be a working engineer, a well informed and working engineer, as opposed to, a creative one? Um, (laughs) it was, and I mean, writing your resume, there is a way to do it. Like, they always say, you want some sort of personality, but as soon as you put something like, a color on it... (laughs)

> So there's creativity within the lines? Um, one professor gave a presentation comparing scientists and engineers. And one of the clear differences was hairstyles. Um, (laughs) the scientists tend to have really unkempt hair, all over the place.
>
> I think that was a joke, among them as well, saying like, this is clearly, this is the engineer we want to be, we want to be the successful person, the like, not crazy out there, um, inventor.

The lines between work and creativity were seen as the same lines that exist between engineer/ing and non-engineer/ing, and between professional and unprofessional, and between success and failure. Her narrative tells the same story as the stereotypes, wherein engineers look at themselves and at their own work more seriously than they do others. Furthermore, these were perceptions of engineers that engineers themselves were promoting, thus reinforcing, to some extent, stereotypes.

Students also talked about what engineers are. As a reaction to many of the readings, they offered critiques of engineers and engineering, especially regarding how they differed from expectations. Rowena said, "It's [engineering's] not de-politicized; it's not apolitical." Recognizing that engineering encounters politics at every level was an important component of the course, as it demonstrated a broader understanding of engineering literacy. Marley was surprised with the lack of political engagement that engineers thought they had, that engineers believed themselves to be exclusively project-oriented. They were "less concerned with the community than I initially expected."

The actions of engineers, or what engineers do, was also a strong component of students' previous experiences with engineers. Milburn aligned himself with engineers, especially how engineers "critically think and how they think about problems was kind of, the general way I approach things." Rowena saw the actions of engineers as expanding beyond "math and problems you solve," acknowledging that the course exposed her to "more opportunities than I thought in engineering." However, Marley's description of engineering was simple: "Build it in a way that won't negatively impact that community." This is not an indictment against engineers, but a simple expectation of what engineers do, or what they *ought* to do.

Normative ideals of engineers and engineering include the "ought-to"s of the practice. In their descriptions of what engineers are, and their previous encounters with engineers and engineering, students had a specific normative vision as to what engineers ought to be and do. Milburn said, "They [Engineers] have a moral obligation to try and help out the general public," a sentiment echoed by Rowena, who said that engineers have some responsibility to evaluate "how we can make this better." She also called for engineers to expand their design considerations into "engaging with politics, like voting, local politicians, that sort of thing." Or, as Marley said, "Engineers should also be more considerate of um the local communities that they're building in and perhaps consider their [communities'] needs over the employer even in some cases."

Engineering Literacy Improvements

Though upon enrollment into the course students were not asked about their engineering literacy, they were interviewed as to their perception of how their literacy had improved. Students were given this working definition of engineering literacy, for discussion of their perception of their own engineering literacy: "First, the ability to discuss, critique, and make decisions about national, local, and personal issues that involve engineering solutions; to understand and explain how basic societal needs--such as, water, food, and energy--are processed, produced, and transported; and to solve basic problems faced in everyday life by employing concepts and models of science, technology, and mathematics. Or, more succinctly, the ability to solve problems and accomplish goals by applying the engineering design process." Milburn acknowledged his lack of engineering literacy, at least at this academic level: "I'd say coming in I really didn't have any of them [engineering literacy, knowledge, attitude, or abilities]." Others saw their literacy expand, especially in notions of engineering literacy, and of what goes into the design process in particular. Kameron said, "Pretty much for every single hard fact in society, like, there is some kind of process involved in it. Like, building a chair for example, I'm pretty sure there's some sort of elaborate design behind it, like where they try to figure out different sizes of the chair, what an average person's like structure is. So I think that like design is pretty much involved in every aspect of society where, when it comes to product and stuff like that."

The design process was the piece of knowledge that many students identified as the greatest source of improvement in engineering literacy. Reness identified assent from institutions as a component of design where her knowledge improved: "Government approval or institutional approval, something where you have a supervisor who has to check off that it's good, and they give it to their supervisor, and then it gets integrated into something larger." Similarly, Marley looked at the community impact as a new component, for him, of the design process: "consideration of the concerns of local communities as well as types of designs and ethics." Together, these were a part of the iterative process of design, which takes longer and goes through many steps before the final product. A knowledge of the documentation and methods of engineering was likewise new to Reness, who said, "I guess the informal engineering process would probably be a smaller scale, for people who aren't trained, going through iterations. And I guess, with the internet, that kind of stuff's becoming more well documented, because there's a lot of sites, like, instructables that people put up step-by-step instructions for how they build things, and they update them, saying, you know, we tried this again and it worked better if you do this."

The role of the community and nuance to science and engineering were similarly new pieces of knowledge to students in the course. The complementary roles of the engineer in a community and of the community in engineering were important for Rowena: "I feel like I learned more about these community engagement, like…that's actually something I really care about, and will probably be involved with, as a citizen." Likewise complicating the quality of research, and understanding the ideas of constructed knowledge, was a component of the course that stood out to Rowena: "I thought the [idea that] good science could also be bad science, was very enlightening, because it's something where, like I want to believe in science, it's like no, this is right, it's proven, maybe, in this study, something is proven, but the like conventional wisdom that comes from it isn't necessarily true." Knowledge of the complications presented by scientific and engineering research, and that engineers exist within a system, were of critical importance for these students' engineering literacy.

Additionally, a knowledge of how engineering and the design process work were key for engineering literacy. Primarily, students found improvement in their understanding of how engineering itself works. Rowena said, "I needed to understand how components work and how that might affect me." She also cited the broader components of the engineering design process, especially creativity: "imagination is needed in kind of the early stages, to think about what are the possibilities, what is maybe some grand like end goal that we want to get to." Concluding that "more experience leads to a better intuition about design," she identified iterations and improving engineering as central components of the design process, and of her engineering literacy.

Reness saw that her "knowledge and attitude, or like, my shift in them have kind of gone hand and hand." Knowledge about what engineers are and do, and the broadened nature of engineering projects developed the change in attitude toward engineers and engineering. Students found that their attitudes toward engineers, especially in identifying their role in society, changed their expectations of engineers and engineering projects. Milburn said, "I feel like my attitude has changed towards it because I look at it, I look at like engineering problems somewhat in the same way that engineers do now, because I look at it very methodical point of view, how, like, there's a process you need to work through to get to something, you can't just start something and expect it to be done quickly and think it's actually going to work. There's a process to like designing it and then multiple iterations to see which one comes out being the strongest and then finally making like an ending product that could be mass produced or making an ending product that could last for a long time and like be beneficial." Seeing the often circuitous route of an engineering project encouraged him to look at engineers differently, as people who at times faced restrictions.

In addition to attitudes that appreciate the breadth of engineers and engineering projects, students also recognized the engineers who promoted their communities above others. "I think knowing what you have to say and you have to believe in order to write those pieces, um, is very important, you can't cite people, like, the public, you can't just say, 'This is important because in my community where I grew up;' you have to, you have to define it as an important global societal problem. Because that's where your funding comes from. But also so it applies to the greater scientific and engineering community." Part of this recognition came through an appreciation for knowledge that was not common knowledge, but that took years of research and education to attain. Reness said, "Not everybody knows science or engineering, they can't understand it unless they're in that very specific field, they just read the introduction and conclusions. Unless they really really want to know the details of your paper, because that's, the beginning and end are what they say so that everyone can understand in their field. That's their outreach goal."

Mostly, students embraced the idea that engineers are people, too. Their engineering literacy increased, in their attitudes toward engineers, through a positivity toward engineers and engineering projects. Those who work on the projects have other responsibilities and pressures that a lot of people cannot see. Rowena said, "I feel like this class has given me an actual experience, with engineering. I mean, working with engineering, with engineers, was an experience. But this kind of like, interface, was, it definitely, I have a more positive attitude since the class, and I can understand how why engineers sometimes get pigeonholed as one thing, or how engineers might be responsible for things that weren't so great, or what happens when,

yeah, when design fails, or if it's political against like a people group or something, I definitely understand how that happens. And it's not because the engineers are socially inept and evil. So I definitely have a more positive and open attitude towards working with engineers."

The most significant aspect of engineering literacy was the confidence that goes hand-in-hand with any sort of literacy. An important component of literacy, confidence in a given subject or ability improves the ways that person approaches, in this case, engineering, and wants to learn more.[6] Kameron saw, as a result of the course, "I'm definitely more confident about reading engineering literature." Reading engineering studies and having some improved understandings of engineering made Marley "a little more confidence and know more about it than I did before." Milburn saw his confidence similarly changed, looking at engineering more deeply—not just applied mathematics, but something that touches all aspects of humanity: "I guess like my confidence is somewhat altered, because the way I look at things is more in-depth, so I have more confidence in what I say instead of like saying something that has no backing or saying something that I really don't have much knowledge about. Like if I actually look at it from the point of view of like an engineer looking at it, the way we've been looking at it this semester, I have more background knowledge to like back up my argument."

Other students saw that the course made them more confident in their abilities to understand larger projects. Reness said, "My confidence in being able to like understand a more comprehensive view of projects has increased." Furthermore, she expressed a confidence to work within the existing system, with its reliance on engineering: "Outside of my academics, engineering is just like a part of life that you have to try to understand in order to work well within the system." Rowena saw her confidence increase with her ability to ask good, clarifying questions, making her a better citizen: "I think before I felt like, I couldn't interface because I wasn't super familiar with all the engineering things. But going to the [Mountain Valley] pipeline meetings and saying, wait, I don't know what you're talking about, and just having someone explain the vocabulary they're using, I feel like I become more able at realizing what I don't know and how to figure out how to learn that. In order to act with engineers, not necessarily maybe act as an engineer." And most importantly for her, the confidence is prodding her to go out and engage with engineering projects as a citizen. "I'm thinking about the big engineering projects that affect me as an actual citizen."

Expanding engineering literacy

Students gave ideas as to what elements of engineering are necessary for literacy. Most broadly, Milburn said, "they need to have more common knowledge." Though he did not expand on the composition of "common knowledge," Marley clarified at his interview: "not the mathematics of it, but the principles of it." A more nuanced approach appeared from Kameron: "It kind of depends on their background. If they're more from like a STEM field they'll be more inclined to, well I won't say more inclined but they'll have a better chance of working in engineering whereas a non engineer is not in the STEM fields so it'd probably like go to like different community meetings and try to get the overall gist of what's happening and then they would try to like use their skills which for I guess like one of the teams right now they were try to like, I don't know, I just overheard this but they were trying to make a poster, like the other 4 people. So like that could be like for somebody who's like aesthetically like a better person who make arts and crafts to like contribute to engineering better by raising awareness of like different

projects and stuff like that." Background, for Kameron, was limited to education and abilities, and how that background already tied into engineering literacy. For the students, the clearest aspect of engineering literacy was the acquisition of knowledge. Marley said, "They still need to acquire at least a basic engineering knowledge. If not that, then they at least need to find out how local engineering issues affect them."

In addition to the *what* of engineering literacy, students offered ideas as to *why* non-engineers needed to be engineering literate. The most prominent response relied on political engagement. Milburn said, "I feel like just engineering projects are going to always come up in conversation in the future, especially cause even wants this like everyone wants the future to change, everyone wants stuff to kind of accelerate and become newer and more advanced and expand." Reness was more practical with her response, identifying, "to be an informed citizen for voting" as the most salient rationale for engineering literacy. Combining the ideas, Marley discussed economic practicality, saying, "It's just a way more and more of the economy and more and more of daily life just becomes involved with advanced technology. Engineering is just sort of becoming a bigger part of it. So, not I'm not sure engineering is at the point where it's essential in day to day life. But it's certainly getting there."

Most clearly, engineering literacy provides the skills to engage with engineering projects. It gives the confidence to interact with engineering literature and manuals, and to converse with engineers and others engaged with engineering projects. Reness said, "You need to be able to have the research skills to learn whatever you encounter." This idea, of finding the necessary material, combines the ability to do research with the confidence to understand that information, to develop new knowledge. But all this begins with a knowledge of what questions to ask, who to look for. Rowena identified this very notion: "So how can I find an expert, um, who can educate me, how can I, what, what needs to be done that maybe isn't being done effectively by engineers?" By asking good questions, engineering literacy improves.

Conclusions

The interviews resulted in three broad conclusions:

First, exposure to engineering concepts, such as the design process, illuminated much of engineering literacy to them. While knowledge of particulars principles and concepts in engineering were not critical to the course, students emerged from the course able to identify concepts such as design as central components of engineering.

Second, students found the course helpful in connecting engineering with their broader lives, both within and outside of academia. Though the students came from STEM fields, and were already somewhat linked to engineering concepts, this course strengthened the connections between engineering and their major fields of study, as well as with their broader lives as citizens.

Third, and perhaps most revealing, is that the students found their engineering literacy to increase most significantly in their confidence in approaching engineering topics. The confidence in their ability to converse, to comprehend, and to understand all manner of engineering topics.

This conclusion furthers links between confidence and literacy,[6] and it is encouraging that students who enrolled in the course were able to further their own literacy and become better citizens.

[1] National Assessment Governing Board (NAGB). (2010). *Technology and Engineering Literacy Framework for the 2014 National Assessment of Educational Progress (NAEP).* Washington, DC: NAGB. http://www.nagb.org/publications/frameworks/technology/2014-technology-framework/toc.html

[2] Heywood, John. "Engineering literacy: A component of Liberal Education." In *American Society for Engineering Education*. American Society for Engineering Education, 2010.

[3] Garmire, E. M., Pearson, G., & National Academy of Engineering. (2006). *Tech Tally: Approaches to Assessing Technological Literacy*. Washington, DC: National Academies Press.

[4] Grunert, J., & Doolittle, P., & Adams, S. G. (2015, June), *Reaching Out to the Masses: Building Literacy About Engineering Amongst Non-engineering Students* Paper presented at 2015 ASEE Annual Conference and Exposition, Seattle, Washington. 10.18260/p.24641

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[6] Bandura, Albert. (1977). "Self-efficacy: Toward a unifying theory of behavioral change." *Psychological Review*, Vol 84(2), Mar 1977, 191-215.

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For more on content of the course, see Riley, D., Grunert, J., Jalali, Y., Adams, S.G., and Doolittle, P. (2016). Citizen Engineering: Disrupting Expertise in Classroom and Community. *ASEE Annual Conference Proceedings*, New Orleans, LA, June 26-29.

Appendix: Semi-structured interview

Tell me why you enrolled in this course. What did you anticipate learning?

probe: Ask the interviewee to expand beyond classroom learning.

How did you envision it connecting with your major, and with your general education?

probe: Ask how the field might benefit from engineering knowledge.

How have you found this course meeting those expectations?

(Interviewee will need additional affirmation that responses will not impact grade)

probe: How could the course have improved to meet those expectations?

Describe your experiences with engineering before this course.

probe: Remind interviewee that talking with engineering majors about their major is an experience with engineering.

How has your engineering literacy changed through this semester, especially regarding engineering knowledge, attitude, and abilities?

probe: Negative change is okay

How do you see engineering as a component of your life outside of academic circles?

prompt: How to you plan to use what you've learned in this class later? What area(s) of life does/might it appear?