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Engineering Cultures

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Each summer in Paris, an enormous military parade commemorates Bastille Day, July 14 1789, when commoners stormed the royal fortress and wrested power from the King, formally initiating what later became known as the French Revolution. The parade is led each year by 2nd year students from the École Polytechnique, the top engineering school in France. At the key moment on the key day when the entire nation is focused on itself and its accomplishments under the leadership of a republican government, France makes its elite engineers visible to an extent found nowhere else in the world. Those engineering graduates who make it into the state administration in fact constitute the highest-ranked occupation in the country. Importantly both those engineers and the majority of engineers employed in lower-status locations in provincial governments or the private sector demonstrate through their work and careers that advanced mathematical knowledge is valued above all else in French engineering training and practice.

In sharp contrast, engineers in the United Kingdom, especially in England and Wales, have struggled with relatively low status throughout their more than 200-year history. A 19th century emphasis on training through an apprenticeship system established a focus on the value of practical engineering knowledge that continues to this day, even amidst the 20th century emergence of school-based training and increased attention to theoretical knowledge. Also, with the exception of work within the military, engineers have tended to seek employment and build their careers in the private sector, outside of government. Struggling for higher status in a hierarchical class system that placed greatest value on classical training in the liberal arts, engineers have relied on a type of practice-based membership group, the professional society, in an effort to advance engineering as a legitimate profession alongside law, medicine, and the clergy.

Germany offers yet another pattern in the knowledge and social positioning of engineers. As suggested by the pervasive cultural icon, the BMW motor vehicle, German engineers have developed over time a primary focus on the production of quality technics, where 'quality' entails the realization of engineering precision, measured in close tolerances, and 'technics' refers to both the outputs and the mechanisms of technological production. Quality technics has served as a marker of advancement in German society since the late 19th century, becoming especially important during the 1930s under National Socialism. Developing in parallel, an engineering focus on precision has involved actively developing what some historians have called "scientific technology," or forms of scientific knowledge specifically designed to help solve technical problems. Through the linkage between technics and advancement, engineers have come to know that by applying engineering precision in quality processes of technological development, they also contribute directly to advancing both the German nation state and humanity in general. In other words, although German engineers have tended to work in the private sector, similar to British engineers, they have also had the opportunity to be identified directly with national development, similar to French engineers.

Although the number of engineers in the world is comparable to the number of scientists, engineers have received far less attention in studies of science and technology in society. Distinct patterns among French, British, and German engineers call attention to what has been a key barrier to the understanding of engineers and engineering in society, great diversity in what counts as an engineer and engineering knowledge. Wide variations exist in different countries in the central concerns and social locations of engineers amidst other knowledge workers, including scientists, technicians, government officials, business managers, and so on. Different types of people are called engineers. Sometimes the term 'engineer' refers to the holder of a degree and sometimes to a job title that one can occupy. Sometimes engineers experience high status, sometimes low status, and often ambiguous status. Important differences in engineering careers lie not only between countries but within countries as well.

One pathway to understanding contingent developments and persistent patterns in engineering knowledge and personhood is to examine the cultural meanings that challenge engineers in their work. However, doing so effectively requires considering what is happening when engineers experience and respond to configurations of cultural challenges. A focus on the professional identities of engineers provides a way of following links between engineering knowledge and engineering personhood and, hence, understanding how engineers have been active agents of their own positioning in different countries.

Mapping engineering 'up' from society

One reason that engineering knowledge and engineers have received far less attention than science and scientists is dominance of the view, both inside and outside of academia, that engineering is located 'downstream' of basic science. In this view, engineering consists of forms of knowledge and collections of activities associated in some way with the 'application' of scientific knowledge to practical problems. To the extent that engineering knowledge lives or gains form in this derivative sense, one should seek to understand its essential elements by first looking 'upstream,' sorting out the defining features of the relevant scientific knowledge. Only after such prior work is completed can one begin to understand and find order in the application of this knowledge to solve problems. In this way, the downstream location of engineering thus also appears to be an accurate indicator of its apparent subordinate level of importance. Along with the applied sciences, engineering gains both content and significance fundamentally through its links to basic science.

However, strong reasons exist for pulling engineering epistemology, or theorizing about the content and positioning of engineering knowledge, out from under the shadow of scientific knowledge. In particular, consider the fact that the key mathematical activity of 'engineering analysis' always works with the goal of somehow making society 'better.' As historian Ken Alder (1997:60) observes in describing the emergence of engineering analysis in 18^{th} century France, its operational method is "to describe quantitatively the relationships among measurable quantities, and then to use these descriptions to seek a region of optimal gain." Today, school curricula for engineering training tend to present engineering analysis as a disciplined activity of mathematical problem solving. For students in the United States, such problem solving involves drawing a boundary around a given problem, abstracting its features out into mathematical worlds (e.g. statics, dynamics, fluid mechanics, thermodynamics, etc.), solving it in the mathematical terms of those worlds, and then applying the solution back to the original problem, all to facilitate a gain for whomever is faced with the problem in the first place. In other words, where scientists have long been charged with bringing new objects into the purview of society, as discovery, with the ultimate goal of benefiting society, the key expectation confronting engineers has been to improve society directly by developing and improving the performance of human constructs.

Born in the European Enlightenment, this mandate to improve society also brings design methodology and practice into the epistemological mix of engineering. The activity of design embeds engineering deeply in everyday life, generating outputs that are supposed to count as solutions to everyday problems and making it difficult to distinguish *a priori* engineering knowing from engineering doing.

In parallel with other developments in science and technology studies, researchers are increasingly inquiring into engineering epistemology by attempting to map engineering 'up' from society rather than 'down' from science. When scrutinized from the bottom up, engineering knowledge begins to appear so diverse because it is mapped so closely onto the diverse societies that engineers serve and in which they function. In other words, the activity of serving, of making society better, depends upon what counts as better at particular times and in particular places. Perhaps engineers, rather than functioning as mere disseminators of basic knowledge, are actively engaged in selecting, adapting, and developing the forms of scientific knowledge they need in order to successfully intervene in and, hopefully, improve everyday life. In this way of thinking, diversity in the knowledge and social positioning of engineers appears as an accomplishment, a product of successful struggle in diverse circumstances, rather than an unfortunate limitation. The challenge is to show how the epistemological value of engineering knowledge is linked to the wider social value of engineering work and the professional identities of engineers. Here is where culture comes in.

Responding to culture

How do cultural meanings act on, or influence, engineers? The issue comes down to the question: what do engineers share? Consider the cases introduced above of France, U.K., and Germany. It would be both grossly misleading and analytically unhelpful to claim that these countries have distinct and independent cultures that shape their engineers in uniform ways.

In the first place, the cultural contrasts traditionally thought to distinguish countries from one another are by no means sharp. With dramatic increases in both the virtual and physical movements of engineers around the world using emergent transportation and communications technologies, not are such cultural boundaries between countries increasingly porous but perhaps it no longer makes sense to posit them at all. Such is especially the case for Europe, where much evidence exists of engineers actively working in the context of perspectives from other countries. Secondly, the life trajectories and experiences of engineers vary greatly within a given country, such that differences among engineers within a given country might actually be greater than differences among engineers from different countries. In short, no one-to-one correspondence can be said to exist between the culture of a country and the knowledge and personhood of engineers. It makes little sense to argue that French, British, and German engineers share distinct national cultures.

But the idea that cultural meanings that have become national in scale influence engineers still has merit. One way to elaborate this idea is to think about engineers not as passively sharing cultures, as underlying sets of beliefs or assumptions, but as actively 'responding' to cultures as 'codes of meaning' that challenge them as people. For example, rather than saying that all engineers in a given country share a value in mathematics or believe in the importance of practical knowledge, one can say that all engineers trained or working in a given country may have to respond to a code of meaning that places value on mathematical or practical knowledge, respectively.

How engineers actually respond to a code of meaning affects its future scale, depending on whether their actions reproduce, transform, and/or replace the code. In this sense, national engineering cultures are not membership groups but codes of meaning that have scaled up and, hence, become dominant at the level of the nation state. So when engineering schools in France emphasize mathematical theory over everything else in their texts, teaching, and exams, and 'successful' engineering students demonstrably accept this as what counts as engineering knowledge, then we can say that mathematical theory has become part of a dominant code of meaning challenging people who study and practice engineering in France.

The key question for engineering epistemology in this way of thinking lies in how patterns in engineering knowledge and personhood might emerge amidst historical contingencies. In their lives and work, engineers regularly respond to all sorts of meanings from inside and outside of engineering that have different contents and live at different scales, depending upon unique life experiences with family, religion, education, travel, friendship, etc. Accordingly, one must treat differences among engineers as the expected norm, the default setting. Yet patterns do emerge, especially at national scales. Since the identity of the engineer emerged along with the Enlightenment concept of advancement in society, perhaps national patterns in engineering knowledge and personhood may have developed as engineers responded to distinct popular images of national progress.

Responding to popular images of progress

In the French context, a fundamental focus on mathematics and the positioning of elite engineers in the executive branch of government suggests that engineers have long responded to a teleological image of national progress, i.e. as advancement toward a potential future state of perfection. As 18th century French *philosophes* argued in advocating greater rationality for social life, since nature is perfect, having been created by God, human society could become more God-like by making itself more like nature, i.e., more orderly. Both before and after the French revolution, the state administration has been the major agent for increasing social order. A key vehicle has been the development of a national infrastructure of transportation, communications, and energy technologies. Private industry has been of far less interest. For example, despite considerable deposits of coal and iron ore, the country never developed a private steel industry. The authoritative position of the state administration remained stable even as the French battled over defining the titular leadership, producing a dizzying mix of three monarchies, two empires, and five republics in a two-hundred year period.

Engineering analysis based in abstract mathematics gained legitimacy as the crucial national tool for theorizing and enacting the march toward perfection through higher states of social order. The 17th century philosopher René Descartes had established the idea that nature could be seen as a huge mechanism, analyzable in mathematical terms. Working to fulfill the popular image of progress, French administrators constructed parallel hierarchies of education and employment, with engineering schools and state employment at the top. Higher ranked than universities, the elite engineering schools, or *grandes écoles*, have been limited to top performers on an extremely difficult math-based examination, *les concours*, have consistently placed greatest emphasis on training in advanced mathematics, and have provided graduates with direct pathways to top positions in the state. In other words, French engineers have responded to a national image of progress in a patterned way by privileging mathematical capabilities and activities. Accordingly, they have successfully built and managed a large state apparatus that has made them the envy of engineers worldwide.

In contrast, the commitment of British engineers to practical knowledge and their struggles with lower-status positions suggests a patterned response to an image of social progress as material improvement over the past. In the British context, successful improvement within society has been defined competitively as the increasing material welfare and comfort of individuals, or self improvement, measured in part by the distance individuals achieve from manual labor and by the quality of their education. Class status became an indicator of one's level of social advancement. Importantly, the English industrial revolution was a phenomenon of lower-status crafts, transforming artisans and craftsmen into wage laborers while enabling some new industrialists to climb into gentlemanly status alongside traditional agricultural elites and gentry. But in contrast with the United States, English industry focused not on mass production for mass use and benefit but on batch processing oriented toward society's upper echelons. In contrast with France, the state adopted a *laissez faire* stance toward national progress, limiting itself mainly to authorizing charters to private companies.

Responding to the dominant code of self-improvement, British engineers explicitly rejected the French emphasis on mathematical theory and assessed their work in terms of its practical benefit. Insisting on training through the apprenticeship system, engineers both emerged from the ranks of craftsmen and emphasized hands-on experience and craft knowledge. Engineers sought gentlemanly status by emulating the traditional professions of law, medicine, and clergy, and organized themselves into professional societies, however with uneven success. In a country in which material success was indicated by distance from manual labor, the idea of an elite engineer was almost a contradiction in terms. Even the children of relatively prominent 19th century engineers tended to avoid careers in engineering. The polytechnic institutes that eventually emerged to provide school training were located below universities, and professional societies were never able to displace employers in the control of engineering work. In short, responding to a call for progress through material improvement, engineers produced a pattern that established a passionate attachment to practical knowledge and a permanent struggle for higher status.

In the German case, in placing high value on quality technics, engineers have responded to an evolving image of progress as emancipation of the human spirit, a freeing of something that is naturally internal to the human essence. During the German Enlightenment, progress in society came to be known as the unfolding of reason, articulated by philosophers in universities and enacted by bureaucrats in rationalized governments, especially in Prussia. The concept of engineering was not indigenous to Germany but was borrowed from Great Britain and, especially, France. Engineers emerged among the lower status guilds of artisans, which had long been known for their conservatism. Responding to the idea of progress through reason, activist engineers sought higher status through education, establishing Higher Technical Institutes for engineering education. Their efforts met with increasing success after unification of the German states in 1870, as industry became a new site for marking human and, hence, German progress. The unfolding German spirit could now be found in the physical and material existence of quality technologies and products. Late 19th and early 20th century Germany is a story of the rapid rise of high-quality German industry, especially the steel and chemical industries.

Beginning in the 20th century, especially during and after the Weimar Republic, engineers responded to the idea of progress through industry by dedicating themselves to the production of quality technics, working up from practice to theory only to the extent necessary to produce a quality outcome. Engineers organized a second tier of engineering education, in which 'gaining a feel' for materials became a defining activity and work producing quality products in private industry simultaneously brought national significance because it demonstrated German advancement. The engineering emphasis on quality as precision became prominent after World War II as engineers gained stable status as an important category of German society. In sum, German engineers were able to gain increasing credibility for themselves and their forms of knowledge by responding strategically to the national shift from reason to technics as the main site for emancipation of the German spirit.

Research Questions

One key category of questions to pursue involves following how European patterns in engineering knowledge and personhood have traveled through colonial relations to challenge people in other parts of the world. How, for example, do engineers respond to differing configurations of what counts as national progress, advancement in society, and/or improvement. Engineers in the United States have blended British and French traditions while responding to a distinctive national image of progress as increased standard of living for the masses, a concept and challenge that may indeed be central to the contemporary experience of what is today called ‘globalization.’ Engineers in former British and French colonies often struggle with mixes of challenges that are of indigenous, as well as colonial, origin. The distinct patterns that have emerged presumably depend upon unique national trajectories and participation in ongoing international interactions.

A second, crucially important, set of questions concerns how engineers have responded to codes of meaning that extend beyond the boundaries of nation states. A key example is the capitalist organization of the private firm. Might examining the patterns through which engineers in different countries tend to position themselves as mediators between management and labor be a practical strategy for examining and assessing the so-called ‘structural effects’ of capitalism on engineers? Might national similarities and differences lie precisely in configurations of challenges from codes of meaning living inside capitalist organizations and codes of meaning originating in everyday life?

Third, what sorts of factors distinguish more successful from less successful engineers at different times and in different places? Historians of engineering tend to focus on the small number of engineers that have achieved prominence. How might we understand the populations of engineers who have had more routine careers? What about engineers who failed, or who have left before becoming engineers? Might following engineers as active agents of identity formation provide a means for providing a more complete mapping of similarities and differences among engineers?

Lastly, what counts as reform in engineering? By asserting that engineers actively respond to cultural codes of meaning, we are implicitly describing engineers as engaged in ‘cultural projects,’ for their activities affect those codes of meaning. By thinking about codes of meaning as posing challenges to people rather than grounding their assumptions, cultural change becomes an attainable goal, requiring one to develop and scale up alternative meanings. Serious study of how engineers have in fact built identities for themselves by responding to cultural codes of meaning may perhaps make it easier to identity and scale up better alternatives in the future.

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