Social Context

Our project reviews the history of engineering education and engineering education reform in order to understand the systematic principles and changes throughout time that affect how engineers and engineering education works today. We analyse the history of engineering on both a national level and specifically at Lafayette. Our research then focused on a contemporary scope of engineering: a look into engineering culture. In this report, we describe engineering culture as the dynamic between community-centered work and engineers. We analysed engineering culture in both a national scope and Lafayette-specific scope, and concluded that Lafayette, albeit a liberal arts institution, represents a microcosm of overarching national norms. Lastly, this context explains why our team believes that the implementation of a 200-level community-centric engineering course at Lafayette College will lead to both inwardly-focusing and outwardly-focusing economic benefits to future engineers and the communities they design for and with. A well established, community-centric, non-technical skill set will increase students' professional marketability, helpfulness to community, efficiency, and social impact.

Historical Scope

National History

The Cold War marked a turning point for engineering in the Western world, and more specifically, a turning point in engineering reform in the United States. Before the 1960's, engineers were active members of the community, helping solve societal problems. However, at the peak of the Cold War, engineers lost the trust of society and the American public. Engineers became the key component of government projects, leaving behind their old identity as community members. Society emphasized the need for engineers and "by 1960, engineering was the most common occupation for white-collar males in the United States" (Wisnioski, 2016, 23). The speed in which technology progressed and the increase in demand for engineers made the humanistic and non-technical aspects of engineering fall behind a heightened priority for technological advancements. The workforce and educational focuses in the 1960s illustrated this switch; at this time, the Cold War influenced many schools' curricula. Many programs offered classes that revolved around weaponry and industrial military production. Classes that involved technology and engineering practices that impacted the common person in society did not exist (Wisnioski, 2016, 24).

In the 1960's, engineering education focused on the technical outcomes and neglected the importance of the socio-technical aspects of engineering. This lead to a disconnect between engineers and society because engineers had a lack of understanding of their larger social and cultural impact on society. This lack of trust in the engineering profession led many intellectuals to challenge the approach of engineering education. Many of these philosophers aimed to take control of the technologies that were developing without consideration of impacted communities by taking away the autonomy of technology. This was done by investing in a more collaborative and holistic engineering education after the Cold War. Both professional and educational reforms reflect the notion that "during the 1980s, engineering as a discipline began to recognize the importance of sustainable and community-driven practices" (Vanderburg, 1991; Gilbert et. al, 2015, 257). Specifically, UCLA, Caltech, Harvey Mudd, and MIT aimed to make engineering more holistically minded and to train well-rounded engineers (Wisnioski, 2016, 170-179). This educational reform continued into the 1990s with a “surge in interest and action related to sustainable community development in engineering”(Lucena, Schneider, & Leydens, 2010; Gilbert et. al, 2015, 257). This report will discuss how this reform continues nationally, and within Lafayette’s borders.

Lafayette History

Lafayette’s engineering department’s mindset aligned chronologically with engineering education reforms occurring throughout the country. For instance, a 1969 editorial in *The Lafayette*, “Priorities,” detailed some of the changes that the Lafayette community wanted to see. The authors, representatives of the student body, found that the College continued to “exhibit many of the disadvantages and few of the advantages of a small college” (Wilmer & Rehrig, 1969, 6). The editorial outlined a list of priorities that the College needed to change in order to become a more competitive institution. The second priority stated that the entirety of the engineering department and curriculum needed to be re-evaluated because Lafayette could not compete with larger universities which had excelling engineering programs (Wilmer & Rehrig, 1969, 6). This request fits into a historical chronology, as this aligns with a time when professional engineers demanded high quality training for engineers for militaristic, Cold War related jobs. Furthermore, the list requested a change to both the Bachelor of Arts (A.B.) and Bachelor of Science (B.S.) curricula so the requirements were more integrated and liberalized. Another component of the editorial requested an exploration of more interdisciplinary subjects (Wilmer & Rehrig, 1969, 6). Per these requests, in 1970, the Lafayette community saw the emergence of a new interdisciplinary degree, an A.B. in engineering, which is now known as Engineering Studies.

The offical push to reform the A.B. degree from the administration started in 1975 with the proposal to educate and train more interdisciplinary graduates. This curriculum change required students to meet certain outcomes from an array of courses (similar to what Lafayette's curriculum models today with social science, values, global multiculturalism, and more "outcomes"). This proposal largely pushed students pursuing A.B. degrees to strongly grasp quantitative reasoning as well as scientific inquiry. The debates surrounding this new curriculum continued through 1982, when the Lafayette community started to see a tangible emergence of interdisciplinary degrees (Cunningham, 1982, 2). These changes in curriculum made the College's focus more centered on interdisciplinary and liberal learning. Through this, degrees such as the A.B. in engineering strengthened and bridged the gap between the engineering department and a more liberal arts based curriculum.

One commentary in the 1980s stood out as specifically lucrative in uncovering Lafayette's historical outlook in engineering. One student writer for *The Lafayette* complained that Lafayette had "become a place to be trained rather than a place to be educated. Engineers [were] being taught what to think, not how to think" (Cunningham, 1981, 6). This statement represented the student body's disappointment, as this sentiment quickly led to another period of reform at Lafayette. Lafayette soon became much more liberalized with the engineering degree due to a large reform in the late 1980s (D. Veshosky, personal communication, November 10, 2018). Eventually, the program would require students to complete competencies that qualified for more liberal learning, showing the school's receptiveness to the changing era.

While Lafayette experienced reform in the 1980's, this reform does not exclude Lafayette from the overpowering engineering culture that exists today. Our project challenges Lafayette to see that once again we need a change in curriculum. Our B.S. engineers are being taught the how's of engineering instead of the why's. Asking "how" typically results in a methodological solution, rather than a solution that conveys understanding. We, as a community, need to challenge our engineers to ask "why" instead of "how" in order to result in a better understanding of the reasoning behind concepts, as well as an increased awareness of methodology. Our research guides our team in believing that the most important part of our Engineering Studies degree is our ability to understand the why's in engineering. Lafayette has contributed to this type of reform within the Engineering Studies department. The true investment into Engineering Studies began in the mid 1990's when the major began to develop more courses regarding engineering economics and engineering and public policy. This investment in a liberal engineering curriculum was directly observed around 2007 when Engineering Studies became its own department, separate from the B.S. degrees (D. Veshosky, personal communication, November 10, 2018) . Lafayette continued to invest in the department as its faculty grew five-fold in 2011 (B. Cohen, personal communication, November 8, 2018). We find ourselves in a new age of engineering reform, and Lafayette will need to continue to adapt and change like other universities in order to stay competitive as an engineering department (Wisnioski, 2016, 128-158).

Cultural Scope

The relationship between technology and culture helps us understand the perspective of engineers in academia, in the professional world, and how these engineers interact with the technologies they create. Addressing how professionals in the engineering world view and address sustainable community development (SCD) and community engaged education will help to define how our proposed curriculum can infiltrate this long standing mindset. We look at this culture on a national scale and at Lafayette College specifically.

National Culture

The historical push for mastery of technical skills in engineering is perpetuated by the established lack of willingness to learn technical skills from the non-engineer's perspective, as well as a lack of educational push for non-engineers to fill this gap (Phase, 2005). As discussed later in our report, our curriculum aims to break down this barrier so that eventually, engineers and non-engineers alike will redefine the engineer as a social agent, an intellectual, and a technological representative. Although those within the engineering community would ideally adopt this shifted mindset willingly, doubts arise surrounding this adoption because "either public or private engineering schools can find additional funds to implement new educational paradigm" (Prados, 1998, 7). This notion perpetuates the technical emphasis in engineering culture, and opens an avenue for our project to halt this perpetuation, via successful implementation of this curriculum on Lafayette's campus.

In contemporary engineering culture, there exists a common sentiment of disconnect between engineers in industry and their community. On one side, this barrier between the design process of the physical technology and its usage leaves consumers and community members on the receiving end of this technology unaware of who engineered their product and how the technological systems work, beyond the surface level (Phase, 2005). In this current mindset, technologists view their work in solely a technical context, rather than as a part of an outreaching, social, economic, and political technological system. A book about the potential for engineering education in 2020 notes that "the public is unclear about what most engineers do and secondary students (and their parents and advisors) have poorly formed ideas about what an engineering education offers and how they can serve society through engineering practice" (Phase, 2005, 4). Engineers have disassociated from their old roles as "social agents" and the public views them more to technical creators due to their lack of interaction (Gilbert, Held, Ellzey, Bailey, & Young, 2015). This shows that engineering culture pushes technology and culture apart, from both the perspective of the engineer, and the non-engineer.

While contemporary engineering culture emphasizes and exhibits successful technological productivity, this solely technical push creates setbacks in overall efficiency and productivity as well. On top of the general sense of disconnect, this lack of efficiency manifests in multiple ways: engineering project outcomes, professional engineering settings, and engineering education. In terms of project outcomes, a typical setback of the separation of engineers and the communities they work for is simply that they work for, and not with, these communities (Lucena et. al, 2010). One study found that "often the language used by engineers reinforces the inherent power differential between the developers themselves and communities being served," therefore illustrating a manifestation of the barrier discussed above (Gilbert et. al, 2015, 5). Because "community participation in development projects is an element that is largely lacking in the engineering educational arena," once graduated engineers enter the workforce, they lack explicit training in community engagement skills, and rely predominantly on just their technical backgrounds (Gilbert et. al, 2015, 4). The technical skills that engineers have could gain legitimacy, efficiency, and influence if they were incorporated with the skills needed for proper community evaluation, communication, and an ultimate ability to listen and work alongside a community (Gilbert et. al, 2015).

Contemporary engineering culture aligns with Western capitalistic outlooks in that "small-scale technology has never been attractive to the engineering profession, despite the need for it at the international level. Appropriate technology has been mostly promoted by NGOs and non-engineers" (Amadei, 2010, 86). This lack of excitement and emphasis on community engagement as an attractive and necessary component of the 21st century engineer's job, leads to an ultimate lack of "endorse[ment] by the mainstream engineering profession and is rarely integrated in engineering education" (Amadei, 2010, 86). In order to change this trend, engineering education needs to shift in educating a new wave of socially aware, willing, enthusiastic, and adequately trained engineers, ready to work alongside the communities in which they design for (Amadei, 2010).

One of the specific disconnects in engineering education manifests in the longevity and follow through in community-based products. While Sustainable Community Development (SCD) projects exist, the traditional Engineering Problem Solving (EPS) educational strategy does not emphasize the non-technical skill set necessary to successfully implement SCD projects all the time (Lucena et. al, 2010). Nieusma and Riley (2010) evaluate the effectiveness, or lack thereof, of engineers in sustainable community engagement while considering the current state of engineering culture. They conclude that traditional engineering culture and education leads to an emphasis on "product over process" (p. 36). By valuing product over the process, the community's needs and existing capabilities often falls back to the engineer's technical, solution based, focus (Lucena et. al, 2010).

The book, *Engineering and Sustainable Community Development (ESCD)* presents several case studies that demonstrate the failures of community development projects due to this lack of focus on process. An example of this describes an engineering firm that was funded to implement a water supply and sanitation system, in an underdeveloped village. The engineers implemented the sanitation system and left under the impression that they made a lasting impact on the sanitation of the community through their design. However, five years after the engineers implemented the systems, only 30% of sanitation units were still in operation. Furthermore, only 12% of these units were still in operation after fifteen years. Even though these engineers believed they made a positive impact on the community, when looking long term, these engineers did not consider the need for the maintenance of the system. Their inefficiencies in working alongside the community neglected the long term sustainable solutions that this community needed (Lucena et. al, 2010).

This short case study reveals how the engineers overlooked community needs. The engineers in this case took a generalized approach to water sanitation solutions and immediately expected their designs to work for a specific community (Lucena et. al, 2010). There are many case studies within *ESCD* that highlight this disconnect between engineers and end-product users. Through these examples of engineering failures, *ESCD* illustrates the cultural gap in engineers' ability to understand community wants and needs.

In addition to the negative reflection of engineering culture in SCD, a cohort of literature focuses on the wants and needs of engineering professionals from graduating engineering students. The Accreditation Board for Engineering and Technology (ABET) guides engineering curriculum in providing both technical and non-technical requirements for all ABET accredited schools, however, Western engineering culture has lead to a far more thorough emphasis on the development of a technical skill set (Shuman, Besterfield-Sacre, & McGourty, 2005). The early 1990's discussions surrounding the training of engineers in undergraduate education were prevalent. These conversations noted that, in order to be fully prepared for the professional engineering world, students would need "professional skills, including the ability to work in a team environment, communicate effectively, work with customers, and manage projects; awareness of the many issues affecting any engineering project, including ethical, legal, and environmental issues; and the ability to work with people from many different backgrounds and in many social settings" (Coyle, 2006, 1). A community-centric education in engineering addresses all of these current disregarded and undervalued skill sets. Community-centric education decreases the gap between engineers and their technologies, and society, therefore breaking from "traditional engineering labor pattern(s)" (Wisnioski, 2012, 27).

Nationally, the "traditional engineering method" of education utilized by professors no longer adequately "create[s] global citizen engineers who have the skills to address complex geopolitical and economic problems" and the "complex problems of our society," therefore creating a gap for the curriculum (Amadei, 2010, 86). While professional engineering dynamics and project outcomes encompass a large portion of the post Cold War changes in engineering culture, this historical shift "also produced a major shift in engineering faculty culture away from its traditional roots in professional practice toward academic science perspective" (Prados, 1998). We aim to break from this trajectory by teaching students that a shift exists and how to mitigate the effects.

Lafayette Culture

Our team investigated the specific expressions of Western engineering culture through outreach directed towards Lafayette faculty and students in the Engineering division. This outreach included both surveys for engineering students and professors at Lafayette, respectively. These surveys gauged the level of importance that faculty and students allocate to the development of non-technical skills in the context of engineering classes. As predicted by our literature based research and experiences, survey results indicated that students care about their community, however, they feel as if they have not yet made a community-based impact through their engineering classes. Empirical survey results from students and professors are located in this report's technical context.

Aside from survey results are additional observational reports from a mechanical engineering community engaged senior design course, also found in our technical context. These observations uncovered a lack of knowledge amongst students regarding procedural norms when conducting research and outreach in the community. In addition to survey results and classroom observational reports, Lafayette's engineering culture is reflected in a seemingly small but telling colloquialism, the "pretendgineer." This term is used to describe Engineering Studies majors, and alludes to the lack of respect that contemporary engineering culture gives to non-technical engineering skills, specifically at Lafayette.

Economic Scope

Engineers tend to design in regards to a solely technical context. Although traditional engineering understanding does not explicitly state this knowledge, industrial metrics, in particular, have motivated engineering education and practice for over a century. The economic conditions that design work affects are inherently tied to broader political structures. Additional economic conditions relate most closely to effects within communities and have the potential to positively influence local economies.

Economic benefits to community-centric design exist in both a community-based, outwardly-focused context and a professional, inwardly-focused one. We outlined these benefits to clarify the legitimacy and value of our proposed course. The economic benefits appear in the work that graduated engineers pursue in the future, including marketability, efficiency within the workforce, and longevity of engineering design impact. The potential increase in efficiencies of engineering graduates with a knowledge of community-centric and non-technical skill sets justify the necessity of incorporating our proposed course into Lafayette College's offered curriculum, and its benefits.

Community Impacts

The primary outwardly-focusing economic impact of a community-centric course includes an ultimate betterment of SCD projects for the community at hand. While SCD projects are inherently designed to positively impact the lives of community members, the current use of Engineering Problem Solving methods in SCD projects inhibits engineers' ability to make sustainable impacts (Lucena et. al. 2010). The economic benefit of a community-centric skill set would divert engineers from using traditional, inefficient, solution-oriented, engineering problem solving tactics and therefore increase potential in efficiency and effectiveness for community impacts.

Engineers invest both time and money while working in SCD projects. As our brief case study review shows, these efforts can lead to a lack of product acceptance amongst the community or end with a disconnect between communities and the final design product. In community outreach, the community's "adoption of the [technology] [could] mean changing their lifestyle, habits, values, and interests" (Lucena et. al, 2010, 98). Teaching engineers how to recognize and work with existing cultural, economic, and infrastructure-based barriers, they can increase their impact and reduce their potential to harm communities. While monetary investments remain crucial in the success of SCD projects, "the critical resource for enhancing social capital is not money—rather, the critical resources are trust, imagination, the relations between individuals and groups, and time, the literal currency of life. Many of the social issues that people relate to most intimately—family, neighbourhood, community, decompression from work, recreation, culture, etc.—depend on these resources at least as much as money" (Roseland, 2000, 98). Although "good intentions" exist in SCD, a non-technical skill set would make these efforts more worthwhile, for both the engineer and the community (Lucena et. al, 2010).

As traditional technically-focused training tends to ignore community perspectives and is "not neutral with respect to incorporating a diversity of perspectives," community-centric education aims to teach students how to communicate with communities to best understand and work alongside them to fulfill their needs and to adopt their perspectives (Lucena et. al, 2010, 92). As engineering culture evolves, a body of literature regarding the disconnect between engineers and the communities that they design for recognizes that "focusing solely on money to provide security is using 19th century thinking to address 21st century challenges," and that a better holistic understand of community needs results in a better use of project investments

(Roseland, 2000, 98). As engineers work, they need to understand the dynamics of the communities at hand so that once they leave, communities remain well equipped to sustain their respective projects. Specific examples include “converting to greater reliance on renewable energy sources; increasing community self-reliance (e.g. food and energy production); and sustainable management of natural resources (e.g. community forestry). [Economic demand management] shifts our economic development emphasis from the traditional concern with increasing growth to instead reducing social dependence on economic growth” (Roseland, 2000, 95). If community needs remain unmet, community members and economies could suffer, however, a community-centric education could decrease the risk of this failure.

While SCD most explicitly entails a combination of engineering design and community outreach, a subset of the economic benefits to the community at hand rest in the concept of “community economic development.” This entails “ a process by which communities can initiate and generate their own solutions to their common economic problems and thereby build long-term community capacity and foster the integration of economic, social and environmental objectives” (Roseland, 2000, 97). Training Lafayette engineers more holistically will reframe them as not solely design managers, but as social agents, equipped to help communities once engineers physically leave these sites. Longevity of the specific design of the product and the outreaching technological system that each physical technology includes relies on the engineer’s ability to understand the economic impacts and ripple effect that their work has on the community at hand.

Professional Engineer Impacts

The second economic consideration is the impact that this type of education would have on the professional engineer and marketability. Changing the way that engineers approach traditional problems by challenging them to understand different perspectives and to think with a more interdisciplinary mindset will lead to producing more holistic engineers in society. Making our engineers better thinkers rather than just better problem solvers will lead them to be able to take on more challenging problems with an array of perspectives.

Andersson (2010) claims that there is a dissatisfaction with the quality of the common engineer in the workforce. Naturally, this requires companies to invest in training for their new college graduate hires. Studies have found that nearly half of employees have said that they need to provide additional training for new engineers that goes beyond the job type experience (Andersson, 2010). This training revolves around non-technical skills that should be taught in undergraduate programs. Training requires a lot of money no matter what the specifics of the training entails, especially for large engineering companies that hire many new engineers every year (Andersson, 2010).

This dissatisfaction is due to a lack of development of quality engineering education that focuses on non-technical skills which correlate to professional skills in the workforce. Primarily, these skills fall under five qualifications including, “communication, interpersonal skills, analytical ability, self-confidence, and willingness to adapt to change” (Dahir, 1998, 2). While Lafayette trains their engineers to have strong communication and analytical abilities, there is still room for improvement. Our course would shed light on developing these non-technical skills within the topics of interdisciplinary thinking and external contexts. This ability to think outside of the technical perspective is a skill that is highly desired within the workforce.

As a more straightforward economic measure, we investigated the top-ranked bachelor's programs based off of early salaries as well as mid-career salaries. The four schools (Harvey Mudd, Stanford, MIT, and the California Institute of Technology) mentioned in *Engineers for Change* in reference to reforming their engineering curriculum to more interdisciplinary programs are all ranked in the top five of the "The Best Universities For a Bachelor's Degree" list on *payscale.com*. Additionally, the Colorado School of Mines is ranked eleventh on the list. The high rankings of these programs on this salary report show that investing in bettering engineering via interdisciplinary education pays off in more than just helping communities and the professional skills of engineers. This shows that investing in more holistic engineering education can potentially lead to better jobs for graduates in the industry because they have more fine tuned non-technical skills paired alongside the technical fundamentals. Their graduates are earning more than other schools' graduates throughout the country. It is important to note that Lafayette is ranked fifty-eighth on this list. This shows that we can economically benefit our graduates through investing in a more holistic approach to engineering education (Payscale, 2018).

Engineering for a Changing World (Duderstadt, 2010) highlights the engineer's role in society is correlated with the growing impact of technological innovation (Duderstadt, 2010). As this increases, engineering has to adapt to the society's changing expectations. As Duderstadt states, "technological innovation plays an ever more critical role in sustaining the nation's economic prosperity, security, and social well-being, engineering practice will be challenged to shift from traditional problem solving and design skills toward more innovative solutions imbedded in an array of social, environmental, cultural, and ethical issues" (Duderstadt, 2008, 2). Engineers' changing identity from the "traditional engineer" to the "urban engineer" is highly dependent on their understanding of their role within technological innovation. Therefore, "the key to the ability of engineers to develop the products, systems, and services that are essential to national security, public health, and the economic competitiveness of the nation's business and industry is the knowledge base created by engineering research" (Duderstadt, 2008, 28). In order to adapt to this shift, the engineering curriculum must go through a large change.

Our research and ultimate curriculum design aims to help Lafayette in beginning to change its culture around engineering. By identifying the historical shift in engineering culture, triggered by the Cold War, we better understand the root of this disconnect. With an understanding of contemporary engineering culture, we can analyse how this disconnect manifests in present day design flaws. Lastly, by identifying both community-based and professionally-based economic benefits of community centric design, we began to define what necessary components are needed in our course, and why this course will be beneficial to Lafayette. In order to create the best curriculum with the best potential traction and support, we investigated relevant stakeholders. These stakeholders exist both within and outside of Lafayette's borders and provided our team with the necessary input for our curriculum design.