The New College for Humanistic Engineering:

Curricular Strategies to Educate Engineers as Liberal Learners

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The engineering profession has acknowledged its responsibility to address societal needs (National Academy of Engineering, 2004). Yet, the rampant ideology of depoliticization in engineering education positions public welfare concerns as irrelevant to "real" engineering, and technical/social dualism further devalues the development of social competencies in lieu of the technical competencies held central to the engineer's professional identity (Cech, 2014). In recognition of the inherent coupling of technical and social dimensions in the problems society faces, recent movements have promoted educating engineers as liberal learners and as good global citizens. At this intersection of professional and liberal education, students should be prepared not only "for productive careers, but also to enable them to live lives of dignity and purpose; not only to generate new knowledge, but to channel that knowledge to humane ends" (Poston & Boyer, 1992).

This idea comes in many names: the humanistic engineer (Bolton, 2022; Fisher & Mahajan, 2003), the engaged engineer (Cech, 2014), and the engineer-citizen (Allen, 2016). They are civically engaged, capable of critical thinking and ethical reasoning, and strive to do public good with proactive consideration of societal contexts and ethical responsibilities in their practice (Allen, 2016; Bolton, 2022; Cech, 2014; Fisher & Mahajan, 2003). The education of this engineer involves developing technical knowledge-based and skills-based competencies alongside the humanistic capacities invoked by a liberal education.

The purpose of this review is to characterize how—and how well—nontraditional engineering programs have innovated curricula to educate humanistic engineers. I will briefly provide working definitions of liberal, professional, and general education before offering case studies of Harvey Mudd College and Olin College of Engineering: two institutions recently founded with the mission of making engineering education more humanistic. I draw from primary source materials on each college's founding principles and aims before highlighting unique aspects of their curriculum. I critique their approaches through a theoretical lens informed by engineering education scholarship and draw upon data relaying student outcomes where available. I conclude with limitations of this work and areas for future research.

For the purpose of this review, I anchor the principles of liberal education in its broader capacities to cultivate humanity: those of critical examination, empathy, and civic engagement (Nussbaum, 1997). Professional education is here distinguished by its primary aims to develop knowledge-based and skills-based competencies in preparation for a career in a particular discipline (Snedden, 1977), and general education by its call for the integration of knowledge across several disciplines—as is often materialized through breadth requirements—with the goal of students' preparedness to "engage important issues of contemporary civilization" (Brint et al., 2009). The boundaries between disciplines, and between these educational forms, have become increasingly blurred over time (Brint et al., 2009; Haberberger, 2018; Labaree, 2006). To different extents, Harvey Mudd College and Olin College allude to the liberalization of a professional engineering education in the service of public good and recognize how that can manifest in models of general education, though their stated priorities align more with the dissolution of such boundaries than categorization within them.

Literature Review

Harvey Mudd College and Olin College of Engineering were both recently founded to educate "a new type of engineer." They share in many institutional characteristics, championing small student bodies (with enrollments of 906 and 386 students, respectively), high student-to-faculty ratios (9:1 and 8:1), representation of gender identities historically underrepresented in engineering (48-49%), and highly residential campuses (Harvey Mudd College, 2022; Olin

College of Engineering, 2022). They promote transcending disciplinary boundaries in the name of addressing the complex challenges of today's world. They hire faculty in the humanities, social sciences, and arts (despite not granting degrees in these disciplines) and have created consortiums with liberal arts colleges to further increase the strength of their students' liberal education. Both programs center collaborative and experiential learning in their engineering courses with the intention to expose students to the complexity of real-world problems and to practice collective problem solving, following in the principles of good practice for combining learning and public service (Honnett & Poulsen, 1989).

Harvey Mudd College

The consortium of the Claremont Colleges was founded in 1925 with the goal of preserving the values of the small college while providing the facilities of the larger university (Platt, 1994). Missing from these facilities for the consortium's first 30 years was a technical college. In 1955, a report commissioned by the American Society of Engineering Education to formalize goals and guidelines for modern engineering educators highlighted the need for more socially responsible engineers (Grinter, 1955). Goals coalescing, the governing board of the Claremont Colleges put into motion the founding of Harvey Mudd: "a college which teaches engineering and science in a humanistic setting" (Platt, 1994).

Today, Harvey Mudd describes itself as a liberal arts college focused on technical subject matter: "We're one of the premier engineering, science and mathematics colleges in the United States. We're also unique because we are a liberal arts college. Aren't engineering, science and mathematics mutually exclusive of the liberal arts? Maybe at some places, but not at Harvey Mudd" (Harvey Mudd College, n.d.-b). The college has six departments and associated majors in the physical sciences, computer science, engineering, and mathematics as well as a Department of Humanities, Social Sciences, and the Arts (HSA) with no associated majors. Harvey Mudd requires students to take ten courses in the humanities, social sciences, or arts—the most required in any engineering college in the United States, they claim proudly—comprising around 30% of total credit requirements in the engineering curriculum (Dym et al., 2012; Harvey Mudd College, n.d.-a, Introduction). While six of these requirements can be fulfilled through other Claremont Colleges, four must be taken through Harvey Mudd's HSA department. The founding idea to teach engineering "in a humanistic setting" has been narrowed to more explicitly "embody the aims of a liberal arts education *on our campus* [emphasis added]" (Harvey Mudd College, n.d.-d, Department Goals).

The philosophy of Harvey Mudd's engineering program is explicitly "to produce generalists" (Harvey Mudd College, n.d.-c). They strive to provide students a general education in engineering, science, and mathematics as well as a general education in the humanities, social sciences, and arts. In addition to the HSA requirements, this is attempted through Harvey Mudd's core curriculum: containing eleven required courses in STEM, one on academic writing, one on critical inquiry, and another on "STEM & Social Impact," a project-based course specifically focused on climate impacts of engineering (Harvey Mudd College, n.d.-d, HMC Common Core). Stated as a primary goal of this and other experiential engineering courses is for students to understand the impact of engineering solutions in a global and societal context (Dym et al., 2012). However, little scholarship is available on the approaches specifically employed in Harvey Mudd's curricular design or on their assessment of student outcomes.

Olin College of Engineering

Olin College of Engineering was founded in 1997 "to be different—not for the mere sake of being different—but to be an important and constant contributor to the advancement of engineering education in America and throughout the world and, through its graduates, to do good for humankind" (Olin College of Engineering, 2002). Their mission is to educate a new type of engineer, who embodies capacities upheld as the products of a liberal education (Nussbaum, 1997). They have "the inclination to serve society and the planet, not just themselves and their employer" and the "willing[ness] to question whether engineering is the right approach to a given situation" (Olin College of Engineering, n.d.-c). In Nussbaum's words, they are people bound to humankind and its universal aspirations, not by their local loyalties, who practice reflection and critical examination before potential action. Olin's strategic aims further uphold both technical and human competencies; this new type of engineer should possess "the professional and technical skill and attitudes to solve problems by understanding people's needs" and "appreciate and understand perspectives other than their own" (Olin College of Engineering, n.d.-c). These abilities of intelligent reading of another's story and of imagination, empathy, and judgment for needs-based problem solving further reflect Nussbaum's description of humanistic capacities cultivated in a liberal education.

Like Harvey Mudd, Olin establishes that a central component of this undertaking is having engineering students take courses in the arts, humanities, and social sciences. These requirements can be fulfilled either through Olin College or Wellesley College, albeit in fewer numbers than at Harvey Mudd. There is no formal Core Curriculum, but all students must take one of the foundational arts, humanities, and social science classes offered at Olin in their first semester (each containing emphases on writing, critical reading, and discussion) in addition to five classes in engineering and design throughout their first and second years (Olin College of Engineering, n.d.-a, n.d.-b).

Olin's flagship engineering design courses are interdisciplinary and project based (Somerville et al., 2005). From semester-long projects to help older adults in the local community age in place to years-long efforts to co-create social ventures in poverty-afflicted areas across the globe, the goal of these courses (for students) is to "understand the unique needs and challenges their stakeholder's face, to construct and manage a co-design process and strive to generate a measurable social impact" (Lynch et al., 2014; Noyes et al., 2015). Context is studied in the classroom and then explored in the community (e.g., through required trips to partner sites for two weeks every semester). Humility, relationship-building, and collaborative problem solving are at the center of the educational experience (Lynch et al., 2014; Noyes et al., 2015; Somerville et al., 2005). A three-year study of learning outcomes in one such course revealed transformations in students' understanding and empathetic knowledge of community partners, a reconceptualization of the role of engineers in collaboration with community partners, and a widened understanding of career trajectories that fulfill students' values and align with their desired forms of practice (Lynch et al., 2014).

Olin has also experimented with non-experiential course offerings that target student reflection and self-integration. In 2019, a course entitled "Change the World: Personal Values, Global Perspectives, and Making an Olin Grand Challenge Scholars Program" was created, intended to provide structured support for students' reflection on "engineering for good" in relation to personal and societal contexts (Graeff & Wood, 2021). Assignments include written and creative pieces on the relation of one's engineering work to their values and notions of self, to their local communities, and to the world at large. In 2023, a course entitled "Engineering in Context" was created with a similar ethos, targeting students' self-integration of concepts of sustainability, ethics, and history through the lens of a STEM course of their choosing (Olin

College of Engineering, 2023). Rather than developing a course for each contextual framework (such as in Harvey Mudd's "STEM & Social Impact: Climate Change") or creating a chain of courses, each in its own discipline, designed to be strung together, "Engineering in Context" was left broad with the intention to reflect the interconnected nature of all these dimensions in the real world.

Critiques

The rigor of these various liberal education experiences at Harvey Mudd and at Olin are not clearly demonstrated in the literature. At both colleges, the majority of faculty have a traditional STEM background with a smaller number trained in humanities, arts, or social sciences. Attempts to reshape a liberal education for (and potentially by) engineers risks diluting its core qualities. A well-studied example is the reductive treatment the engineering profession has given to ethics education. Engineering ethics is typically only conceptualized as "microethics" or the individual decision-making of the engineering professional, rather than "macroethics" or the proactive contemplation of the broader collective and social impacts of technology (Herkert, 2004; Riley, 2008). The Fundamentals of Engineering Exam, required to become a licensed professional engineer, includes an ethical competency section comprised exclusively of multiple-choice questions for which there is always one right answer and any knowledge needed to grasp relevant organizational, cultural, and social contexts can be summarized in a few sentences, if provided at all.

Not all experiences in the arts, humanities, and social sciences will cultivate the capacities desired from a liberal education, and sparse breadth requirements in these areas are certainly among the least well-positioned to do so. In 2014, Erin Cech surveyed students about how they perceived the priorities of their engineering programs with respect to nine technical and humanities-centered emphases. She found that, even in the programs designed explicitly to educate socially responsible engineers (including Olin College), consideration of ethical and social issues was perceived by students to be of least importance to their programs out of all surveyed factors (Cech, 2014). Higher rated were all emphases related to technical competencies followed by priorities in “broad education in humanities and social sciences” and writing skills. In a qualitative study of students in similar programs (including Harvey Mudd), engagement in social and ethical considerations was assessed to be narrow, for example due to students consistently assessing the primary social impact of their designed technology to be its improved efficiency and cost (Tang, 2014). A stated focus on “an understanding” of social context (e.g., Harvey Mudd College, n.d.-a) could be limited to just that: general awareness of circumstance that does not extend to critical examination in engineering practice.

Harvey Mudd builds in many student experiences in the humanities, social sciences, and arts; Olin has fewer of these experiences, but more that are explicitly designed to integrate learning across these and technical domains. The former model with interspersed courses on self-chosen topics in humanities, social science, arts, and STEM puts the onus on students to integrate their learnings outside of formal academic structures. This may not happen at all; students in such programs report liberal education as “helpful but separate” to their engineering learning, considering their college education “a parallel of engineering and the liberal arts, rather than an integration of the two” (Tang, 2014). In contrast, course offerings like “Engineering in Context” have the potential to formalize aspects of this integration process under the supportive structures of a course with collaboration and advising from faculty. However, tools to assess the outcomes of these efforts remain to be developed.

Effectively building self-directed learning into curricula is an ongoing challenge for educators. Faculty have reported concerns about losses in content acquisition during self-directed learning while students cite high frustration, lower perception of acquired knowledge, and concern about what content they are learning versus what they "should be" learning (Martello & Stolk, 2007). These critiques could reflect a tension between recognizing value in nontraditional, self-directed educational experiences and recognizing legitimacy in experiences steeped in tradition. Cech references the difficulty that nontraditional engineering colleges like Harvey Mudd and Olin face in their efforts to diverge from normative structures and cultures because of "the need to be recognized as legitimate purveyors of knowledge" (Cech, 2014), which in turn can give rise to institutional isomorphism (DiMaggio & Powell, 1983). Indeed, when assessing students' priorities on public welfare and social-ethical engagement throughout their educational experiences, she observed little variation between students in nontraditional and traditional engineering programs (Cech, 2014).

Limitations and Areas of Future Research

This literature review was scoped around colleges founded specifically to educate a new type of socially engaged engineer; therefore, only two case studies were provided. Still, a more complete picture of these colleges' efforts could be made by drawing comparisons to other engineering programs with different founding principles and institutional characteristics (e.g., larger, traditional engineering programs or engineering programs situated in traditional liberal arts colleges). The comparison of strategies provided between Harvey Mudd and Olin was also limited in its imbalance as the latter has more publicly available material on their curricular design and course outcomes.

There are several limitations in the assessment of how well these colleges' curricular strategies achieved their missions. First, the nature of the described experimental courses inherently yields small amounts of data: they occur only in a few institutions, may take place as briefly as in one academic term, and always in small class sizes. Second, few formal outcomes have been proposed by which to assess effectiveness at educating humanistic engineers. Select studies outline changes in student behavior and attitudes throughout specific courses or undergraduate education (e.g., Cech, 2014; Lynch et al., 2014; Tang, 2014), but these measures are coarse or inductive and do not capture all relevant dimensions of the aims of humanistic engineering education. Additionally, where literature on assessment outcomes for these programs does exist, it quickly becomes outdated due to the rate of change in these institutions.

Future work should attend to the challenging but critical task of developing more rigorous learning outcomes for humanistic engineering education. Longitudinal studies will be critical and investigating student perceptions of their college's priorities could be a rich source of data. Learning outcomes and student perceptions should be examined throughout the undergraduate experience and well into individuals' professional careers to provide greater insight onto the effects of students' education on their continued engineering practice. It would also be fruitful to investigate what factors are informing students' perceptions of their college's priorities, specifically teasing apart curricular, structural, and cultural elements.

Continued curricular experimentation will be crucial in the effort to move toward humanistic engineering education. A close catalog of the learning outcomes for each iteration in curriculum design should be prioritized, such that a longitudinal study can synthesize a profile of the college throughout its various experimental phases. Finally, if these attempts can be demonstrated effective at the colleges' greater missions, the question of scale is introduced: how can larger, more traditional engineering programs be reformed in the image of these small, pedagogically innovative colleges?

Conclusion

It is imperative that engineers be educated as liberal learners and take a place in society not only as professionals but as good citizens. Two engineering colleges have staked claim in leading this effort; they put forward the significance of exposing engineering students to traditional curricula in the liberal arts in addition to creating new course forms that directly position engineering in broader personal, societal, and ethical contexts. Attempts to simultaneously engage with social, ethical, environmental, and technical considerations in a short timespan risk loss of depth in pursuing any, while attempts to focus on only one such dimension artificially simplifies the true nature of engaging with today's world. Promoting self-integration of learning across domains is critical and gaps exist in the approaches used by both Harvey Mudd College and Olin College of Engineering. Recent experimental curricula show promise to bolster humanistic considerations in engineering education, but the formulation and rigorous assessment of learning outcomes are needed to fulfill this greater mission.

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