Downey, Gary Lee and Juan C. Lucena. 2004. "Knowledge and Professional Identity in Engineering." History and Technology 20(December)4:393-420.

Abstract

When nations redefine their priorities and re-plot their directions of travel, engineers get worried about the contents of their knowledge. The cultural and historical specificity of their responses illustrates the extent to which the questions of what counts as engineering knowledge and what counts as an engineer are linked tightly together, and also suggests that both may be tied to local images of the nation. After summarizing recent historical work comparing national patterns in engineering knowledge and engineers' work, this essay outlines how a focus on professional identity may provide a way of accounting for national and transnational influences on engineers while avoiding the specter of determinism. Offering brief case studies drawn from France, Great Britain, Germany, and the United States, we describe engineers as "responding" to codes of meaning that live at different scales, including contrasting metrics of progress and images of private industry. We conclude by briefly assessing some further implications of the analysis of professional identity for work in engineering studies.

In July 2003, an Egyptian engineer was explaining in an interview why he had returned to Egypt after completing his Ph.D. in the United States and had been working hard to build an information infrastructure in his country. After recounting with pride the engineering achievements of ancient Egyptian civilization followed by an informed list of subsequent world empires and the relative decline of his country, he asked, "Is it possible for a country to have a second chance?" He also explained that he never bought a house in the United States to remind himself that his eight-year stay was temporary, and that for some time he had been grappling with a tension between helping his country through extensive consulting work and being a good father.

A second engineer offered an account of how pressure for reform in engineering education in Egypt often comes from young faculty who return from Canada, U.S.A., France, Germany, and the U.K. wanting to build an educational enterprise oriented more toward developments in private industry. A third engineer was following a career trajectory that converged with an emerging national commitment to private industry. Working for Partners for a Competitive Egypt, funded by USAID, he was evaluating programs designed to change the organizational cultures of Egyptian companies. A related team was conducting a skill-gap analysis of Egyptian higher education, based on a list of 13 skills a Harvard professor had identified as essential for companies to achieve competitiveness.

What does industrial competitiveness mean to activist Egyptian engineers? Is this a case of Western-trained engineers serving as willful or unwitting missionaries for a Euroamerican, especially U.S., doctrine of progress through industry and, hence, as agents for expanding networks of multi-national capitalism? A fourth engineer inhibited such easy labeling in a three-hour discussion of his many struggles to build a hybrid structure of private/public higher education in engineering and technology despite passive resistance from the Egyptian Ministry of Education. His dream is to build a Union of Arab States, akin to the European Union or even the United States of America. He asserted that war with Israel will end but that conflict will shift to a new frame. Since 1970, he said, economic development in Israel has far outpaced that in Egypt. Reform in engineering education is a key to achieving parity, and he pooh-poohed the significance of insidious influences from USAID funding. In other words, for engineers living in the context of a glorious engineering past, centuries of dominance by outsiders, and a long-standing ethnic and religious conflict marking the present, could industrial development actually offer a quantifiable pathway for asserting and advancing an authentic Egypt? Could competitiveness become Egyptian, too?

When nations redefine their priorities and re-plot their directions of travel, engineers get worried about the contents of their knowledge. Their anxiety regularly transforms into efforts to reform engineering education. The present is just such a period. Over the past two decades, virtually every country in the world that produces engineering graduates has been rethinking and restructuring the contents of engineering education.

In the United States, for example, during the 1990s the National Science Foundation spent hundreds of millions of dollars to fund eight coalitions of schools interested in working together to restructure engineering training. Also, the Accreditation Board for Engineering and Technology, formerly an acutely conservative organization, became the lead change agent in 2000 by dramatically transforming its criteria for acceptable engineering curricula. In Germany, the main supply source of engineering graduates, the *fachhochschulen*, or Institutes of Specialized Higher Education, gained authority to call themselves Universities of Applied Sciences and, following the European Bologna Declaration, are rapidly replacing their five-year degree programs with bachelor's and master's programs modeled after the United States. In the U.K., recent reforms trace their trajectories back to the famous Finneston Report of 1980 and include increasing scientific content, expanding continuing education, centralizing accreditation authority, and elevating the polytechnics to university status. Even in France, the site that has accorded elite status to state engineers over the past two centuries, one can find increased emphasis on internships in industry, even for students at the *grandes ecoles,* and, most remarkably, new degree programs that students can actually earn on the job and get credit for practical experience while working in private companies. [1] That one can find equally vigorous efforts in such countries as Egypt, Taiwan, Mexico, and Brazil is remarkable not because engineers appear to be responding to felt national needs but that, for the first time in the history of engineering education, the motivating visions appear to be roughly the same and the trajectories plotted are all in parallel. But are they?

One is struck in all these cases by a felt lack among engineers. That is, movement leaders regularly present their fields as potentially falling short, missing something that risks putting them out of step with national priorities. But why do activist engineers feel a responsibility or, better, a need to keep in step with national priorities in the first place? The greatest passion in engineering reform movements is found in efforts to redefine the contents of engineering

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[1] The literature on these developments is extensive. Starting points include J. Yearganl and K. Hernaut, "The Globalization of European Engineering Education: An American Observer's Perspective," Proceedings of 31st ASEE/IEEE Frontiers in Education Conference (Reno: IEEE, 2001), S2D-1-S2D-4; Engineering Education in France (Paris: Comité d'études sur les formations d'ingénieurs, 1995); Sir M. Finneston, FRS (Chairman), Engineering Our Future---Report of the Committee of Inquiry into the Engineering Profession, Cmnd. 7794 (London: HMSO, 1980).

education, especially the forms of knowledge that make engineers maximally appropriate for the time and place. The cultural and historical specificity of such efforts illustrates the extent to which the questions of what counts as engineering knowledge and what counts as an engineer are linked tightly together, and also suggests that both may be tied in some way to what counts as a nation.

The term 'identity politics' usually refers to the efforts of a subordinate group to assert its distinctiveness, or essential substance and value, in relation to a dominant group.[2] Usually aimed at rectifying asymmetrical power relationships between races and/or genders, or between colonized peoples and colonizers, the assertions of essence in identity politics typically respond to felt denials of essence. Yet as the example of engineering reform movements suggests, the strategies and tactics that make up identity politics, especially assertions of shared essence, can also be found elsewhere in efforts to prevent a threatened loss of essence or even to transform an essence in order to respond proactively to an anticipated or potential loss. As sociologist Thomas Gieryn has shown with his accounts of boundary work in the arena of science, the question of essence can be as much a concern for those jockeying for superordinate status as for the historically subaltern. Gieryn explains, for example, how John Tyndall, prominent apologist for science in mid-19th century Britain, worked carefully to both define and scale up an image of science with an essence that distinguished it from the essences of both religion and mechanics. [3]

In this essay, we suggest that following the identity politics of engineers may provide a conceptual and methodological vehicle for mapping linkages between what counts as engineering and what counts as engineers at different times and places. In two previous reviews of research in interdisciplinary engineering studies, we make the case that the field has no core, no sets of questions that those who enter might feel compelled to engage.[4] In research in science and technology studies (STS), engineers often make cameo appearances but rarely do they get lead roles. The works that do focus on engineering tend to be a diverse mix exploring the contents of engineering knowledge and practice on the one side and the positioning of engineering work amidst the relations of production in capitalism on the other, with assorted interests in gender in engineering, demographics of engineers, engineering education, and engineering ethics, all largely independent of one another.

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[2] Anthropologist Tanya Luhrmann writes that identity politics typically "takes the central relationship between a dominant group and a subordinate group, an us and a them, and makes theories out of attempts to change it." She further points out that many studies have documented how those on the margins "nevertheless conceive of themselves as effective actors in relationship to the center, and to some extent actually are" (T. Luhrman, "Identity in Anthropology," International Encyclopedia of the Social & Behavioral Sciences, edited by N. J. Smelser and P. B. Baltes (Oxford: Elsevier Science Ltd, 2002), pp. 7154-7159, on p. 7157. See, for example, A. Memmi, The Colonizer and the Colonized, translated by H. Greenfield (New York: Orian Press, 1965); R. Ferguson et al. (eds.), Out There: Marginalization and Contemporary Cultures (Cambridge: MIT Press, 1990); A. L. Tsing, In the Realm of the Diamond Queen: Marginality in a out-of-the-way Place (Princeton: Princeton University Press, 1993).

[3] T. Gieryn, Cultural Boundaries of Science: Credibility on the Line (Chicago and London: The University of Chicago Press, 1999), pp. 37-64.

[4] G.L. Downey and J.C. Lucena, "Engineering Studies" Handbook of Science, Technology, and Society, edited by S. Jasanoff, G. Markle, J. Petersen, and T. Pinch (Newbury Park: SAGE, 1994), pp.167-188; and G.L. Downey, A. Donovan, and T.J. Elliott, "The Invisible Engineer: How Engineering Ceased to Be a Problem in Science and Technology Studies," Knowledge and Society (1989), 8: 189-216.

While the very malleability of the concepts ‘engineer’ and ‘engineering knowledge’ justifies, in our view, greatly expanded attention to their contents, achieving greater engagement, or even overlap, among these research traditions may require more explicit attempts at linking together questions of interest to different researchers. Accordingly, in this contribution we invite you into our own struggle by outlining a way of thinking about engineers and engineering. Specifically, we offer a theoretical framework that places central focus on the problematics of professional identity, especially the question: what is the relationship between the knowledge contents of engineering and the professional identities of engineers? We offer the metaphor ‘code-switching’ to call attention to and label a key mechanism of identity management, the process through which engineers build legitimacy for themselves and their knowledge simultaneously in professional and popular terms. Our work lives across the boundary between STS and cultural anthropology, and we see value in bringing anthropological interests in the relationship between the popular and the professional more completely into STS discourses, while at the same time drawing on STS interests in scale to understand the distinction between the popular and professional as a difference in scale.

We begin by reporting some important recent work comparing national patterns in engineering knowledge and engineers’ work in order to address the question--What counts as the ‘national’ in national patterns of knowledge and personhood?—by linking it to the question--How do transnational forms of industrial capitalism inflect patterns of engineers and engineering knowledge? An analytic issue common to both questions concerns how to conceptualize and analyze the effects of shared influences. We briefly outline how a focus on professional identity may provide a way of talking about national and transnational influences on engineers without determinism, by viewing engineers as ‘responding’ simultaneously to ‘codes of meaning’ that live at different scales, including contrasting and changing metrics of progress and images of private industry. Thus construing the problem of identity as the “management of responses,” we account for distinct patterns in engineering as, in part, responses to codes that have scaled up to the level of popular theorizing amidst different populations, making engineering a project for and about nations. We conclude by briefly assessing some further implications of the analysis of professional identity for work in engineering studies.

National Patterns

Many historians and historical sociologists have persuasively documented national patterns among engineers and engineering knowledge. In doing so, they routinely encounter the problem of accounting for both the development of such patterns, typically construed as national ‘cultures,’ ‘styles,’ or ‘systems,’ and the influences these patterns have on people.

For example, historian Eda Kranakis offers a detailed comparison of what she describes as the distinct “engineering cultures” in France and the United States. She writes,

In France the prevailing view was that mathematical theory should precede and guide both experimental research and design. For the French technologist, ‘theory’ meant, above all, quantitative mathematical theory. In the United States the prevailing view was that experimental research and empirical practice should guide design effort, and that they should emerge from experimental and empirical work. Theory for nineteenth-century American technologists could, moreover, just as well be qualitative and explanatory as mathematical and 'predictive.' [5]

Kranakis outlines the historical development of distinct patterns among engineers and engineering knowledge in the two countries. The French built tightly-linked hierarchies of education and employment, with the *grandes écoles* and state employment at the top, united by the supreme value accorded mathematical analysis. For French engineers, Kranakis observes, "theories could reveal phenomena or functional characteristics of technologies that could not be intuited or fully understood from practice."[6] Such learning should occur in schools. In contrast, in the absence of a rigid social hierarchy and a positive attitude toward manual labor, the Americans built a diverse engineering community whose "principal concern . . . was to achieve material success—that is, to create 'successful' artifacts and to achieve commercial success in the market."[7] For American engineers, the neglect of mathematics bordered on hostility, and what counted as theories were basically conceptual condensations of experience.

Rather than claiming that these engineering cultures were somehow the product of corresponding national cultures, Kranakis argues that distinct sets of "social and institutional factors" were at work, producing shared engineering cultures as outcomes. National differences lay in the different configurations of factors. A key reason for isolating engineering cultures is to show that these could be factors, too. In a concluding account, Kranakis maintains that "the difference between the engineering cultures of the two countries was a factor" in their differential technological development during the 19^{th} century, making France "less dynamic" industrially than the United States.[8]

In a parallel argument, historian John Brown provides a detailed account of differences in the drawing practices of British and American engineers as examples of distinct engineering cultures, this time linked in some way to "national cultures." He argues that "because British and American engineers operated in different social contexts, their applications of plans (and the drawings themselves) came to reflect and reinforce their host cultures."[9] The main difference, according to Brown, was that where British engineers used dimensional plans "as a sophisticated instrument for the design of heavy machinery," the Americans came to use dimensioned plans "as a production-control instrument, to subordinate work and thus shift the balance of power over production from workers to engineer-managers."[10]

Brown explains that, during the late 19^{th} century, American engineers developed a new genre of shop drawings, embodied in blueprints, which, by providing detailed descriptions of how to carry designs through production, were part of a larger process whereby "engineering choices and

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[5] E. Kranakis, Constructing a Bridge: An Exploration of Engineering Culture, Design, and Research in Nineteenth-Century France and America (Cambridge: The MIT Press, 1997), p. 11.

[6] Kranakis, Constructing a Bridge, p. 284.

[7] Kranakis, Constructing a Bridge, p. 282.

[8] Kranakis, Constructing a Bridge, p. 304.

[9] J.K. Brown, "Design Plans, Working Drawings, National Styles: Engineering Practice in Great Britain and the United States, 1775-1945" Technology and Culture (2000), 41(April):195-240, on p. 196.

[10] Brown, "Design Plans," p. 199.

business decisions became inextricably intertwined" in the control of work.[11] British engineers, meanwhile, working in a context in which production was controlled by craftsmen, focused on design drafting as an end in itself, "elevat[ing] creativity as a central professional value." By focusing on "design originality" and "product quality," they "formed a de facto alliance with skilled workers that was antithetical to the control values of American proprietor engineers."[12]

Third, historians Mikael Hård and Andreas Knie mobilize the concept of national engineering 'styles' in order to compare German and French diesel engineers in the early 20th century. Drawing on John Staudenamier's definition of technological style as "a set of congruent technologies that become 'normal' (accepted as ordinary and at the same time as normative) . . . within a given culture,"[13] they find that the German diesel engineers developed such a style but, curiously, the French did not. Whereas "German engineers were preoccupied with defining the diesel engine as a German machine," the comparable French firms, to the authors' surprise, showed a great deal of "flexibility and lack of interest in protecting . . . technical fingerprinting."[14]

Hård and Knie describe how the Germans went about codifying "an engineering 'grammar' meant to create conformity among those who spoke the oil-engine 'language'" and seemed to "have gone consciously out of their way not to pick up any foreign patents or other design solutions"[15] Meanwhile, the French engineers were "multilingual" in that they "had license agreements with different foreign companies" on which they busily worked only to "copy and improve" and a "French 'uniform diesel' was never on the agenda."[16] Hård and Knie do not attempt to account for this patterned difference between German and French industry, except to show that one adopted a grammar to structure their engineering practices and the other did not.

A different approach to comparison appears in an important edited collection comparing 'technical work' in different countries. Sociologists Peter Meiksins and Chris Smith position national influences on engineers as 'forces' that emerge from differential experiences with capitalism, supplementing the forces that emerge from industrial capitalism itself. They assert that

there are . . . powerful forces sustaining national difference. And [the] engineers' role is particularly important here. Engineers are organized differently and follow received wisdom, transforming it in novel ways in different societies. And engineers develop nationally specific ways in response to their own peculiar national version of the internal contradictions and interests generated by the engineers' role. These create national versions of what is best practice.

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[11] Brown, "Design Plans," p. 211.

[12] Brown, "Design Plans," p. 211.

[13] M. Hård and A.Knie, "The Grammar of Technology: German and French Diesel Engineering, 1920-1940" Technology and Culture (1999), 40(January): 26-46, on p. 42.

[14] Hård and Knie, "The Grammar of Technology," p. 42.

[15] Hård and Knie, "The Grammar of Technology," p. 35.

[16] Hård and Knie, "The Grammar of Technology," p. 46.

They are hard to transfer from one society to another, in part because they reflect distinct national recipes of industrial capitalist production.[17]

Contributions to the collection document distinct patterns in the "engineers' role" in industrial capitalism in the U.K., U.S.A., France, Germany, Sweden, and Japan, treating engineering knowledge as a constitutive dimension of engineering work. The editors chastise Marxist and other structuralist approaches for overlooking the significance of national differences in their efforts to articulate the structural characteristics of technical work in industrial capitalism. Indeed, Meiksins and Smith go so far as to claim that "it is impossible to develop a definition of what an engineer is, or where the boundaries of engineering lie, which would apply to all industrial capitalist countries."[18]

At the same time, however, Meiksins and Smith also reject as too limited what they describe as "culturalist" approaches, which seek to explain national differences wholly in terms of engineers' participation in distinct national cultures.[19] "To argue in this way," they contend, "simply inverts the error of those who argue as if structure is everything."[20] In other words, one must not ignore either the transnational influences of capitalism or the contingent products of history. Meiksins and Smith opt for a model they call "structural contingency," which starts with the capitalist structure of production and then adds historical contingency, holding that "under capitalism engineers are shaped by and organized around the central contradictions of capitalism, but that this in no way points to any eventual convergence on a single way of organizing technical labor."[21] National differences count.

Influence and Identity

By finding patterned differences among engineers and engineering knowledge to warrant explicitly comparative work, all of the above accounts directly confront the conceptual problem of influence. In a poststructuralist era that privileges case study analyses of movements from states of heterogeneity to states of order, any effort at systematic comparison becomes a risky endeavor. To propose or posit a mechanism of influence is to raise the specter of determinism, through which historical actors lose the agency that they have only so recently gained. The conceptual and methodological problem of influence, in fact, tends to be so salient in comparative work that researchers have come either to avoid such work completely or to limit comparison to the simpler activity of juxtaposing described outcomes.

The authors of the above comparative accounts are clearly well aware of these risks. For while all four do posit some sort of deterministic influences, in the form of 'factors,' 'cultures,'

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[17] P. Meiksins and C. Smith, "Introduction: Engineers and Comparative Research" Engineering Labour: Technical Workers in Comparative Perspective, edited by P. Meiksins and C. Smith (London: Verso, 1996), p.20.

[18] Meiksins and Smith, "Introduction," p. 3.

[19] Meiksins and Smith, "Introduction," p. 18.

[20] P. Meiksins and C. Smith, "Engineers and Convergence," Engineering Labour: Technical Workers in Comparative Perspective, edited by P. Meiksins and C. Smith (London: Verso, 1996), pp. 256-285, on p. 254. On similar grounds, Meiksins and Smith would presumably be skeptical of efforts to posit influences on engineers from distinct 'engineering cultures.'

[21] Meiksins and Smith, "Engineers and Convergence," p. 253.

'grammars,' or 'forces,' they also take great pains to soften or diversify the determinism by re-injecting agency as unique 'mixes' of factors, 'reflections' of cultures, 'styles' that do or do not appear, or historical 'contingencies' that inflect forces. In a way, these works are all taking the position, indeed with considerable courage, that it is better to dance with determinism than to ignore national differences in engineering. The implicit claim appears to be that to ignore patterns of difference among engineers and engineering knowledge just might be to miss their most important characteristic.

Is it possible to accept the problem of influence but resist the specter of determinism? One potential pathway may be to distinguish moments of influence from moments of reaction and, accordingly, to separate what comes out of the person from what goes in. In other words, rather than thinking of engineers as passively sharing cultures or grammatical styles, or simply manifesting structural interests or factors, it may be helpful to construe engineers as actively 'responding' to the cultures, styles, interests, or factors that confront them. Thus, 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 have to 'respond' to the value placed on mathematical or practical knowledge, respectively. That engineers may do so differently from one another illustrates the separation between the shared historical experience of influences as challenges, expectations, or pressures and the diversity that emerges in events of affirmation, resistance, and transformation. Distinguishing influences from reactions also has the effect of making influences, in principle, comparable to one another.

We use the term 'code' to label the influences that are salient in patterns of engineers and engineering knowledge. One reason for this choice is that, in close to everyday terms, the idea of code fits the sense that scaled-up meanings, or 'dominant images,' pose challenges that one ignores at one's peril—one has to 'deal with' a code. Also, the concept of code construes responses as projects of categorization and identity formation more easily than the concepts of 'discourse' and 'narrative,' which tend to fix the contents of response stories when the latter have yet to be told. One limitation in the concept of code is that it conveys too strong a sense of boundedness, but this worry tends to erode when the focus of analysis becomes following codes that live at different scales.

In this way of thinking, one would expect engineers, as people, to have to respond to images living at small scales amidst narrowly-defined engineering communities, images that have scaled up to the level of dominant popular theorizing defining 'national' populations, and images that live or emerge in transnational spaces. Remember, for example, the Egyptian engineer trying to reconcile the felt responsibilities of consulting and fatherhood. He was also responding to what counts as good electrical engineering. One might say this engineer was 'code-switching' in the sense that he found himself jumping back and forth on a regular basis, comparing himself against himself in terms of different codes. Here code-switching refers to the search for congruences and contradictions in the meanings that potential alternative reactions such as expanded consulting or spending extra time with the children might have in terms of different codes.[22]

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[22] Linguistic anthropologists describe code-switching as situationally-specific movements back and forth between natural languages, or linguistic 'codes.' In the anthropology of science, Rayna Rapp uses the concept to point to the co-presence of different cultural codes in everyday life. Her use is part of a larger project demonstrating that, in everyday life, "the hegemony of the scientific model can never be absolute" (R. Rapp, Testing Women, Testing the Fetus: The Social Impact of Amniocentesis in America [New

Can a polysemic pathway be found that meets all the expectations and, thus, appears to merge distinct influences together into a single influence?

That engineers have unique life trajectories necessarily makes variability and difference among them the default expectation. At the same time, populations of engineers responding to similar configurations of challenges or expectations may respond in somewhat predictable ways, yielding what the anthropologist Stefan Helmreich has labeled in another context 'interference patterns.'[23] Interference patterns merge issues of knowledge and personhood together in engineering identities that may scale up, scale down, or maintain the level of influence of particular codes or images.

The identity politics of engineers is always ontological work, positioning engineers as entities in the world amidst other entities. A code or image is also a representational project, for battles over entities are battles over representation, the authority to refer. For example, German engineers worked throughout the 19th century to increase their importance by simultaneously repositioning the identity of 'technics.' When the view gained full force under National Socialism and the Third Reich that technics emanate from the deepest impulses of the German people rather than from Western materialism more generally, engineers were finally able to establish themselves as [among those] essential to the German nation [see below]. As projects of objectification, the identities of engineers also imply their agencies, for as the anthropologist Tanya Luhrmann observes, the identity of a person "answers the question 'who am I?' by asking 'what can I do in this world?[24]

York: Routledge 1999], p.79). In an account of Spanish-English bilingualism in lower Manhattan, Ana Celia Zentella argues that its most important feature is that "[c]ode-switching is so maligned" (A.C. Zentella, Growing Up Bilingual: Puerto Rican Children in New York City [Oxford: Blackwell 1995], pp. 4-5). The examples of Spanglish and TexMex, whose very labels approach accusations, provide cases in point. Such malignment leads her attention to the relationship between language use and identity. We are focusing on a case of such malignment, code-switching between academic and popular arenas to legitimize modes of engineering knowledge and personhood.

[23] S. Helmreich, "After Culture: Reflections on the Apparition of Anthropology in Artificial Life, a Science of Simulation," Cultural Anthropology (2001) 16 (4): 612-627, on p. 621.

[24] Luhrmann, *op. cit.*, note 2, p. 7156. With this concept of identity as projects of objectification, we are endeavoring to avoid distinguishing between objective positioning and subjective self-understanding. Indeed, in this way of thinking, acting in terms of self-understanding is integral to the process of objective positioning. In a way, this approach to identity generalizes the process Joseph Dumit labels "objective self-fashioning," or the fashioning of selves through facts, by viewing identification as always about objectification and, hence, involving identity politics. See J. Dumit, "A Digital Image of the Category of the Person: Pet Scanning and Objective Self-Fashioning," Cyborgs and Citadels: Anthropological Interventions in Emerging Sciences and Technologies, edited by G.L. Downey and J. Dumit (Santa Fe: School of American Research Press, 1997), pp. 88-89. We are also linking to the current trend to see the self as multiple. For other discussions of identity and agency, see D. Holland, et al., Identity and Agency in Cultural Worlds (Cambridge, MA: Harvard University Press, 1998); D. Kondo, Crafting Selves: Power, Gender and Discourses of Identity in a Japanese Workplace (Chicago: The University of Chicago Press, 1990); K.J. Gergen The Saturated Self: Dilemmas of Identity in Contemporary Life (New York: Basic Books, 1991). A rich history exists of efforts to 'socialize' the idea of a person or self, beginning especially with G.H. Mead, Mind, Self, and Society from the Standpoint of a Social Behaviorist (Chicago: The University of Chicago Press, 1934).

Finally, in this way of thinking, efforts to change engineering identities involve marketing work, for building a new identity involves both reformulating labels for engineers and engineering knowledge and scaling these up by convincing others to use them. For example, engineering reformers in the United States following Sputnik (October 1957) who wanted to remake engineering education in terms of the sciences had to convince other engineers that making such a significant change was both necessary and important in order for the idea to scale up. That such reformers were responsive code-switchers is suggested by the fact that in popular theorizing Sputnik had been categorized as a success of science, not engineering. For them to have moved in any other direction would have risked a serious decline in the status of engineering work.

The Parsing of Progress

What sorts of codes might have scaled up to the level of popular theorizing differently in different populations, and to which engineers may have responded in patterned ways? Historian Antoine Picon offers a key insight when he shows that, at their historical point of origin, French engineers distanced themselves from architects by successfully embracing and identifying themselves with the concept of 'progress.' "Engineers believed firmly in progress," he writes. For them, "calculation was rightly identified with progress, the progress of the human mind, economic and social progress . . ." [25] Similarly, in describing the emergence of engineering analysis in 18th century France through the artillery corps, historian Ken Alder describes its operational method as geared to making things better, namely: "to describe quantitatively the relationship among measurable quantities, and then to use these descriptions to seek a region of optimal gain." [26] In other words, just at the time when words shifted from resembling things to referring to them as objects, people came into visibility as humans, the world became populated with sets of natural and human-made objects, and humanity gained the capacity to 'advance' through human intervention in God-created nature, so engineers gained distinctive identities as people.[27]

Importantly, however, what came to count as progress was not the same everywhere. The late 19th century French engineer, Gustave Eiffel, distinguished the French mathematical approach to engineering from the British emphasis on experiment and trial and error by claiming "we have had the honor in France to surpass them by far in the theory and to create methods which open up a sure path to progress, disengaged from all empiricism."[28] In other words, progress could come only when engineering was disengaged from empiricism. Meanwhile, on the other side of the Channel, the famous British engineer I.K. Brunel had long been suspicious of French engineering, positioning interest in mathematics as perhaps enjoyable but not particularly relevant, as he wrote to one young colleague:

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[25] A. Picon, French Architects and Engineers in the Age of Enlightenment (Cambridge: Cambridge University Press, 1992), p.150, p.338.

[26] K. Alder, Engineering the Revolution: Arms and Enlightenment in France, 1763-1815 (Princeton: Princeton University Press, 1997), p.60.

[27] M. Foucault, The Order of Things: An Archaeology of the Human Sciences (New York: Vintage Books, 1970); M. Foucault, Discipline and Punish: The Birth of the Prison (New York: Pantheon Books 1977); L. Dumont, Homo Hierarchicus: The Caste System and Its Implications, translated by Mark Sainsbury (London: Weidenfeld & Nicolson, 1970).

[28] Quoted in Kranakis, Constructing a Bridge, p.278.

I must caution you strongly against studying *practical* mechanics among French authors—take them for abstract science and study their statics dynamics geometry etc. etc. to your heart's content but never even read any of their works on mechanics any more than you would search their modern authors for religious principles. A few hours spent in a blacksmiths and wheelwrights' shop will teach you more practical mechanics—read *English* books for practice—There is little enough to be learnt in them but you will not have to unlearn that little.[29]

In other words, the new dominant image of progress scaling up across Europe and its colonies did not stipulate the metrics for documenting how humanity was progressing and, hence, what one should do to make it progress. Populations separated by geography and language scaled up different metrics, and the parsing of progress helped constitute images of national identity.

The possible pathways for progress were, and continue to be, enormously variable. One possibility was to find nature to provide direct evidence of God's perfection and then organize society to advance by getting closer to nature. That is, progress could be teleological, a movement *toward* a pre-conceived ideal, a perfect social order. Another possibility was to picture progress as a movement *from*, as systematic 'improvement' in human existence, evidenced by the material comforts achieved by its most advanced members, measured by their relative distance from manual labor. In other words, an image of evolutionary progress could operate within a population as the differential advancement of social classes. A third possibility was to see progress as movement from the inside of human beings *outward*, as progressive emancipation of the God-created perfection of mind and spirit immanent in all human beings. Progress could be measured by the extent of this emancipation, or release and adoption into the public fabric of human society. A fourth possibility was to see progress as improved material comfort, but measured this time by the enhanced well-being *of the masses* rather than the most elite sectors of society. Furthermore, the influences from a given metric change over time as images of the present change, and responses to any given metric vary greatly at a given point in time since how one construes desirable futures depends upon where one locates the present. Consider a brief sampling of evidence lending some plausibility to the idea that engineers in different countries have responded to distinct images of progress in building patterns of engineering knowledge and personhood.

Metrics of progress

In France, engineers who came to place high value on mathematical knowledge and the derivation of new technologies from first principles were arguably responding to the first metric, a teleological image of progress. Picon, for example, beautifully describes how 18th century engineers linked freeing society from the irrationalities of aristocratic and ecclesiastical privilege with the rationalization of the rural countryside. "This accident-ridden terrain," he observes, "was replaced by that of the developer, who filled in ravines and leveled mountains, just as politics abolished obsolete privileges and compartmentalizations." [30] Historian Wolfhard Weber, explains that Gaspard Monge, the "father of the École Polytechnique" which was founded during the French Revolution, explicitly saw mathematical theory as a key tool for steering the present by enabling clear descriptions of the future:

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[29] Quoted in R.A. Buchanan, The Engineers: A History of the Engineering Profession in Britain, 1750-1914 (London: Jessica Kingsley Publishers, 1989), p. 163.

[30] Picon, French Architects and Engineers, pp. 253-4.

Monge himself insisted that descriptive geometry was an answer to the French nation's requirements. He said that this science had two aims. First, it would make it possible to represent three-dimensional objects in two dimensions, which was of course most important to designers. Second, Monge could fix the exact site of objects and of their several parts, and how they fit together. In this way, he brought together a series of factors fundamental . . . as he put it, for progress. He advocated rationalization of the work process by strict observance of the prescription, by execution of scientific knowledge, by quantification, and by the introduction of machines.[31]

An image of progress as advancement towards an ideal future had arguably scaled up among the literate public long before establishment of the École Polytechnique. In the 17th century, Descartes had established the idea that nature could be seen as a huge mechanism, analyzable in mathematical terms, and 18th century *philosophes*, the supreme ontological marketers, had facilitated the scaling up, or popularization, of rationality as an ideal. Progress was about fulfilling everywhere the rationalities that artillerists, as Ken Alder demonstrates, were accomplishing inside the Old Regime.

A scaled-up imagination of progress thus may have served as a key source of popular influence and, hence, legitimacy as engineering analysis based in abstract mathematics gained authority as a key tool of the nation state for theorizing and enacting a march toward perfection.[32] French administrators built parallel structures of education and employment, with engineering schools and state employment at the top. Higher ranked than universities, the elite engineering schools limited admission to top performers on the mathematically-intensive *concours,* an exam scored by such graders as Auguste Comte, who in his leisure time wrote about history progressing according to a law of three stages.[33] Staffed by graduates of elite schools, the state administration became the major agent for perfecting society, especially by developing national infrastructures of transportation, communications, and energy technologies. The authoritative position of the state administration remained stable even as the French battled over who would

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[31] W. Weber, "German 'Technologie' versus French 'Polytechnique' in Germany, 1780-1830," Technological Education-Technological Style, edited by M. Kranzberg (San Francisco: San Francisco Press, 1986), pp. 20-25.

[32] Since the dominance of a dominant image is a matter of scale, perhaps the best way to document its presence and influence is to record its presence and influence beyond engineering arenas. For example, in describing at length French efforts to reform society during the 19th century, anthropologist Paul Rabinow regularly characterizes reform efforts as enacting a movement 'towards.' Such is implied in such statements as "History for Saint Simon had a telos" and De Gérando and the Ideologues held that "human history led through stages to an increasing perfection" (P. Rabinow, French Modern: Norms and Forms of the Social Environment [Cambridge: The MIT Press, 1989], p. 28, p. xx). Also, historian of technology Rosalind Williams describe French efforts to position and justify the rise of mass consumption in France as a search for ideals in terms of which the spreading interest in consumption would be more than an insinuation in France of crass self-interest (R. Williams, Dream Worlds: Mass Consumption in Late Nineteenth-Century France [Berkeley: University of California Press, 1982]). Finally, historian of technology Gabrielle Hecht explains in The Radiance of France how nuclear power was interpreted as a pathway toward building a more perfect society (G. Hecht, The Radiance of France: Nuclear Power and National Identity after World War II [Cambridge: MIT Press, 1998]).

[33] A. Comte, Introduction to Positive Philosophy, translated by Frederick Ferre (Indianapolis: Bobbs-Merrill, 1970).

get to define the ideal future, producing a dizzying mix of two Empires, three Restorations, and five Republics in a two-hundred year period.

One way to follow how the responses of engineers to metrics of progress changed over time is to explore their changing fears, for different fears in the present suggest different audiences for advocacy about the future. Where the concern during the Revolution was a return to the irrationalities of the past, a mere thirty years' later the dominant concern was 'backwardness' in industry, relative to England. When Alphonse Lavallée, a wealthy landowner also involved in shipping, offered to fund an engineering school in the private sector, the possibility existed for a whole new metric of progress to scale up across France. After all, English industry had established clear superiority, and Lavallée offered a vision shared by many that a new emphasis on the private sector was the only solution. Indeed, establishment in 1829 of the École Centrale des Arts et Manufactures offers evidence of an emerging transnational influence on French engineers from industrial capitalism.

But establishing a school to solve the problems of the present is a tip-off that its founders were responding to a configuration of influences distinct from British engineers, for the latter were not trained in schools. The French had established a pattern of training leaders whose merit matched the key problems of the time. The main issue at stake was the definition of the problem and, hence, the appropriate merit. As historian John Weiss explains, the École Centrale was designed to produce an army of engineers in the private sector who would better Britain's "uneducated industrialization" with an approach to industry that would achieve "greater efficiency" by placing highest priority on "a systematically reasoned common education."[34] Rather than replicate British craft-based industry, they sought to conceptualize and teach a new "industrial science, so that private industry could become the key site of rationalization."[35] But in the midst of attempting a challenge to the École Polytechnique, they also reaffirmed the consummate value of mathematics. And when, two decades later, they successfully convinced the French state to take over the school, they also reaffirmed the lower status accorded the private sector in France.

One can detect continued influence from a teleological image of progress when the establishment of new schools for electrical and chemical engineering in the 20th century were responses, as sociologist Stephen Crawford puts it, to "fear of German industrial might" or when engineers in private industry today "greatly value industrial efficiency" and are seen as "impressive technical officer[s] in the nation's industrial army."[36] When Hard and Knie found 20th century diesel engineers in the private sector to not care particularly about establishing a distinct technological style, perhaps they had also discovered evidence that private industry, despite its relative size as primary host for engineering employment, was still subordinate to the state as a key site for advancing French progress. To this day, as the journalist Jean-Louis Barsoux wrote in 1989, "In France, engineering education does not play second fiddle to medicine, law, or architecture—it is *the* recognized way to the top, both socially and professionally." [37] But it is also important to

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[34] J. H. Weiss, The Formation of Technological Man: The Social Origins of French Engineering Education (Cambridge: The MIT Press, 1982), pp. 223, 224.

[35] Weiss, The Formation of Technological Man, pp. 89-122.

[36] S. Crawford, "The Making of the French Engineer," Engineering Labour: Technical Workers in Comparative Perspective, edited by P. Meiksins and C. Smith (London: Verso, 1996), p. 111, 126, 122.

[37] Barsoux, Jean-Louis, 1989, "Leaders for Every Occasion," IEE Review (January), p. 26.

recognize that the huge military parade in Paris each year on Bastille Day, commemorating the accomplishments of the Republic, is led by 2nd year students from the École Polytechnique, not the École Centrale.[38]

In contrast with the French, British engineers have grappled with a dominant metric of progress as self-directed 'improvement' over the past, demonstrated especially by material comforts and elevated character in the lives of elites, measured especially by the distance achieved from manual labor. William Clark, Jan Golinski, and Simon Schaffer point out, for example, that "the key term of the Scottish version of Enlightenment was 'improvement.'"[39] In British contexts, what scaled up to the level of popular theorizing was not the perfectibility of society but the importance to society of the self-directed 'individual.' Progress to humanity would come as the collective product of progress achieved by individuals originating in a hierarchy of class identities. In other words, for lower classes to progress, they had to evolve and gain the trappings of upper classes.

Industrialization in Great Britain in the late 18th and 19th centuries was not an activity of the elite aristocracy, nor was it in the purview of the state. As sociologists Chris Smith and Peter Whalley explain, industrialization was a phenomenon of aspiring artisanal classes operating entirely in the private sector:

British industrialization was not, as it was elsewhere in Europe, the result of state intervention or direction; nor was it, as in the United States, the work of an economic and social elite which could culturally appropriate the national symbols of a new society. Far from it, the Industrial Revolution in Britain was carried out by master artisans, the self-made man, the tinkerer and the

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[38] For additional work on engineering in France, see S. Crawford, Technical Workers in an Advanced Society: The Work, Careers and Politics of French Engineers (Cambridge and Paris: Cambridge University Press, 1989); C. R. Day, Education for the Industrial World: The Ecoles d'Arts and Metiers and the Rise of French Industrial Engineering (Cambridge: MIT Press 1987); R. Fox, 1986, "Contingency or Mentality? Technical Innovation in France in the Age of Science-Based Industry," Technological Education--Technological Style, edited by M. Kranzberg (Cambridge: Cambridge University Press, 1986); R. Fox and G. Weisz, The Organization of Science and Technology in France, 1808-1914 (Cambridge: Cambridge University Press, 1980); A. Grelon, "The Training and Career Structures of Engineers in France, 1880-1939," Education, Technology and Industrial Performance in Europe, 1850-1939, edited by R. Fox and A. Guagnini (Cambridge: Cambridge University Press 1993), pp. 42-63; Herlea, Alexandre, "Advanced Technology Education and Industrial Research Laboratories in 19th Century France: The Example of Conservatoire des Arts et Metiers in Paris," Technological Education--Technological Style, edited by M. Kranzberg (Cambridge: Cambridge University Press 1986), pp. 49-57; E. T. Layton,"European Origins of the American Engineering Style of the Nineteenth Century," Scientific Colonialism, edited by N. Reingold and M. Rothenberg (Washington, D.C.: Smithsonian Institution, 1987); T. Shinn, "From 'Corps' to 'Profession': the Emergence and Definition of Industrial Engineering in Modern France," The Organization of Science and Technology in France, edited by R. Fox and G. Weisz (Cambridge and Paris: Cambridgey University Press, 1980); Walsh, John, "French Reforming Higher Education—Again," Science (1982) 216(21 May):834-5; W. Weber, "German 'Technologie' versus Frence 'Polytechnique' in Germany, 1780-1830, Technological Education--Technological Style, edited by M. Kranzberg (Cambridge: Cambridge University Press, 1986), pp. 20-25.

[39] W. Clark, J. Golinski, and S. Schaffer, "Introduction," The Sciences in Enlightened Europe edited by W. Clark, J. Golinski, and S. Schaffer (Chicago and London, The University of Chicago Press, 1999), p.22.

craftsman. It was craftsmen, not formally trained engineers, who built the steam engineers, the textile machinery, and the machine tools that gave Britain technological and economic mastery in the first half of the nineteenth century.[40]

A state-led approach to harnessing nature for material comforts would have had difficulty finding legitimacy. Accomplishments in social life had long been measured in terms of their distance from centralized control by the state, dating back as far as the Magna Carta, and now the image of self-help had scaled up. *Laissez faire* clearly made more sense in a British than a French context.

The British thus developed a distinctive 'trickle-up' approach to improvement through industry. Not only would increasing affluence enable artisans and industrialists to advance and move up, producing improvement in humanity, but industry itself was organized around the small-scale production of quality goods. As John Brown explains, in contrast with an emerging American commitment to standardization for the purposes of mass production, British industry focused on methods of batch manufacturing, organizing around the craft administration of work. Similarly, Smith and Whalley assert that "The organization and control of production was largely in the hands of craftworkers who regulated both the methods and amount of output with little or no input from employers."[41] This pattern continued into the twentieth century as "British industry continued to focus on what it thought of as quality, small-scale production rather than mass production."[42] Indeed, perhaps even the large transportation projects of the early 19^{th} century can plausibly be read as responding to a trickle-up image of human improvement, for to progress the elite classes needed the outputs of production to be transported efficiently and for the working classes to be able to reach the new places of work. An industrial revolution that furthered the comforts of the elite classes could plausibly be counted as evidencing progress for humanity as a whole provided the well-being of the lower classes had a chance to improve as well.

Some people identified with the artisanal classes responded to the meaning of progress and emerging image of private industry by advancing themselves as engineers. As historian R.A. Buchanan explains, "[P]roto-professional engineers were a very motley crew. They came from a wide variety of backgrounds, with different sorts of training—even with no particular training at all. Most of them began their careers as some type of craftsmen: millwright, stonemason, instrument maker, and such like."[43]

British engineers latched onto the image of the autonomous professional, whose identity linked "an emphasis on learning by practical experience" with the status of gentlemen. The emphasis on practical education was detailed by an 1870 report by the Institution of Civil Engineers on the "The education and status of civil engineers, in the United Kingdom and in Foreign Countries,"

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[40] C. Smith and P. Whalley, "Engineers in Britain: A Study in Persistence," Engineering Labor: Technical Workers in Comparative Perspective (London: Verso, 1996), p.31

[41] Smith and Whalley, "Engineers in Britain," p32.

[42] Smith and Whalley, "Engineers in Britain," p36

[43] quoted in R.A. Buchanan, The Engineers: A History of the Engineering Profession in Britain, 1750-1914 (London: Jessica Kingsley Publishers, 1989), p. 44

Every candidate for the profession must get his technical, like his general education, as best as he can; and this necessity has led to conditions of education peculiarly and essentially practical, such being the most direct and expeditious mode of getting into the way of practical employment . . . The education of an Engineer is, in fact, effected by a process analogous to that followed generally in trades, namely, by a simple course of apprenticeship, usually with a premium, to a practicing Engineer, during which the pupil is supposed, by taking part in the ordinary business routine, to become gradually familiar with the practical duties of the profession, so as at last to acquire competency to perform them along, or, at least, after some further practical experience in a subordinate capacity . . . It is not the custom in England to consider theoretical knowledge as absolutely essential . . . ."[44]

Brown found the emphasis on craft knowledge in engineering drawings without dimensions. Smith and Whalley point out that "engineering's origins in the manual craft's control of production remains an important current influence in Britain long after such traces have disappeared elsewhere."[45]

By all accounts, the main strategy for linking engineers to gentlemen was the professional society, or institution. An institution that received a charter from Parliament, established clear rules for membership, and met regularly to share knowledge in a club-like atmosphere showed promise of locating engineers alongside physicians, lawyers, and the clergy as members of an autonomous, self-regulating profession. Tracing the efforts of engineers to increase their status, Buchanan finds that "from the outset there was an inclination to emphasize the qualities summed up in the English concept of a 'gentleman' as those which were appropriate to membership in the profession. This was not so much snobbishness as a recognition of the value of 'character,' 'integrity,' 'reliability,' and such like, amongst people who were striving to assert their professional self-consciousness in a competitive and enterprising society."[46]

However, while some engineers successfully achieved the upward mobility that marked progress, engineering practice never escaped its close association with manual labor and, accordingly, the engineering institutions have to this day met with uneven success in scaling up a professional image of engineers. Even the children of relatively prominent 19th century engineers trended to avoid careers in engineering. Smith and Whalley, referring generally to successful artisans and industrialists, explain that Brtain's traditional agricultural elites typically assimilated them: "In this case it meant that industrialists and their children had to accept the cultural iconography of the 'gentleman.' Gentlemen lived, where possible, on their country estates; sent their children to the renascent public schools to be educated in classics; favored, if working was necessary at all, public or colonial administration, banking or the newly respectable professions of medicine or law; and rejected as inferior the socially tainted aspects of industry that involved engineering or production."[47] Referring specifically to engineers, Buchanan

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[44] Buchanan, The Engineers, p.169.

[45] Smith and Whalley, Engineers in Britain, p. 37.

[46] Buchanan, The Engineers, p.

[47] Smith and Whalley, Engineers in Britain, p. 31.

laments the "hemorrhage of talent" through which the children of engineers "tended to disperse rapidly into other professions and occupations."[48]

In a population in which one's progress was indicated by the distance one achieved from manual labor, the idea of an elite engineer committed to practical training and knowledge was almost a contradiction in terms. The polytechnic institutes that emerged in the late 19th century in response to perceived threats from the United States and Germany were located below universities, and unions were eventually more successful than professional societies at speaking for engineers in the workplace. In short, responding to a metric of progress focused on material improvement, engineers produced a pattern that established a passionate attachment to practical knowledge and a permanent struggle for higher status. To this day, as Smith and Whalley put it, "their identity remains tainted with manual connotations."[49] In a BBC poll taken in 2002, the British public scandalously voted I.K. Brunel as the 2nd "Greatest Briton" of all time, behind Churchill but well ahead of Diana, Darwin, Shakespeare, Newton, Elizabeth I, Lennon, Nelson, and Cromwell. One must remember, however, that Brunel's most celebrated work, the Great Western Railway, was explicitly to serve members of the upper classes.[50]

Germany offers an especially interesting case in which systematic increases in the statuses of engineers were linked to an equally significant change in the identity of industrial production. Since the mid-19th century, identity politicians among German engineers have grappled with an evolving image of progress as an emancipation of *geist*, or human mind/spirit, a freeing of something that is natural to the human essence. During the German Enlightenment, scaling up an image of progress in society displaced a previous preoccupation with high culture (music, art, etc.) as a vehicle for effective competition among German states by replacing it with 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, from whom the Germans adopted the French word *ingénieur* as a label for a diverse mix of new identities that was developing. As in Britain, engineers emerged among the lower-status guilds of artisans, which had long been known for their conservatism. However, responding to the idea of progress through reason, activist engineers sought higher status primarily through education, establishing Higher Technical Institutes for engineering education. Their efforts met with increasing success after unification of the German states in

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[48] Buchanan, The Engineers, p. 194.

[49] Smith and Whalley, Engineers in Britain, p. 55.

[50] For additional work on British engineering, see I. A. Glover and M. P. Kelly, Engineers in Britain: A Sociological Study of the Engineering Dimension (London: Unwin Hyman, 1987); G. Jordon and A.G. Jordon, Engineers and Professional Self-Regulation: From the Finneston Committee to the Engineering Council (Oxford: Clarendon Press, 1992); G. Lee and C. Smith, eds., Engineers and Management: International Comparisons (London: Routledge, 1992); K. McCormick, "Engineers, British Culture and Engineering Manpower Reports: The Historical legacy Revisited," Manpower Studies (1981) (Spring):131-5; Smith, Technical Workers: Class, Labour and Trade Unionism (London: Palgrave Macmillan,1987); M. J. Wiener, English Culture and the Decline of the Industrial Spirit, 1850-1980 (Cambridge: Penguin Putnam, 1981); P. Whalley, The Social Production of Technical Work,(State University of New York Press, 1986); P. Whalley, "Constructing an Occupation: The Case of British Engineers," Current Research on Occupations and Professions (1987) 4:3-20.

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 offers a story of the rapid rise of high-quality German industry, especially the steel and chemical industries.

The idea of explicitly 'national' progress emerging, in a way, from the inside out, as an unfolding of features essential to the German people, is illustrated by the fact that Germans resisted development of a patent system. As historian Karl-Heinz Manegold explains in describing the debate over the imperial patent law of 1877, the inventor could not 'own' something that in fact belonged to humanity as a whole:

"[I]nventors and engineers, following the socially influential value systems underlying the prevailing notion of education, were regarded as mere executors of an immanent technical progress that occurred of itself; therefore they could not rely on a principle of 'intellectual ownership' like artists and writers. Indeed when the patent law was finally enacted it was not on the grounds of 'intellectual property',' a juridical construction of legal theory, but solely on the grounds of economic and national political arguments."[51]

The image of industry that scaled up after unification thus differed greatly from the British image of a site for improving society through the maximization of self-interest.

Engineers responded to the image of progress through technics and the new national emphasis on industry by building a specifically technical and scientific domain of knowledge that was as sharply contrasted with 'pure' as with 'applied' science and 'mere empiricism.' As Manegold explains, their main goal was to distinguish German from mathematical French engineering by developing an arena of "scientific technology":

The task . . . was to reach an autonomous area of scientific technology in which it should become possible to reconcile scientific theory and the empirical practice of the trades; that is, in the conviction that technical science was not the same as applied science, in opposition to the view of the École Polytechnique in Paris.

To argue that progress could only be conveyed in mathematical form would suggest that the source of progress lay outside of the German people. German *geist* would have no significance or play no role. "The engineer would become scientifically bankrupt, so it was argued," reports Manegold, "if 'scientific' merely meant 'mathematical' or one-sidedly like 'mathematical-scientific'[52]

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. In 1904, the German engineer Max Eyth argued in *Living Forces* contra the Hegelian philosophers and Prussian lawyers that technology rather than reason should be seen as the vehicle for the unfolding of '*geist*', or mind/spirit. Historian Jeffrey Herfe summarized Eyth's claim that "there was more *Geist* in a beautiful locomotive or electric motor than in the

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[51] K. Manegold, "Technology Academized: Education and Training of the Engineer in the Nineteenth Century," The Dynamics of Science and Technology: Sociology of the Sciences, edited by Krohn, E. Layton, and P. Weingart, (Dordrecht, Holland: D. Reidel Publishing Company, 1978) II:137-158, p.142.

[52] Manegold, "Technology Academized," p. 153

most elegant phrases of Cicero or Virgil. Technology, like poetry, dominates matter rather than serves it. . . . [T]echnology was actually more cultural than culture itself."[53] Work producing quality products in private industry simultaneously also carried national significance because it demonstrated German advancement. To provide engineers for German private industry, they successfully organized a second tier of engineering education, the Institutes of Specialized Higher Education, or *fachhochschulen,* in which 'gaining a feel' for materials became a defining activity. Engineers openly challenged the value of the universities and "praised their own achievements as 'national' ones and engineers as 'pioneers of German value and culture.'"[54] Also, engineers benefited greatly under National Socialism, which repositioned the aristocracy as working against German progress rather than leading it. Finally, 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 successfully gained 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.[55]

Finally, engineers in the United States offer an example of a postcolonial experience in the sense that they have struggled with a derivative metric, transported through colonial relations and then transformed by confronting other meanings in a new national context. Americans found significance in the British metric of progress through improvements in material comfort, but measured this time by the enhanced well-being of people in general rather than of the most elite sectors of society. Differential class status was more of a problem, indicating that all had to

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[53] quoted in J. Herf , Reactionary Modernism: Technology, Culture, and Politics in Weimar and the Third Reich (Cambridge: Cambridge University Press, 1986) p. 159.

[54] Manegold, "Technology Academized," p. 156

[55] For additional work on engineering in Germany, see H.-J.Braun, "Technological Education and Technological Style in German Mechanical Engineering, 1850-1914," Technological Education-Technological Style,edited by M. Kranzberg (San Francisco: San Francisco Press, 1986), pp. 33-39; R. Collins, Randall, The Sociology of Philosophies: A Global Theory of Intellectual Change (Cambridge: Harvard University Press, 2000; K. Gispen, "The long quest for professional identity," Engineering Labour: Technical Workers in Comparative Perspective, edited by P. Meiksins and C. Smith (London: Verso Books, 1996), pp. 132-167; K. Gispen, ,"German Engineers and American Social Theory: Historical Perspectives on Professionalization," Comparative Studies in Society and History (1988) 30 (Summer) 3: 550-74; T. Grose, "Re-engineering in Germany," *Prism* (March 2000):28-30; K. Hernaut, "European Engineers: Unity of Diversity," Journal of Engineering Education (January 1994):35-40; S. Kennedy, "Engineering Education in Germany," Industrial Robot (1996) 23(2):21-24; W. König, "Sciences and Practice: Key Categories for the Professionalization of German Engineers,"Technological Education-Technological Style,edited by M. Kranzberg (San Francisco: San Francisco Press, 1986), pp. 41-7; G. Legg, "Measuring the Cost of Quality: German Engineering at the Crossroads, EDN (1990) 35:59-62; P. Lundgreen , "Engineering Education in Europe and the U.S.A, 1750-1930: The Rise to Dominance of School Culture and the Engineering Professions," Annals of Sciences (1990) 47:33-75; H. Schulze, Germany: A New History (Cambridge: Harvard University Press, 1998); R. W. Staufenbiel, "German Education in Mechanical Engineering from the Perspective of RWTH Aachen," International Journal of Engineering Education (1993) 9(1): 29-42; R. Taurit, "German Engineering Education from a Fachhochschule Perspective," International Journal of Engineering Education (1993) 9(1):21-28; E. Wächtler, "Causes and Problems of the Institutionalization of the Technical Colleges in the 18th Century," Technological Education-Technological Style,edited by M. Kranzberg, San Francisco, CA.: San Francisco Press, 1986), pp. 15-19.

progress; if only some did, the result would be unacceptable inequality rather than desirable societal progress. The French metric of progress never had much of a chance, for the teleological idea of advancement toward a future state of perfection and the method of government-led advancement could not scale up in a population for whom the image of centralized governmental authority was associated with the colonial past. "American fear of centralized government, born under English rule," historian Terry Reynolds writes, "produced a weak federal government."[56]

American historians regularly point to the conclusion of the Civil War, or 'War of Southern Independence.' as bringing the so-called "early national" period to a close and, hence, initiating a fully national identity. The 1870s and 1880s in particular mark the scaling up of an image of progress in terms of increased standards of living for all, including the South, marked by the expansion of private industry selling lower-cost goods for mass consumption. For example, in From the American System to Mass Production, 1800-1932, historian David Hounshell reports that between 1874 and 1880, the annual production of sewing machines by the Singer Manufacturing Company doubled from a quarter of a million to over half a million. "[T]he company," Hounshell explains, "was feeling the pressures of mass consumption to an extent unknown to most American manufacturers of that time."[57] Also, in A Nation of Steel: The Making of Modern America, 1865-1925, historian Thomas Misa describes the enormous increase in demand for steel in the 1870s and 1880s, especially for railroads. "Responding to wide shifts in demand," he reports, "the industry transferred and adapted the Bessemer process to yield the reckless mass production of steel rails. This emphasis on high-volume, low-quality production . . . set . . . in motion a series of events that distinguished the U.S. steel industry in size and character from its European rivals."[58] The story is repeated many times over in virtually every industry. Hounshell goes on to explain efforts in the McCormick reaper and bicycle industries to meet growing demand, leading to Henry Ford resounding success with the Model T, explicitly designed as the "car for the masses."[59]

In the first half of the 20th century, industrial corporations explicitly identified themselves with national welfare through the distribution of low-cost goods for mass consumption. For example, historian David Nye shows how, through advertising in the 1920s, General Electric made itself "appear the guarantor of low electrical costs":

General Electric wove its name into the fabric of American mythology. . . . General Electric thereby became an engine of history, an integral part of the culture, which could later claim,

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[56] T.S. Reynolds, "The Engineer in 19th-Century America," The Engineer in America: A Historical Anthology from *Technology and Culture*, edited by T.S. Reynolds (Chicago and London: The University of Chicago Press, 1991), p.11.

[57] D. Hounshell, From the American System to Mass Production, 1800-1933: The Development of Manufacturing Technology in the United States (Baltimore and London: The Johns Hopkins University Press, 1984), p.122.

[58] T. Misa, A Nation of Steel: The Making of Modern America, 1865-1925 (Baltimore and London: The Johns Hopkins University Press, 1995), pp. xx-xxi.

[59] Hounshell, From the American System, p.9.

'Progress is our most important product.' The corporation ceased to be a private interest; it became America.[60]

But perhaps the most prominent indicator of the distinctive American linkage between progress and private industry was accomplished by General Motors, which successfully displaced Ford during the 1920s with its strategy of "a car for every purpose and every purse."[61] By the 1940s, it was difficult to question the widespread slogan, "What is good for G.M. is good for America."

The evolution of engineers and engineering knowledge in the United States is marked at once by great diversity and what might be seen as a patterned continuity. On the one side, as Reynolds shows, the history of engineering during the early national period involved a developing and diverse tension between British and French patterns in civil, and then mechanical, engineering. Managers of the Erie Canal, constructed during the period 1816-1825, emulated the British in established a system of practical, on-the-job training for engineers that was used throughout the 19th century. Kranakis explained above the American hostility toward mathematics and an understanding of theories as "conceptual condensations of experience." Meanwhile, establishment of West Point in 1802 on the model of the École Polytechnique initiated a pattern of training in schools that regularly involved struggles over how much engineering science and theory to teach, and in what way. And indeed, by the 1880s the so-called 'shop culture' was giving way to the 'school culture' in engineering training.

On the other side, however, the patterned continuity that emerged during the 1870s and 1880s was the link between engineering and private industry. In other words, engineering in the United States came to be about advancing private industry, not simply as workers subservient to controlling captains of industry but as workers contributing, as they understood it, to human progress, progress that just happened to be parsed by a distinctively national population. The story of engineers and engineering knowledge through World War II is a story of engineers positioning themselves inside the industrial corporation. As Reynolds explains,

Engineers . . . gradually accommodated themselves to the emergence of the large corporation as the locus of engineering work in 20th century America. They did this by increasingly aligning themselves with the aims and aspirations of their companies. By mid-century, professional standing for many engineers had become identical with corporate standing. The approval of one's superiors in corporate or governmental hierarchies become more important than the approval of one's technical peers, contrary to the values of the traditional professions of law, medicine, and the clergy.[62]

However, as Peter Meiksins demonstrates, focusing struggle inside the corporation produced a 'house divided,' i.e., a separation between communities of elite engineers who measured their success as ascension up the corporate ladder, and rank and file 'middle workers' mediating capital and labor, with a commitment to forms of knowledge that made mass production work.[63]

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[60] D. Nye, Image Worlds (), p.133.

[61] quoted in Houshell, From the American System, p. 13.

[62] Reynolds, T.S., "The Engineer in 20th-Century America," The Engineers in America: A Historical Anthology From *Technology and Culture* (Chicago and London: The University of Chicago Press, 1991), p.174.

[63] P. Meiksins, "Engineers in the United States: A House Divided,"Engineering Labour, pp. 61-97.

Perhaps John Brown was reporting evidence of an anxiety not to be identified with labor when he found 19th century engineers using blueprints as a "production-control instrument" designed to help "shift the balance of power over production from workers to engineer-managers."[64]

A seeming exception to this pattern emerged during the Cold War, when engineers joined a national response to the perceived threat of Communism by focusing on science. Relying for technical justification on the so-called "Grinter Report" commissioned by the American Society for Engineering Education, and building on foundational programs established by transplanted European engineers, engineering educators in the United States dramatically restructured engineering education around the engineering sciences, sharply reducing and in many cases eliminating significant practical experiences. As historian Bruce Seely explains, this effort was led by faculty seeking massively available federal funding to build university-based research enterprises.[65]

However, when seen in comparative terms, this government-sponsored movement signaled not a move toward a French pattern of government-led movement, for through a simultaneous rapid expansion in government contracts, the federal government was also making itself a facilitator of a new type of industry, the defense industry. Also, as Reynolds points out, "[S]ince the Cold War also involved competition with the Soviet Union in nonmilitary areas, such as scientific prestige and aid projects to nonaligned countries, government contracting activities soon involved university and corporate engineers in nondefense contract employment on a large scale as well." By the 1980s, Reynolds asserts, approximately 40 percent of all engineers worked in private firms supported through contractual relationships with industry.[66] In other words, what changed for engineers with World War II and the Cold War when the United States judged its very survival to be at risk was less a shift of locus away from private industry and more a shift in emphasis within private industry to include strategic national technologies, both military and nonmilitary, alongside the production of low-cost, mass use consumer goods.

A regular call for "balance" between theory and practice in engineering knowledge among American engineers is one indicator of a national positioning of engineers and engineering knowledge to serve progress by advancing private industry. Although the precise form of this call has varied greatly depending upon what was judged to be mismatch in the present, indeed changing what has counted as theory or practice with each swing of the pendulum, engineers have made embracing private industry a patterned feature of their identity. As in the other cases, a dominant metric of progress has served as a key source of influence and legitimacy. While identity politicians among engineers have used this metric as a resource to advance their interests and projects, it is important to recognize that the dominant image of progress is a required resource. For engineers, to not appeal to it is to risk losing legitimacy.

What is engineering for?

One implication of following the identity politics of engineers is that such may facilitate a rethinking of engineering epistemology. Research in science and technology studies often

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[64] See note 10 above.

[65] B. E. Seely, "The Other Re-Engineering of Engineering Education, 1900-1965," Journal of Engineering Education (July 1999): 285-294.

[66] Reynolds, "The Engineer in 20th-Century America," p. 180.

permits engineering to make cameo appearances but rarely does it warrant the lead role. Might it be the case that researchers, whether wittingly or not, are responding affirmatively to a dominant popular image that locates engineering 'downstream' of basic science? In this image, engineering is associated with the 'application' of scientific knowledge to practical problems. Hence, to understand it, one should first look 'upstream' to sort out the defining features of the relevant scientific knowledge, before turning to the application of this knowledge to solve problems. Because the application process always gets messy, the diversity in what counts as engineering is an accurate indicator of its subordinate level of importance relative to science.

Following the identity politics of engineers, however, provides reasons for pulling engineering epistemology out from under the shadow of scientific knowledge. By scrutinizing engineering from the 'bottom up,' as it were, as strategic, patterned responses to changing codes of meaning that appear in varying configurations, engineering begins to appear so diverse because it is mapped so closely onto the diverse arenas of everyday life that engineers serve and in which they function. The analytical challenge in accounting for such diversity becomes showing how the epistemological values of engineering knowledge are linked to the wider social values of engineering work and the professional identities of engineers. Methodologically, the task is to identify the dominant images challenging engineers at particular times and places, follow how different engineers respond to configurations of such challenges in interactions with others, and document how patterned responses scale up certain forms of knowledge and identities that, in turn, challenge subsequent generations of engineers.

To push the point a bit more provocatively, might the diversity of engineering knowledge actually be an indicator of its superordinate importance? Following diverse flows of influence into engineering personhood and practice has the effect of repositioning the basic sciences as themselves a form of external influence to be selected, adapted, or further developed in order to facilitate successful engineering interventions in everyday life. To identity politicians in engineering, and quite possibly also in medicine and the so-called, but misnamed, 'applied sciences,' the so-called, but misnamed, 'basic sciences' begin to appear as large, specialized consulting operations rather than the essential fount of new knowledge. It may be worth at least testing the view that, because they respond systematically to popular as well as professional codes of meaning, engineering and the applied sciences constitute the default case, making the purity of 'pure science' a historical and cultural aberration to be explained.

While following engineers as they respond to distinct metrics of progress and distinct images of private industry offers examples of how the modes of knowledge that engineers build for themselves respond not only to professional domains of meaning but to popular domains as well, importantly there are only two examples. While highlighting differences that become 'national' or 'transnational' in content, they also leave unanalyzed yet other contrasts among engineers that emerge at different levels of analysis. For example, Alphonse Lavallée, the financial benefactor of the École Centrale, had to negotiate relationships with Théodore Olivier, Eugène Péclet, and Jean-Baptiste Dumas, all of whom were co-founders with somewhat different ideas about the content and significance of 'industrial science.' Indeed, a fifth founder had dropped out of the project when he learned of Lavallée's intent to enroll 300 to 400 students rather than 50 to 80. Although we maintain that understanding patterned identities and emergent influences facilitates informed speculation about likely responses or even, in some cases, prediction, one can never wholly specify in advance just what levels of influence will be most salient in engineers' responses or how emergent patterns might scale up new images, including in what gets to count as engineering knowledge.

A second implication of following the identity politics of engineers is that, by calling attention to the importance of metrics of progress, it raises novel questions about what counts as ‘globalization’ in the present. Might it be the case, for example, that since the end of the Cold War the world has witnessed the scaling up of a distinctively American image of progress to the level of dominant transnational theorizing? In other words, might every country in the world now be facing a challenge to demonstrate its commitment to private-sector, low-cost industrial production for mass use?

For the United States, the scaling up of its image in a kind of philosophical colonialism would not mean that it gains centralized authority in the process, precisely because of its deference to private industry. The expansion of domestic companies into multinationals has changed everything. Americans can no longer claim that what is good General Motors is good for America because they do not know if G.M. is American. The nation state can complain but has given itself no right to object when firms extend their longstanding search for cheaper labor by moving manufacturing plants to other countries.

For every other nation in the world, scaling up an American image means having to code-switch with an additional image of progress. Where, for example, the French have to figure out how to accord new prestige to the private sector, the Germans face the challenge of finding progress in lower-quality technics, and the British have to figure out how to make leveling in consumption something other than an evolutionary reversal. For countries such as Egypt, where the dominant image of progress is about recovering past glory, committing to private industry can mean joining a game in which one has a chance of rising status, with East Asian countries as exemplary role models. However, the commitment is hardly voluntary when not joining the game risks humiliation or even disappearance.

For engineers in all countries, the major challenge of the present is to live both within and beyond the nation at the same time. At the 2003 meeting of the European Association for Engineering Education, participants ruminated on the theme “Training Engineers for Mobility.” That organizers focused attention on strategies to achieve mobility within Europe and into Europe from other countries illustrated the palpable fear across the meeting of European engineers leaving the Union entirely through jobs in multinational corporations. Making European engineers more attractive to multinational corporations may be the only way to advance national agendas in a world defined in terms of industrial competitiveness, yet it is itself an agenda that is thoroughly ambiguous for both engineers and nations.

Finally, that engineers intervene in patterned forms of knowledge and personhood makes it clear that that academic engineering studies is a form of identity politics as well. Whether we like it or not, by making knowledge claims that pose new entities or offer new distinctions, we engage in ontological marketing that responds to existing configurations of dominant images and, hence, must take account of audience. When we respond only to disciplinary codes in our work, we can perhaps satisfy ourselves with extending disciplinary agendas and seeking elite disciplinary identities in the hope that the benefits of disciplinary insights will somehow diffuse into outside worlds. However, when we step onto an interdisciplinary stage, we accept an identity whose very legitimacy is defined by the expectation to intervene in some dominant mode of theorizing by making visible what it hides and pointing to, if not plotting, alternative pathways.

Accordingly, in engineering studies it matters how engineers understand their own projects. We researchers in engineering studies would do well to become accomplished identity politicians through competent code-switching, especially by understanding the angles of engagement through which the codes of meaning we nominate through our scholarship encounter the codes that live among engineers. This paper participates in a research and teaching project designed to make engineers more visible by repositioning the vast diversity among them as a strength rather than a limitation. Its larger purpose is to help engineers move beyond simply evaluating how they may or may not be contributing to progress to better assess and intervene in what counts as progress in the first place.

Acknowledgements: The authors are pleased to acknowledge research support from the National Science Foundation's Course, Curriculum, and Laboratory Improvement (CCLI) Education Materials Development Program (DUE-0230992). Juan also acknowledges research support from the National Science Foundation's Societal Dimensions of Engineering, Science, and Technology (SDEST) Program (SES-0228542). Thanks to Michalis Assimakopoulos and Kostas Chatzis for inviting the paper as part of its 2003 conference "Current Trends in STS" in Syros, Greece and the STS Program at MIT for including it in its Spring 2004 seminar series. The published draft attempts to take account of many thoughtful and provocative comments from Yiannis Antoniou, Michalis Assimakopoulos, Aristides Baltas, Wiebe Bijker, Kostas Chatzis, Joseph Dumit, Michael Fischer, Stefan Helmreich, Jonson Miller, Constance Perin, Dominique Pestre, Antoine Picon, Maria Rentetzi, Susan Silbey, Amy Slaton, Rosalind Williams, Steve Woolgar, and other participants at the Syros conference and MIT seminar. We appreciate these gifts and invite readers to contact us with further reflections.