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Nonlinear STS, Engineering Studies, and Dominant Images of Engineering Formation: An Interview with Professor Gary Downey

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About the authors:

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Abstract: As Alumni Distinguished Professor at Virginia tech, Professor Gary Downey is current President of the Society for Social Studies of Science (4S; 2013-2015), and a renowed scholar in the fields of STS and engineering studies. In this interview, Professor Downey describes how he is leading 4S initiatives to call attention to STS scholarship that goes beyond the linear model of knowledge creation, diffusion, and utilization, or what Downey calls "nonlinear STS." Having been trained initially as a mechanical engineer and cultural anthropologist studying controversies over nuclear power and nuclear waste disposal, he describes how he developed the concept and practice of "critical participation." His critical participation in engineering formation (engineering education and training) began with critical analysis of the "dominant image" of engineering problem solving as U.S. engineers have understood it since the 1960s. Downey also questioned how and why engineering remained largely invisible in the emergence of STS as a scholarly field, except as a synonym for technology or as a metaphor for the heterogeneous construction of new technologies. Difficulties he encountered in teaching became crucial sites for making visible what the dominant image of engineering problem solving hid in engineering formation, and nominating an alternative image of engineering as collaborative problem definition

image and associated practices scale up across localized arenas of engineering formation and work. Downey also explains how he joined with other researchers to establish and build Engineering Studies as an interdisciplinary field of research committed to both conventional and nonlinear scholarship. Key steps included founding the International Network for Engineering Studies (INES), organizing INES workshops, and creating the SCI journal *Engineering Studies: Journal of the International Network for Engineering Studies.*

Introduction to the interview: Gary Downey is Alumni Distinguished Professor of Science and Technology Studies and affiliated faculty member in Women's and Gender Studies at Virginia Tech. He presents himself as an "ethnographic listener" interested in engineering studies, making and doing in STS, and questions involving expertise and personhood. Trained as a mechanical engineer (B.S. Lehigh University 1974) and cultural anthropologist (M.A. 1977, Ph.D. 1981 The University of Chicago), he serves as President of the Society for Social Studies of Science (2013-2015).

Downey is author of *The Machine in Me: An Anthropologist Sits Among Computer Engineers* (Routledge 1998), co-author of *Engineers for Korea* (with Kyonghee Han; Morgan & Claypool 2014), co-editor of *Cyborgs and Citadels: Anthropological Interventions in Emerging Sciences and Technologies* (School of American Research Press 1998), co-editor of *What Is Global Engineering Education For?: The Making of International Educators* (Morgan & Claypool 2010), and author of the multimedia course *Engineering Cultures* (Virginia Tech 2002). He is editor of the Engineering Studies Series at The MIT Press, the Global Engineering Series at Morgan & Claypool Press, and the journal *Engineering Studies: Journal of the International Network of Engineering Studies.* He is co-founder of the International Network for Engineering Studies. He has been Distinguished Lecturer at the American Society for Engineering Education and Keynote Lecturer at the World Congress of Chemical Engineering and Brazilian Society for Science and Technology Studies (ESOCITE.BR). He received the 2011 Virginia Outstanding Faculty Award, the highest faculty award in the Commonwealth. His current research uses historical ethnography to revisit local connections between dominant practices of engineering formation and countries, asking to what extent these have been normative in content. One goal is to extend critical analysis to critical participation, a version of making and doing in STS, to better enable both engineers and STS scholars identify and reflect critically on their expertise, identities, and commitments. His current research uses historical ethnography to revisit local connections between dominant practices of engineering formation and countries, asking to what extent these have been normative in content. One goal is to extend critical analysis to critical participation, better enabling engineers and STS scholars to identify and reflect

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Interviewee: Professor Gary Downey, Virginia Tech

Interviewer: Zhihui Zhang, Chinese Academy of Science

Downey: So, how can I help you?

Zhang: I saw an interview that Professor Li Bocong published in the Chinese journal *Philosophical Analysis*, in which he explored the rise and development of the philosophy of engineering. In his view, Chinese scholars have done much work in interdisciplinary engineering studies and are in the forefront of this international field. Yet many Chinese scholars remain limited to Chinese-language scholarship, not fully up-to-date on work by Western scholars. Inspired by that interview, I would like to learn more about how you understand the current state of science and technology studies in the U.S. and Europe. I would also like to compare the emergence of Engineering Studies in the U.S. and Europe with that in China. As we know, you have done a great deal of work in Engineering Studies, and you are also the current president of 4S, the Society for Social Studies of Science. You must have developed a broad view of the scope of these scholarly fields, including the challenges and opportunities that each faces.

Downey: OK. It is true. I do have views about the current state of STS, as well as about the development of Engineering Studies. I welcome the opportunity to share my assessments. I would also welcome learning about reactions from readers.

Ⅰ.Promoting nonlinear STS as the new 4S President

Zhang: Let's start with your current work as 4S President. I notice that you have been working hard to promote 4S as an organization and STS as a field. You have said that 4S has limited itself by focusing on what we tend to call the "linear model" or "diffusion model." So you are attempting to lead the Society to promote all the forms of scholarship, including those that go beyond the linear model. Many initiatives appear to be underway. Could you share with us some of this work?

Downey: A wonderful place to begin. I think seriously about these issues every day. When I was first approached to run for the presidency of 4S, I was reluctant to do so. STS has built its scholarly reputation, in part, by successfully critiquing the linear model of knowledge creation, diffusion, and utilization. Yet 4S as a professional society has emphasized exactly that in its practices by highlighting the presentation of academic papers and the production of articles and books for academic audiences. I have long found this disappointing. I had shifted my

primary scholarly allegiance some years earlier from the American Anthropological Association to 4S because I expected STS scholars to be more committed to forms of knowledge production and knowledge expression[1] that go beyond the linear model. I expected prominent commitments to re-theorizing and enacting new practices for the travel of STS knowledge and expertise beyond the boundaries of the field. Yet at professional meetings in STS, especially at 4S, I have seen many scholars championing the linear model, either explicitly or implicitly. 4S book awards, for example, go primarily to books written for academic audiences, including the award that specifically acknowledges "social or political relevance."

I was reluctant to run because I thought my interests in STS scholarship beyond the linear model did not really fit what 4S judged most valuable. Then I realized that, precisely because of this disappointment, I needed to run. I needed to put my body where my mouth has been. I thought, "Well, if I lose, then I can at least go on, knowing I had tried." At the same time, I've been around long enough to know that, if I won, I would face daily challenges to articulate and share my views, my practices, and my hopes for STS with 4S members and its decision-making body, the 4S Council. Well, I won, and felt compelled to jump in with both feet. Now I'm living a version of "Be careful what you ask for; you just might get it."

My current work within 4S involves expanding its boundaries so that it better maps itself across the full range of scholarly work that STS scholars actually do. I assert that all STS scholars do more than perform the linear model. Minimally, most teach students who are not going to follow us into the field. Our challenge with such students is to persuade them that STS knowledge, STS expertise, and STS practices can help them better understand themselves and their work. Beyond that, many STS scholars are involved in a range of activities that 4S Council members have come to call "STS making and doing," activities that accept, even champion, the situatedness of STS research and researchers.

So I came in with a vision and a plan to work with Council members, committees, and the membership to, hopefully, develop an expanded set of practices for 4S. After taking office, I held two-hour Skype meetings with each of the nine Council members to learn what visions, interests, and objectives for 4S they might have. I wanted to see both how I might help them achieve those objectives and the extent to which their visions and interests might overlap with my own. The resonance was remarkable! I had expected significant pushback but got almost none. Quite to the contrary. In every conversation, we not only identified parallel concerns but also began formulating specific actions to address them. We got to work mapping what sorts of 4S practices STS scholarship might itself justify, and then seeing if we could make these fit the Society without disrupting or

Now I have my own approach to refiguring the contents and relations among knowledge production and expression in STS, and the travels of STS knowledge beyond the boundaries of the field. The term is "critical participation." We can certainly discuss here what I mean by critical participation as a mode of STS scholarship. Minimally, it takes account of what I have described as the "twin risks" of co-optation and social engineering. Typically, we STS scholars are not just sharing our knowledge and expertise with audiences, but rather interacting with audiences that have knowledge and expertise and are allowing us into their lives and work as critical participants. Recognizing our work as critical participation makes it more audience-centered. It means figuring out ways of doing STS analysis so it maximally inflects the knowledge, expertise, identities, and commitments of those we study and with whom we work. It also means being willing to accept the risks of having our practices of knowledge production, knowledge expression, and knowledge travel inflected by them as well.

I view my work as 4S president through the lens of critical participation. Life in 4S has been organized around annual meetings. Many scholars present papers, hopefully to be published at some point. A prize session has recognized distinguished articles and books, and an additional Presidential plenary session has introduced cutting-edge topics for members to consider. Between meetings, the daily life of the Society has been limited largely to interactions among its officers and monthly announcements to the membership.

It seemed to me that 4S could fruitfully sponsor a number of additional activities. Decision-making authority in the Society rests with its elected Council, President, and President-Elect (if one is in place) as voting members. The President has significant authority to constitute committees and a responsibility to serve as an intellectual leader. I have charged five committees, which are now doing work and developing proposals for new initiatives. To make sure Council decisions emerge from the membership, these committees will invite comments from members prior to making recommendations to Council. The committees will decide whether or not to edit their proposals, and they can even decide not to put a proposal forward.

Zhang: So what kinds of initiatives are these committees considering?

Downey: Within the annual meeting itself, one initiative involves developing what we have come to call the STS Making and Doing Fair. Picture a large room with tables, booths, and other spaces in which members are demonstrating, enacting, or otherwise embodying the scholarly practices they use to participate critically amidst audiences both within and beyond the field. Their presentations, or demos, could include the development of new artifacts, such as digital works. Many scholars in STS are producing digital artifacts to participate in the worlds

Another example is ethnographic film, which 4S began including in annual meetings in 2013, on the initiative of Wes Shrum and Trevor Pinch.[2] Presentations and demos could include policy work. Indeed, thirty years ago STS scholars used the word "policy" to label practically everything that had to do with the travels of STS work beyond the field. That label is now grossly inadequate to cover the amazing range of creative projects in which STS scholars are now involved.

So a committee is working right now on a draft call for submissions, criteria for acceptance, and practices for assessing presentations and formally acknowledging the best at the prize plenary session. To encourage participants, the committee is suggesting that those who participate in the STS Making and Doing Fair can still present papers in regular sessions. The overall idea is to elevate the status of such work by juxtaposing its highest-quality instantiations with articles and books already judged by other committees to be of highest quality. STS making and doing is not subordinate scholarship, downstream scholarship, or applied STS, but rather modes of doing STS in addition to producing academic articles and books.

Please do not hear me as, in any way, diminishing or devaluing the importance of conventional scholarship. It is essential. It regularly motivates us as STS scholars, enabling us to routinely see new things in new ways. We can't participate critically in worlds of science and technology if we don't analyze them well.

Another important initiative, started during Trevor Pinch's presidency, is to develop digital publications in STS.[3] Our expanded Digital Publications Subcommittee has carried this forward in two directions. One is to create an open-access STS journal. We have an active search underway right now for an editor. The journal will be published in annual volumes, rather than issues, because an open access journal has no upper limit on the number of pages in a volume. Each time the editor accepts a manuscript and copy-editing is complete, the managing editor can upload it into the current volume.

The editor will have significant authority over the types of publication the journal will accept. Minimally, it can include multimedia contents, unlike our print journal. My own hope is that the journal will include publications on making and doing in STS. Along with the annual fair, such can increase the extent to which STS scholars learn from one another about successes and failures, opportunities and barriers, outcomes and imagined possibilities for making and doing. I also fantasize that that management of the journal might someday extend beyond 4S to include other STS societies around the planet, making the open access journal a global STS journal.

In one sense, open access publishing could become just another venue for conventional scholarship. But precisely because anyone can access its contents, including partners in the field and colleagues outside STS, open

The second direction is to develop a range of new digital publications to be shared on the 4S website. 4S currently has a static website. It also distributes a monthly newsletter via email. The subcommittee's plan, borrowing from the Society for Cultural Anthropology, is to make the site a dynamic gathering place for members and prospective members. They're considering adding a blog, interviews with authors and awardees, podcasts, teaching materials, reports and position statements, reflections on current events, archives of various documents, and links to other digital publications relevant to STS. Another possibility is to publish curated theme issues, especially if we can forge an agreement with Sage to re-publish articles from *Science, Technology & Human Values*, the journal 4S edits, or even *Social Studies of Sciences,* which has long been central to STS research. Hopefully, digital publishing through a re-designed user interface can provide another way for STS scholars to both build upon linear-model publications and extend them.

A third activity involves the 4S producing resolutions and reports on issues of public concern. There are precedents for this. Ten years ago, Council asked Jane Summerton, Hugh Gusterson, and me to research and report on changes the U.S. government had made to immigration policy following 9/11. The changes made the immigration of scholars to the U.S. far more difficult. This committee conducted research on what the government was actually doing. We produced a report and a proposed resolution for Council, which approved it and posted it on the 4S website. I understand that several other professional societies subsequently used it as a model for their own resolutions. Prior to that, while Wiebe Bijker was president, Council had also approved a resolution in the wake of 9/11 defending free speech and the role of higher education in promoting free speech.

Given that we have precedents, a committee is now working on extending the practice. What are the possible ways that the 4S membership, and 4S as an organization, could participate critically in matters of public concern? What possible agencies might 4S mobilize? Our membership is now considering a proposal that includes procedures for producing reports and resolutions that would be vetted by the membership and formally considered by Council. They thus could be considered genuine 4S actions. Resolutions could come from groups of members. Council would likely commission reports. Picture, for example, Council commissioning a group to review reports on the so-called 3/11 disasters at the Fukushima nuclear facility. STS scholars could critically analyze such reports, possibly making visible questions or points of view that otherwise had been hidden. Such could shift conversations through juxtaposition. Unlike a decade ago, online media outlets, from bloggers to magazines and newspapers, are desperate for original content. So, in a sense, another way 4S itself could expand its agencies beyond the linear model can be to actively participate in making and doing in science and technology.

In addition to these initiatives, I have recommended that Council establish some new awards to acknowledge other types of scholarship in which 4S members are involved. So we have a committee that is developing an award for distinguished mentoring in STS. Mentoring is an important scholarly activity whose contents and boundaries vary significantly around the world. Practices in the U.S. differ from practices in East Asia, let alone the U.K., continental Europe, and Latin America. This committee has the challenging task of formulating a proposed award that would encompass differing regimes for mentoring STS scholars.

And finally, we have a committee formulating a proposal for a possible award that I have been calling the Building STS Award.[4] This would be an award for people who are doing necessary work behind the scenes, the detailed work of building STS as a field or discipline in ways that go beyond producing articles and books. Such includes building departments, curricula, undergraduate programs, graduate programs, professional societies and other infrastructural forms that ground and promote active scholarship in STS.

Behind all of this, I understand STS as a collection of scholars who share a commitment to versions of a common question: What are the relations between the so-called technical or knowledge dimensions of issues involving science and technology and the so-called social, cultural, political, ethical, value, and other non-technical dimensions? What relationships obtain between these two, and how do these relationships change over time? This understanding is an ethnographic observation from decades of participation in STS, an ethnographic finding.

Different scholars bring distinct forms of knowledge, expertise, interests, and commitments to this central question. I maintain that issues involving the relationships between the technical and nontechnical dimensions appear in every context, every moment, which someone is developing and implementing science and technology and their analogs in medicine, engineering, and so on. Therefore, it is reasonable to imagine that an STS scholar or trained STS practitioner, or their avatars, could be present every time someone or something is making important decisions about developments in science and technology. So I carry a vision of STS becoming a large, planet-wide field that produces scholars and scholarly practitioner's at all educational levels, who then work across a broad range of settings. I have called this image "Big STS."

About eight months ago, I was on a Skype meeting with a Council member, Claire Waterton from Lancaster. Claire said to me, "I hate that image of Big STS." And I said, "Really? Why?" "It is so American," she replied. She pointed out that Americans always advance plans, projects, and activities that are supposed to be big and expansive, and end up being neo-colonial, imperial, presuming that something created by Americans should

blushing. Because she was right. I am an American STS scholar, and I was uncritically performing an American practice through this image of Big STS. And then, remembering that I have served in Women's and Gender Studies since 1995, I said, 'And it's phallic!' Not knowing what sort of man she was talking to, Claire shrugged her shoulders gently, as if to say, 'Ya think?' She then pointed out, rightly, that strength can come in small, fine ways, drawing on fabric metaphors to illustrate. Our conversation then shifted to a thoughtful discussion of ways to imagine large numbers of STS scholars, trained at all levels, present to help others wrestle with the so-called knowledge and social dimensions of the sciences and technologies. I still want STS scholars and practitioners everywhere. But I'm looking for ways to not convey an Americanist image of power and control.

Zhang: Yeah. People from the developing countries, we will appreciate your new image well. But if the vision is too American- centric, it will carry the additional meaning that STS scholars from other countries will have to follow American values.

Downey: My work promoting STS through the 4S is built on concerns about the future of the field. I want to help STS programs throughout the world to flourish, for prospective students to find the field interesting and attractive, and for graduates to find work in settings they desire, whether academic or nonacademic. Increasingly, even existing programs have to re-justify themselves as technology and technoscience become omnipresent.

Many fields of the social sciences and humanities are claiming intellectual jurisdiction over technology and technoscience, introducing them as topics or areas to study and in ways consistent with disciplinary interests. Sociologists, historians, and philosophers have long been there. Now even my own disciplinary field of anthropology has joined enthusiastically. In 1987 and 1988, Sharon Traweek and I were unable to convince the American Anthropological Association to accept proposed sessions on the anthropology of science and technology. We were explicitly told that science and technology did not fall within the purview of anthropological inquiry. Today, probably at least a third of all anthropological work engages issues involving technology and technoscience in one way or another. Such has become true across other disciplines as well.

My first reaction is that such is a good thing. Many scholars are making valuable contributions to understanding emergent arenas of technology and technoscience. My concern is that none of those disciplinary arenas carry with them the core question that motivates work in STS, lies at its center, and gives the field its special challenges and significance. That question is an STS question. If STS declines, or even simply treads water, remaining in place, the world beyond STS risks losing that question. And STS risks losing the ability to participate critically in many environments that desperately needs its contributions.

Ⅱ. From engineering to anthropology, and culture to ideology/agency

Zhang: Before we move to your work in Engineering Studies, could you discuss the evolution of your own work in STS?

Downey: I am interested in mapping dominant images of engineers and engineering, as well as the localized agencies involved in nominating, transporting, resisting, defending, and otherwise responding to them.[5]

This not where I started. I first became interested in STS-type questions while I was completing undergraduate degrees in mechanical engineering and social relations during the 1970s. STS did not yet exist in the United States as a definable field of research. I judged cultural anthropology to be the best pathway to help me wrestle with questions of meaning in technology.

I was closely following public controversies over new technologies, especially nuclear power and radioactive waste disposal. The question that drove me was: How could two groups of people who are both highly-trained, knowledgeable about the issues at stake, and demonstrating high degrees of personal integrity disagree with one another systematically, and even violently, about such technologies as nuclear power? Through my engineering training, I could understand the technical arguments that specialists made on both sides of these disputes, as well as other debates over environmental issues, such as the supersonic transport and clean air. What I could not understand was why people were fighting. I could not understand what was at stake for them.

That's what led me into anthropology, an interest in differences, in contrasting perspectives.[6] I was also led to anthropology by a dream I had in high school, in 11th grade. It was entirely in Spanish. I had been studying Spanish since I was twelve or thirteen years old. In the dream, everyone spoke Spanish, and everything happened through the linguistic categories of Spanish. In anthropological terms, I was confronting the Sapir-Whorf hypothesis about language and seeing, but I didn't have that conceptual language at the time. Rather, I was just experiencing a different world. Afterwards I thought, "Oh my goodness. The world is filled with different languages. People elsewhere see things in different ways." I became fascinated by points of view, or positionality. What does one see when one occupies a certain position, such as an engineer working at a drafting board?

That's why, for me, the key issue in controversy studies became that of the identities in conflict. At an early point in my career, I interviewed a leading critic of nuclear power, an experimental physicist at MIT who had been a founder of the Union of Concerned Scientists. His office was on an upper floor of an MIT building. One floor down was the office of the nation's most prominent proponent of nuclear power. He had authored an important report arguing that the probability of dying from a nuclear core meltdown was roughly equal to the

probability of being struck by a meteor. So here we had two highly-trained, prestigious scholars, one floor apart, yet dramatically opposed to one another. How could that happen?

As a budding anthropologist, I was disciplined into structuralist modes of analysis. These treated cultures as organized structures or systems of symbols and meanings. Cultures grounded identifiable collections of people, including countries. In structuralist terms, action or agency was the product of some prior determining structure. In the United States, the social sciences were fighting over what shaped action or agency. Was it culture? Social structure? The psyche? At the time, what was given, a dominant image for all, was that behavior was human in origin and content and that something shaped it.

In the late 1970s and early 1980s, a complete inversion took place, an epistemological break. I think of it as something of a dialectical overreaction. We in the social sciences shifted from asking how people are shaped by structures to inquiring how both human and non-human agencies produce structures as outcomes of contingent negotiations.

This is what happened in STS, or better, to the old sociology of science in the U.S. It was overtaken by the sociology of scientific knowledge. There was not much anthropology of science and technology at the time. Science was simply beyond the reach of anthropological inquiry and technology, because it involved materiality, was treated as epiphenomenal to structures of human organization. Bruno Latour and Steve Woolgar's *Laboratory Life* was news. It nominated the inverted image that privileged agency. It introduced an entirely new set of questions that involved how configurations of agencies, in this case 'inscriptions', produced stabilized outputs through a variety of contingent negotiations. Over time, these stabilized outputs came to include both scientific knowledge and technological artifacts.

Although challenged to rely on structuralist theories of culture, I found these wanting in my own research. My first inclination was to study engineers, but I couldn't see how they be a single identifiable group sharing one culture. Through my education and experiences in engineering on the job, I was able to discern many differences within engineering. I saw a heterogeneity of points of view, perspectives, and practices. I decided not to study engineers while pursuing a degree at the University of Chicago, the center of symbolic anthropology, because I couldn't figure out a way to implement a structuralist analysis of engineering practices shaped by a shared culture.

So I put engineering on the back burner and turned to study controversies over nuclear power and radioactive waste disposal. Theoretically, I shifted my focus from culture to ideology. Studying ideologies gave

I saw the participants in controversies as agents seeking to nominate and transport specific images of these technologies, to frame it in terms I use now. They were not simply being shaped by some structures that they took for granted or perhaps failed to recognize.

The conceptual move to ideology enabled me to finish a degree. Since all of my examiners were structuralists, this was tricky business. My Ph.D. defense was extremely uncomfortable. All faculty members, and only faculty members, from the department were present. After listening to me characterizing competing ideologies in the nuclear debate, one challenged me by asking, "Are you saying that participants in this debate choose their perspectives?" What I wanted to say was, "Yes!" What I really said was, "Well, not exactly." The man was a British Marxist who was quite confident in his knowledge that class position determined human behavior. I offered a lame argument about how the ideologies I was studying had long historical traditions, and that people were joining these traditions, making the scope of choice sharply delimited.[7]

In any case, studying technological controversies became for me a way to call attention to both agencies and technological development within the disciplinary frame of cultural anthropology. And the co-presence of conflicting ideologies led me to questions of knowledge and personhood, or identity.

For example, how do participants in public controversies find ways of achieving congruence between their identities as technical specialists and their identities as citizens, which can include political commitments? How could the Union of Concerned Scientists make thousands of claims about nuclear power and nuclear waste disposal, all of which were consistent with an antinuclear political position, and still gain significant recognition for doing quality scientific work? The answer became that it required negotiating fit, or congruence, among different identities. They made claims that were both defensible in scientific terms and politically predictable. This happens regularly on all sides of a controversy.

From the moment I started this work, I puzzled over how studies of technological controversies might contribute to their resolution in one way or another. Initially, I focused on making visible positions or perspectives that were subordinated. That's why I used my dissertation to examine antinuclear groups that carried out direct action through civil disobedience. I was using a strategy that the anthropologist Michael Fisher later called "juxtaposition." I was trying to disrupt the power difference by juxtaposing the subordinated perspective with that which was dominant. As time went by, I realized that I had an additional calling, an additional responsibility. Through reading works in feminism, especially the novel *The Women's Room*, I realized I carried many privileges as a white, male, tall engineer-anthropologist. My responsibility was to intervene in centers of

those centers from outside, i.e., the antinuclear groups.

One frustration I repeatedly experienced in studying public controversies over nuclear power and radioactive waste management is that I rarely encountered engineers. The knowledge issues were always about the effects of ionizing radiation through the air, in ground water, through geological formations, etc., and scientists were always front and center. I continued to harbor a desire to understand engineers, especially their persistent invisibility, which I also found frustrating. In part, I wanted to critically analyze my own commitments to engineering. I had loved learning engineering, but found both the learning and the work to be highly constraining. My growing conceptual interest in identities, especially relations among technical and nontechnical identities, gave me the tools to begin asking: "What's an engineer?" and "What is engineering for?"

Ⅲ. Dominant images and critical participation in engineering formation

Zhang: I can tell from your work as 4S President that you have your own approach to nonlinear STS. You mentioned critical participation. Could you please summarize your approach to critical participation and how it developed?

Downey: I do have an approach to nonlinear STS that guides my research, my mentoring, and my teaching, and has done so through most of my career. It actually emerged from experiences in the classroom. It's built on an image of pedagogy, of learner-centered or audience-centered teaching.

In my view, teaching offers students, or nominates for them, ways of thinking and acting that they might incorporate into their own practices, their own activities of thinking and seeing. When viewed through the linear model of knowledge creation, diffusion, and utilization, teaching treats students as empty vessels to be filled up with STS contents.

My approach is quite to the contrary. An individual course has as many classrooms as there are students. The STS instructor's responsibility is to help students take steps beyond where they begin, to enhance their sophistication and critical understanding of science and technology by adding to their identities contents from STS. In other words, I practice teaching as a kind of critical participation in the learning of students.

I have extrapolated this image from the classroom to my research, meaning I treat my research and writing as an extension of teaching. All enact the same scholarly agenda of nominating images that might travel and become taken for granted--just with different audiences. To put it succinctly, the term "critical participation" names practices that articulate, or connect, research-based analysis to other scholarly activities that critically inflect arenas beyond the field, or discipline.

To the extent critical participation is successful, it makes visible images and practices that existing dominant images and practices hide. It potentially also leads to nominations--the formulation of alternatives that may address, or redress, existing limitations in one or more ways. And just as students get to decide whether or not to incorporate STS concepts and practices into their expertise, identities, and commitments, so it is with every potential audience for STS work everywhere.

Let me elaborate with the example of engineering formation, the making of engineers. As I said, I was long frustrated with STS for contributing to a longstanding practice of disappearing engineers. Founding STS scholars tended to focus on science and technology. Even medicine fell outside this demarcation.

Engineers and engineering tended to appear in STS work in one of two ways. The first was to accept the dominant popular image of engineering as downstream of science, linked to applied science and equivalent to technology. Reproducing the linear model, early STS scholarship privileged attention to scientists, the creators. In the same ways that applied sciences were less important, so it was with engineering. Even though the number of engineers working in the world is probably a few orders of magnitude larger than the number of scientists, engineers did not merit central attention from our field.

The second way the word “engineering” appeared in STS discourses was as metaphor. So, for example, John Law offered the helpful label “heterogeneous engineering” to name the messy processes through which diverse collections of human and nonhuman agents engage in contingent, heterogeneous negotiations to produce stabilized outputs and outcomes. He was contributing to a newly-inverted epistemological approach to social studies of science, agency-based accounts of knowledge and technological development. This was an important article, with lasting value. But it also important to remember that his study of heterogeneous engineering was not about engineers, people who are trained and identify as engineers. These were Portuguese sailors and other agents involved in Portuguese navigation. The word “engineering” appeared as a metaphor for the contingent practices of negotiation by heterogeneous agents in heterogeneous encounters.

While I was pleased to see the word appear in a prominent STS context, I also watched as using engineering as a metaphor for contingent negotiations, especially of new technologies, actually had the effect of directing critical STS attention and analysis away from engineers and engineering work.[8] In the first place, it appropriated uncritically the equivalence engineers tend to draw between engineering and technological design. Engineers have long claim jurisdiction over technology via design. Since no other fields challenged this claim, until recently, it became commonplace to equate engineering work with the complex technical machinations of design.

same time, the development of technology studies as a field further devalued engineers and engineering, unintentionally I think, by showing that lots of people, lots of experts, many distinct modes of knowledge, and different kinds of people with different kinds of expertise all could be considered technologists contributing to technological developments.

So during the 1980s and 1990s, I watched as STS continued disappearing engineers and engineering as topics or sites for STS inquiry and critical analysis. In order to clarify for myself just why engineers were not an important object for STS scholars when the field was just getting started, I went back to look at related research in the 1960s and 1970s. What two colleagues and I found was actually quite surprising. In the 1960s, researchers in sociology, history, and philosophy had indeed given serious attention to engineers and engineering. During the 1970s, each lost interest in engineers for reasons specific to that discipline.

Trained myself as an engineer, I understood that the practices involved in engineering problem solving and engineering design were not sufficiently captured by positioning them simply as downstream of science and characterizing them as one set of contributors to technological developments among many. Minimally, engineers explicitly conjoin expertise and normative commitments, although it took me a while to settle on that language.

Once my tenure was secured, I decided to launch myself into the direct study of engineers and engineering. I wanted to understand how engineers understood their relations to technology, and to investigate the equivalence between engineering and technology to see what might be hidden by it. I selected the technologies of computer-aided design and manufacturing (CAD/CAM) as my focus of study because it was expanding rapidly. Nationalist dreams of factories automated by CAD/CAM were appearing regularly in the press.

I was able to show in that study that engineers did indeed seek to claim jurisdiction over it, presenting themselves as the main agents of technological development. In the dominant image I routinely encountered, engineers selectively appropriate the sciences to design technologies, which they then controlled. But computer-aided design was also a problem. You couldn't control it. Rather, to use it you had to adapt to it, give yourself over to its demands. CAD work involves software, and with any software you have to adapt your body to its requirements. You have to fit it to use it.

During this period, when I gave talks and seminars on the CAD/CAM work in different countries, especially in STS and related programs, invariably someone would approach me afterward and confess that they too studied engineers. They present it as work "on the side," because they couldn't get paid to do such work or get recognized for it. As time went by, I resolved to help make visible and bring together scholars around the world

was stabilizing as the name for this new interdisciplinary field, I settled on the label "Engineering Studies" as a scholarly strategy for making visible research on engineers and engineering—both naming it and juxtaposing it alongside STS. Founding the field would become an act of critical participation both within and beyond STS. I hoped to attract scholars who did work on engineers and engineering but didn't identify themselves as STS scholars in the first instance.

A critical stimulus for this would-be initiative also came from frustrations I was experiencing teaching STS courses for undergraduate engineering students. I developed several types of courses, including, for example, courses on technological controversies, technology and society, technology policy, and technology and development. By examining technological controversies, for example, students could come to appreciate that whatever stance they took on a given emerging technology, it was but one point of view or perspective among many that were available. I routinely challenged students to engage perspectives other than their own. We did a great deal of role-playing. I would ask people to adopt and defend a variety of positions. They practiced debating, and I helped them learn to articulate and listen to perspectives other than their own.

Students loved these courses. They gave me high evaluations; I started winning awards for teaching. But I was also always depressed. I was offering students nothing to take back with them to their engineering courses, no practices they could effectively integrate into their engineering work. My courses were holidays for them. Vacation . . . leisure . . . fun. For me, to not give students something to carry back to engineering courses undermined the value of these experiences. I did not consider myself a good teacher because my pedagogies were not participating critically in their education. I was supplementing it. This anxiety motivated me to spend more than a decade developing a course that might genuinely participate in engineering education--that might critically participate in it.

To continue my research into how engineers understand themselves and their work, I gained some funding from the National Science Foundation to examine how engineering curricula and engineering faculty worked to form students as engineers and people. In part, I was exploring what had happened to me at Lehigh. Through this research, it became clear that engineers were learning to perform what I slowly came to describe as the "dominant images" of engineering expertise and engineering practice. That is, engineering students were learning how to apply the engineering sciences to solve problems that would, in turn, empower them to lead the design of new technologies.

Like my own experiences as an undergraduate student, the core of engineering education still consisted of

the key steps “Find,” “Diagram,” “Equations,” and “Solution.” They solved problems that were either right or wrong. Day after day, right or wrong, right or wrong, right or wrong. If they were right, they received good grades and knew they were gaining control, mastering the method. If they were wrong, perhaps they would not become good engineers.

Over time, I realized that solving problems that were always right or wrong could have the effect of predisposing engineers to see the world as divisible into two parts--the right and the wrong. This is one sense in which engineering education is engineering formation, the formation of persons. To the extent learning engineering problem solving predisposes engineers to not see multiple differences in the workplace or in arenas affected by engineering practices, it can lead them to expect others not to have knowledge, not to have value, not to have practices or desires of their own that engineers should take into account in their calculations and action.

Over the ten-year period, I wrestled with the question of how best to persuade engineers that there are other people out there who have different forms of knowledge and expertise than you, which are no less valuable than your own. It occurred to me in the late 1980s that perhaps a good way, a strategic way, to persuade engineers would be to show them that such is true of other engineers. Minimally, engineers who are raised and educated in different countries tend to embrace distinct configurations of knowledge and expertise, expect to gain distinct identities as technical specialists, and acquire distinct arrays of broader commitments for engineering work. The formation of engineers always includes techno-national formation.[9]

Starting with a course on the development of American engineers, I introduced a module on the emergence of engineers in Japan. In addition to the straightforward strategy of elevation via juxtaposition, I was also calling attention to and trying to disrupt a widespread American tendency at the time to demonize Japanese industry, including its engineers, as posing threats to American competitiveness.

Indeed, I first began to re-theorize culture at this time as dominant images that challenge us from above or outside the person, rather than symbolic structures akin to linguistic grammars that are shared deeply in our guts. My students were homogenizing Japanese engineers, treating them as all alike because they shared a culture. I challenged them with the notion that what Japanese engineers shared were challenges from dominant images and practices, and that individuals responded to those challenges differently. Also, each engineer experienced distinct configurations of challenges depending on their life histories. Japanese engineers, in short, were not all alike. The conceptual shift worked, and I continue to teach in those terms. To this day, however, it is difficult to locate or even build sufficient case material to make this point effectively and efficiently in every module. It takes time to

engineering across different countries during the late 1980s. I worked the material into different courses until finally bringing it all together in 1993 and 1994 in the new course Engineering Cultures, which I began teaching in 1995.

Students from the U.S. continue to find it shocking that, in France, graduates of the *Ecole Polytecnique,* and more broadly the *grandes écoles*, have access to the highest-status occupations in the country. Challenged to embrace mathematical knowledge and the expertise of addressing "specific" problems by deriving them from "general" mathematical formulations, the best find positions in the administrative bureaucracies, or *corps*, associated with their individual schools. They can be confident that their work is enhancing social order, especially within France but also beyond it. Meanwhile, across the English Channel, only tens of kilometers away at the closest point, engineers across the U.K. struggle to this day to be seen as professionals, as higher in status than technicians, far removed from manual labor. Even while integrating higher education into the making of engineers, and even expanding it, engineering formation still challenges them to value highly the practical knowledge to be gained on the job, which they largely expect to be in the private sector.[10]

The contrasts between these two sets of dominant images and practices are shocking to American students who learn that founders of engineering formation in the U.S. looked to both for practices to appropriate. Experiencing contrasts both between and within these countries motivates students to examine what it has meant to be an engineer in Germany, Japan, Korea, China, and so on.[11]

So my approach to critical participation in engineering education began with re-theorizing it as the making of persons, or what I came to call engineering formation. An essential step was critical analysis of engineering problem solving in the United States and the relentless challenges it poses to students to divide the world into two parts. Extended research across a range of literatures made it possible to juxtapose distinct accounts of engineering knowledge, identities, and commitments just as budding engineers are experiencing localized versions of these challenges on a daily basis.

To help ensure that students have something to carry back to their classwork in the engineering sciences, I infused the course with a method for helping students to work more efficiently with people who define problems differently than they do. Called "Problem Solving with People," it includes steps with the labels "Location," "Knowledge," and "Desire." That is, when you interact with someone else on the job or who might be affected by your work, figure out how they are located in relation to you. Were they trained in mainland China? If so, are they from Shanghai Jiaotong University, Tsinghua University, Dalian University of Technology, or the University

superior in standing to you, or a subordinate, in your division of the firm or another? Or are we talking here about non-engineers, such as workers, government officers, or someone from a community in which your work has effects?

In every case, presume that they have knowledge and expertise. What sorts of knowledge? What sorts of expertise? Also, what do they desire, or are seeking? What do they want, both for themselves and for others, and how are they seeking to attain it? Finally, and most importantly, in working with them or doing work that affects them, can you figure out ways of adapting yourself to them, of helping them achieve what they want while doing your own work? When the course works best, students become critical analysts of their own knowledge and expertise, identities, and broader commitments. And, hopefully, a big take-away is genuine curiosity about others.

While critical participation is always necessarily localized, there is the issue of travel and scale. What effects does one seek as a scholar? If one wants to go beyond the linear model, which in this case involves publishing articles and books for other scholars in STS and engineering studies, then I find it helpful to think of one's concepts, the names and labels one formulates, as nominations for others to consider within the arenas of study. Before developing the book series, I largely limited the work of travel and scale to linear-model publications for engineering instructors and researchers in engineering education.[12] I considered the lessons of one course to be supplemental to the education of an engineer. I playfully called it the "other half" of engineering work that you needed to learn while in school, and said that you could get it cheaply and efficiently in one course.

Then in 2005, it occurred to me that the practices I had developed for one course could in principle be integrated across the engineering curriculum as a whole. There was a Eureka moment that I describe in the manifesto for engineering studies that I published in the inaugural issue of the new journal. I realized that I was nominating a novel image of engineering work, and developing an initial set of practices that just might have a chance of participating effectively across the formation of engineers, from introductory courses to core engineering science courses to capstone courses in engineering design. I called the image "engineering as problem definition and solution," or PDS. For the purposes of critical participation, it was important to frame this definition not as a replacement for the dominant image of problem solving leading to technological design, but as a complement to it. In other words, no engineering instructor would have to drop anything they do, just add something—attention to collaborative problem definition. And in doing so, perhaps core engineering courses could themselves become sites for helping engineering students learn to reflect critically on their knowledge,

My critical participation work in this project continues to span a wide range of activities. On one side, I must deepen the research documenting how learning engineering challenges students as persons—what engineering formation entails. On the other side, I must look for ways of incorporating PDS into dominant engineering pedagogies. In the middle, I must contribute to a growing body of learning materials that use juxtaposition and other strategies to provoke engineering students and their instructors to recognize and critically assess their own knowledge, identities, and commitments.

Ⅳ. Building scholarly infrastructures for Engineering Studies

Zhang: I see. Could you tell me about your work building engineering studies as an independent research field? I know you were the first to name it as such.

Downey: Building Engineering Studies has also been a project of critical participation, this time within academic arenas. As is always the case, the act of nominating a new or alternative image to address or rectify limitations in dominant images is both necessary and grossly insufficient. Successfully transporting that image across the boundaries of one's field typically requires intensive, localized planning and the often-invisible work of persuading lots of people to add new knowledge, expertise, commitments, and identities. Messing with dominant images, and potential dominant images, always requires one to join with others.

Early on in the process, it occurred to me that a good way to transport Engineering Studies into the social and object spaces of STS was to seek official admission—a sort of visa, if you will. The field of Engineering Studies received its first visa from editors of the STS Handbook in 1994. Juan Lucena, then my Ph.D. student, joined me in producing a review of research on engineers and engineering that had appeared subsequent to my earlier study. Inclusion in the Handbook sanctioned admission. For some years afterward, however, I remained largely unaware of the extent of its effects on readers. It was only in 2010, for example, that Professor Li Bocong told me at a workshop in Golden, Colorado that he had adopted the name as a label for his own work after reading the Handbook chapter. Indeed, he and others went on to build a massive scholarly enterprise in Engineering Studies in China, by far the world's largest. I find that gratifying.

Something else I didn't realize at the time was that seeking an initial visa to STS via 4S, the Handbook's sponsor, would have the effect of linking the field primarily to STS. Many non-STS scholars came to associate the term with specifically social studies of engineers and engineering. Such has been especially true for philosophers of engineering, despite my best efforts and own vision of Engineering Studies. I myself define Engineering Studies as a heterogeneous, interdisciplinary collection of researchers and research clustered around

the question: What are the relationships between the technical and nontechnical dimensions of engineering practices and how do these relationships change over time? In this image, scholars from many different fields and disciplines come together, both to address overlapping questions about engineers and engineering and to participate critically and, hopefully, effectively among them.

Given this initial linkage to STS, transporting the image to scholars from other fields has been tricky. I've long faced the question: How to achieve successful routine travel for the image and practices of Engineering Studies in ways that include but are not limited to STS? I knew from the outset that I'd be dedicating significant time and effort to building scholarly infrastructures to support and develop it. I signed up for that. But what sorts of infrastructures would best achieve the goals of international, trans-disciplinary transportation? It would tough enough to build an academic field focused on objects of study have been relatively invisible. How would scholars in Engineering Studies also place practices of critical participation, intervention, engagement, and so on, at the heart of its practices of knowledge production and expression, its commitments, its identity?

I decided during the early 2000s, erroneously as it turned out, that what Engineering Studies needed to travel and thrive was a new professional society. When the 4S met in Atlanta in 2003, jointly with the Society for the History of Technology [SHOT], I put up notices everywhere inviting anyone interested in the history or social study of engineers and engineering to come to a breakfast on Saturday morning. Nineteen people showed up at the breakfast! Nineteen! I was elated. I delivered a short presentation, summarizing emergent work on engineers and engineering and the opportunities for collaboration. I concluded with a fairly passionate proposal to establish a new professional society focused on engineers and engineering, a Society for Engineering Studies. Of the nineteen, one person said, "Yes." That was me. Eighteen said, "No."

Zhang: They did not think it was necessary.

Downey: They thought it was a bad idea. It was too much to ask, too demanding. Many responded with versions of, "I don't want to commit myself to another professional society. I'm already struggling to maintain my commitment to one [SHOT or 4S]. Another would be too much."

At a crucial moment in the discussion, Maria Paula Diogo, an historian from the New University of Lisbon, Portugal, said, "How about a network?" A network! I looked around: "How about a network?" Heads were nodding: it seemed to be the right level of organization and commitment. "Ok," I said, "let's form a network!"

Zhang: What's the full name of the network?

Downey: International Network for Engineering Studies, or INES. After the meeting, I began emailing scholars

engineering studies." Most responded "Yes!" with considerable enthusiasm.

I knew 4S was planning a meeting in Paris in 2004, a joint meeting with the EASST, the European Association for the Study of Science and Technology. Although historians trace elements of engineering practice to 16th Italy and earlier, there was broad agreement at the time that the person of the engineer had emerged in France, as *ingénieur*, during the late 17th and early 18th centuries. Vauban, the King's lead engineer for fortifications, became an icon across Europe during the 18th century. Study of history of engineering was, and remains, a virtual industry in France. It seemed to me essential to found an international network for engineering studies within France, specifically in Paris.

So I waited to formally establish the network until 2004, enlisting Maria Paula Diogo and Chyuan Yuan Wu, a sociologist from National Tsing Hua University, Taiwan, as founding co-organizers.[13] In retrospect, I should've found a way to reach out to the Society for Philosophy of Technology as well, for many philosophers were turning their attention to the study of engineering and engineers.

In addition to building a listserv and incorporating INES as a non-profit organization in Virginia, I went to the U.S. National Science Foundation to seek funding for an inaugural Engineering Studies workshop. The 2006 event proved to be a roaring success. All 42 participants agreed to videotaped introductions. I think 33 submitted manuscripts in advance, and we organized a rigorous review process with the goal of building solidarity across the heterogeneous group. Each participant had to produce and submit written reviews of about ten manuscripts prior to the workshop. We made these available in booklets so people could refer to them quickly during the sessions.

Each manuscript had exactly 30 minutes of workshop discussion allotted to it. The key feature of these discussions was that the author was prohibited from participating. The author could offer a one-minute introduction and then a two-minute reply at the end. For roughly 25 minutes, they had to sit listening to others discuss their work. A primary respondent led each discussion, followed by a secondary respondent and then others assigned to that discussion group.

Since authors couldn't respond, any time a commentator offered or endorsed a criticism, she or he then had to respond to the criticism. In this way, respondents and commentators gradually came to understand themselves as co-authors. Over the two-and-a-half day workshop, participants grew closer together and began discussing ways to build a permanent infrastructure for the network. Ulrik Jorgensen, then of the Technical University of Copenhagen, had already suggested organizing the network as a set of nodes, university nodes, connected by

has since sponsored or co-sponsored eight or nine workshops and numerous sessions at 4S and SHOT.

Zhang: You told me that the goal of your work as 4S president is to move beyond the linear model. What's the specific meaning of such a goal in Engineering Studies?

Downey: Let me answer this by describing the scholarly infrastructures we have built.

Firstly, at the 2006 workshop, it became obvious to all that, to build a field that could attract interest and commitments from other existing fields or disciplines. we'd need an academic journal. At the time, I was aware of the name Li Bocong and his interest in engineering. I invited him to join to the journal's editorial board. But I had no idea he was already producing a publication using the name Engineering Studies, and was rapidly working toward a quarterly journal himself. We went with Taylor & Francis out of a sense of loyalty. An acquisitions editor at Taylor & Francis for engineering and the social sciences had been pursuing me about an engineering studies journal for at least five years, ever since I had first mentioned the idea at a meeting of SEFI, the European Society for Engineering Education. Juan Lucena joined me in developing the prospectus and then co-editing the journal for its first three or four volumes.[14]

As I pointed out earlier with regard to STS, I've no interest in limiting the transportation of Engineering Studies research to strategies from the linear model. It is, however, essential to do quality conventional research—critical analyses of engineers and engineering, if you will. As its website points out, the journal has three distinct, but overlapping, aims. The first is to advance research on the historical, social, cultural, political, philosophical, rhetorical, and organizational studies of engineers and engineering. *Engineering Studies* is a research journal and must be seen as such.

Because engineers and engineering have largely been invisible, except in France, it would be necessary for the journal to traverse the whole planet. I've worked especially hard to make sure it doesn't emphasize Europe, doesn't emphasize the United States. The journal doesn't work, the field's infrastructures doesn't expand, if it doesn't stimulate research on engineers and engineering across spaces and terrains beyond EuroAmerica.

So, for example, I very much want to encourage submissions on engineers and engineering in China and to collaborate with the Chinese journal. China is a huge country with complex histories. There are many questions pertaining to engineers and engineering that would fit the INES journal. Professor Li showed me the Chinese character that his journal uses to translate the English word "engineering." He explained that it carries the meaning "large technological projects." Knowing something about Stalin's commitment to big engineering projects in the Soviet Union and of subsequent links with China during the 1950s and 1960s, I was fascinated to

large technological projects, but I hadn't identified them as such. I realized that many Chinese scholars who do Engineering Studies are writing on topics that in the United States or in Europe would be located within technology studies. Engineering Studies in the United States and Europe is defined more narrowly than Engineering Studies in China. I suspect that's one of the reasons why the journal that Li Bocong founded and which Wang Peiqiong now edits has become quite large, while the field in the U.S. and Europe remains fairly small.

Zhang: By "small," do you mean the number of scholars contributing to the field?

Downey: Yes, because the work published in the INES journal tends to be about people called engineers, the work they do as engineers, and its implications for others. Research on large technological projects is published in all STS journals. In the Chinese case, studies of people called "engineers" do not constitute the core of Engineering Studies research. So while we in the U.S. and Europe would draw a distinction between engineering studies and technology studies, Engineering Studies in China consists of virtually any topic that pertains to large technological projects. Li Bocong told me that at some point he'd write an article for the INES journal about what Engineering Studies means in China. Perhaps you might do this, or do it with him, for Americans and Europeans by and large don't understand this important point. Some of those attending this fPET conference are surprised at how many Chinese participants are presenting research on technological projects.[15] They don't understand that our Chinese colleagues are presenting research on engineering as they understand it.

In any case, in pursuing the first aim—quality conventional, but heterogeneous, research—it was important to make sure that the infrastructure of authors, editors, manuscripts, reviewers, etc. extended beyond Europe and the U.S. I also thought that the intellectual contents of the journal should, in a way, emulate developments in feminist science studies. That is to say, we need "first wave" research to make visible the invisible engineers and their work. We need "second wave" research, liberal studies of engineers, to document the relations that made them invisible and their positioning in relation to others. We need "third wave" research, post-structuralist studies, to call attention to the images and power relations that have the effect of disappearing, or otherwise locating engineers, engineering work, and the effects of both.

And all this had to be global. As I said, it's for this reason that I'd welcome formal collaborations with the Chinese journal. It's also for this reason that the iconic representation of Engineering Studies on the front cover consists of four images of the globe, all transparent, viewed from different angles, and overlapping with one another. The collection of images is designed to render the planet as engineered and yet complex or problematic,

Zhang: This journal does have a big vision. Well, it actually goes beyond that. The second aim for the journal's infrastructure is to build and serve diverse, even heterogeneous, communities of researchers interested in Engineering Studies. The journal presents itself as a site through which anyone conducting research on engineers or engineering is invited to pass. It is glue to connect them. This is why the journal must escape or overcome an image of Engineering Studies as only about social studies of engineers and engineering.

Thirdly, and importantly, the journal aims to build a different kind of scholarly infrastructure—one that actively, and comfortably, adds novel practices and techniques. The website describes the journal as seeking to link scholarly work in Engineering Studies with broader discussions and debates about engineering education, research, practice, policy, and representation—in other words, to undertake critical participation in the ways I outlined earlier. Generally speaking, I maintain that any scholarly field must transport the images it nominates beyond the boundaries of the field in order to be successful. With the joint meeting coming up in Buenos Aires between 4S and ESOCITE, our Latin American counterpart, I would now say that transporting the images one nominates necessarily involves a lot of "making and doing."[16] In the process, attention to the transport, or travel, of images nominated through quality research moves from the periphery to the center of scholarly attention and focus. The bottom line: it matters what one includes, or not, in the scholarly infrastructure of an academic field.

Zhang: Could you please talk more about how you built such prestige for the journal merely several years after you created it?

Downey: A prestigious journal is one that a broad cross-section of scholars want to read and cite, and one that libraries and other organizations want to purchase and make available to their members. And, of course, the most important steps of all are to gain acceptance into the SCI, the Thomson-Reuters Science Citation Index, and build a significant impact factor. We were well aware that in many parts of the world, including East Asia, scholars simply won't submit articles to journals that are not indexed by the SCI. Promotion and tenure committees in the United States and evaluation committees for universities and individual scholars in Europe rely increasingly upon journal rankings.

Thomson-Reuters decides whether you are worthy of inclusion based on a number of things. One is whether or not you are affiliated with a formal organization, so it helped that we incorporated INES when we initially established the journal. Another is the quality of the publisher. Taylor & Francis made it clear from the outset that they were committed to the journal for the long term.

fortunate to get accepted into SCI on our first try, a highly unusual circumstance I understand, in part because we focused on building a high impact factor from the outset. The first issue included all invited articles. We invited three distinguished scholars: Wendy Faulkner, a sociologist from Edinburgh; Antoine Picon, an historian from both Harvard and the *Ecole des Ponts et Chaussées* in France; and Carl Mitcham, a philosopher from the Colorado School of Mines. I added a manifesto for Engineering Studies. For several subsequent issues, we actively solicited manuscripts from prominent scholars. When the journal was accepted, its first ranking was ninth among 36 journals in history and philosophy of science.

Zhang: An emerging new star! And yes, it is true that if some Chinese scholar in Engineering Studies could publish one paper in an SCI journal, it would be quite influential in advancing that scholar's career.

Downey: I must say, though, that I never wanted to be an editor. I had turned down three invitations to edit STS journals. I've done this because it was necessary to build the infrastructure for the field.

During the initial planning process for the journal, I had a conversation with Michael Lynch, then editor of *Social Studies of Science*, that shocked and frightened me greatly. I had been greatly concerned about quality copy-editing. I was seeing an increasing number of publications with poor copy-editing, and knew that big publishers, including Taylor & Francis, were out-sourcing copy-editing throughout the world. I asked Michael how he managed the copy-editing process. He said that he spent between three and twelve hours on each final manuscript that authors considered ready for publication, in addition to all the other works. I did not have the time or inclination to make myself such a hefty node in the journal's infrastructure. I resolved to distribute editorial labor as broadly as possible, both to make the infrastructure larger and more durable and, hopefully, to build succession into key positions.

The unusually large editorial board includes distinguished scholars from a variety of fields around the world. In addition to myself as chief editor, the journal has twelve associate chief editors. These associate editors organize the review process for manuscripts that pass my initial screening. They solicit and collect reviews, and then make summative recommendations themselves. I then review the manuscripts closely in association with the reviews and issue final decisions, frequently with long explanatory letters.

The key person in the whole operation is the managing editor. After Jen Schneider departed to focus on her case for promotion and tenure, Kacey Beddoes has been serving in that capacity. She ensures that the flow of manuscripts is smooth and timely, so authors who are sharing their work with us feel both visible and respected. She also manages a team of assistant editors who go through the final manuscripts in detail, checking all citations

publisher. I'm convinced that the work Kacey and her team do on final manuscripts has been crucial to building the journal's reputation as a high-quality outlet for Engineering Studies research.

Zhang: That's great.

Downey: Now it does take much work to keep that level of citations high, and our impact factor goes up and down. But, as I said, my goal has never been to produce a journal that is solely academic in the conventional sense. I waited until the journal had established its scholarly reputation and then began expanding its purview. In its fourth year, I began soliciting submissions in two new categories of publication.

The category "Issues in Engineering Studies" supports the journal's second aim. We want the journal to provide a site for scholars and others to deliberate and debate issues of importance to the field. The issues might be conceptual, methodological, or about travel. I borrowed the idea from historians of science, who are doing this effectively. I like the idea because, as my colleague Matt Wisnioski once put it in conversation, the role of the academic journal is changing; it is increasingly a gathering site for scholars, a place where people come together. No one has yet approached me to do a theme issue, but I see this as crucial to infrastructure-building for Engineering Studies. If the journal's going to increase intellectual solidarity in a material sense, then it must invite scholars into active conversations, or at least share short two- or three-page position statements on a given issue. I think the format will become popular over the long term. One worry is that it might not be clear how to cite a lengthy conversation or debate, or to count those citations.

The other category, "Critical Participation," pursues the third aim. It gives scholars an opportunity to discuss and share practices of making and doing. Too often people come up with great ideas and practices that they don't subsequently share. The practices live and die with them. So I'm actively soliciting manuscripts in which scholars show or describe what they are attempting to accomplish among engineers through Engineering Studies. I want to document and help share the range of ways that creative scholars are participating critically in arenas populated by engineers and engineering, both to advance quality knowledge and to address limitations in existing dominant images. I'm currently working with a set of authors who are building a teaching enterprise designed to participate critically with engineering faculty and administrators within a school of engineering. Fascinating challenges there! If the journal didn't take this step but confined itself to conventional research articles for fellow scholars, I'd have little interest in it.

Zhang: I want to ask you about language issues in the journal. I talked with Zhu Qin. He told me the first manuscript he submitted to *Engineering Studies* had good content, but it needed to be revised a lot. This must be

Downey: There is indeed an issue with authors who are not native English speakers. This is a concern for many English language journals. How do we help scholars with their language? When the journal was first getting on its feet, I provided extensive assistance to one scholar who is not native English speaker. I wrote a significant amount of the article because I thought the topic and argument were important for the journal and field. I cannot do this all the time. So we encourage authors to get native English speakers to review and help edit drafts before they submit them. If the articles are accepted, sometimes I provide additional help; sometimes Kacey provides help; sometimes the publisher's copy editor provides help.

The bottom line is that it is difficult for a native Chinese speaker to publish in English. There is no easy or widely-accepted solution. It's a case-by-case problem. In the end, Zhu Qin's article is in wonderful English, wonderfully written with a clear, compelling argument. It's a fine contribution to the journal.

Zhang: How about the other editing that you do?

Downey: To position a new field effectively among existing fields, a journal is not enough. You also need to have a capstone book series, a place for scholars to publish high-quality monographs. I went to MIT Press. I actually went with a proposal for a large book series with two types of books. One type would be the research monograph. The other would be small books for students and working engineers. The idea here was linked to INES's third aim. Could I enroll a prestigious university press into helping advance the project of critical participation through what could become a substantial market for them? The answer was "no." They accepted the proposal only for research books for scholarly audiences, so we created the Engineering Studies book series at MIT Press.

To get books in the hands of students, hopefully for free, I also founded the Global Engineering book series with Morgan & Claypool Publishers. The main attractions of that press are that they license electronic versions of books to libraries, as pdfs, and that they promote their books at the large engineering education conferences and expositions. At the time I founded this series, Caroline Baillie of the University of Western Australia already had the series *Engineers, Technology and Society.* Based on its mission statement and published volumes, it seemed to be focused primarily on issue of social justice. I share that commitment to reducing social injustices propagated via engineering, but thought that the scope of that series was too narrow for the sorts of critical participation I had in mind for Engineering Studies. Caroline did later extend the boundaries of her series a great deal to include works that contribute more generally to inclusivity in engineering. I've been delighted to see that and have referred a number of authors to her. I don't think we can have too many outlets for scholars seeking to

Once I complete my term as president of 4S, I will shift my attention to expanding contributions to the two new journal categories and the two book series, to help other scholars who seek to participate critically in worlds of engineers and engineering. Some people need encouragement to take risks, and all these types of publications are risky in one way or another.

Ⅴ. Agents, Agencies, and Challenges

Zhang: You said earlier that your intellectual background is in anthropology.

Downey: It is, but it's not only that. My formation in anthropology involved adding an identity as an anthropologist to an existing identity as a mechanical engineer.[18] It was the combination that propelled me into STS. Becoming an STS scholar meant I had to figure out how to juxtapose, and hopefully merge, the knowledge, expertise, and commitments I gained from anthropology with those I had gained from engineering.

One implication of formation through anthropology is that I became committed to studying engineering through the lenses of engineers. That is, I am interested in the identities of engineers as agents, particularly in the relations between the technical and non-technical dimensions of those identities. And I examine engineering as the practices or performances of engineers.

Zhang: I am an historian. Some historians have strongly suggested that I apply anthropology in my own research, including research on the history of engineering. I am wondering: do you view anthropology as playing a central role in the interdisciplinary research of Engineering Studies?

Downey: Well, I wouldn't put it quite that way. For me, it's more about attending not only to the agencies in and around engineering but also to the agents called engineers.

As the mission statement for INES puts it, the field juxtaposes work from history, sociology, anthropology, philosophy, political science, communication studies, organizational research, and so on. Since the 1980s, all these fields have tended to focus first on agencies, examining how agencies, both human and nonhuman, interact to produce structures as outcomes. I have viewed this as something of a dialectical overreaction. One consequence was reduced interest in agents, sometimes resulting in their disappearance from studies except as vehicles for practices or agencies.

As I've said, the third aim of linking scholarly work in Engineering Studies with broader debates about engineering education, research, practice, policy, and representation makes the journal, Network, and, hopefully, field audience-oriented in a fundamental way. Critical participation in engineering practice necessarily involves listening to, engaging, and persuading engineers as active agents. We're not critical participants in their work if

they don't listen to us. Who they are, their identities, their knowledge and expertise, their commitments are all central to Engineering Studies scholarship, as INES has defined it. To the extent that anthropologists highlight agents to a greater extent than contributors from other fields, the discipline could play an especially important role in the future development of Engineering Studies.

Zhang: Does using an anthropological approach to study engineers as agents have disadvantages?

Downey: Unfortunately, yes. While anthropologists have wholly embraced the study of science and technology, I have not seen significant levels of interest in engineers as persons.

In 1987 and 1988, Sharon Traweek and I proposed sessions at the American Anthropological Association on the anthropology of science and technology. Both were rejected, quite explicitly, on the grounds that science and technology were not legitimate objects of anthropological research. Today, probably as much as a third of research in American cultural anthropology examines the positioning of science, technology, and, by extension, medicine in everyday cultural life. There's great interest, for example, in the emergence and travel of new images of humans through the biological sciences.

Greater numbers of anthropologists are turning to study scientists, technologists of various sorts, and other technical practitioners. Sometimes this work attends to engineers and engineering, and thus enters the arena of Engineering Studies. But, by and large, anthropologists continue to treat engineering in ways similar to STS scholars—either as a synonym for technology or as a metaphor for technical agencies.

Zhang: But the field is open to anthropologists?

Downey: Yes! I love it when it happens, whether the focus is on engineers or engineering.

Zhang: Given your point about agents and agencies, what are the main challenges confronting Engineering Studies now?

Downey: Apart from overcoming the image of Engineering Studies as including social studies only, perhaps the biggest challenge is to persuade scholars interested in science and technology, especially STS scholars, that engineers and engineering can be core sites for their research.

As is always the case, the analytical issues of a field or discipline trace back ultimately to existing dominant images of the objects of study in that field. For example, as I said earlier, engineering is frequently seen as downstream of science and, hence, less important. We joke that engineers and engineering are actually the center of knowledge production, expression, and travel because of their mediating position. Looking outward from engineering, the sciences become big consulting firms for engineering work. Engineers go to the sciences for

much greater visibility and prestige. But it is the work of scholars to make visible what is hidden and call attention to the limitations of dominant images. The so-called god-trick of science, which has the effect of disappearing engineering downstream, is certainly one such image.

Analytically, a significant challenge is to analyze in clear terms relations in engineering between knowledge and expertise, and the commitments that come with it. I care so much about engineering because, as Ken Alder put it, engineers are "designed to serve." Engineers believe, and accept, that their work has normative dimensions.[19] For scholars interested in science and technology, engineering offers an interesting, even important, site for exploring the normative or value dimensions of knowledge and expertise.

Zhang: Do you still think about setting up a special professional society for Engineering Studies in the U.S. and Europe?

Downey: Not in the near term. For two reasons, I think.

One is similar to what attendees at this fPET conference were just saying about the infrastructure for the philosophy of engineering. Many are members of the American Philosophical Association or Society for Philosophy and Technology. To build and maintain a professional society for the philosophy of engineering would require an enormous amount of work by many scholars over a long period of time. Engineering Studies has an established identity in the U.S. and Europe, but it has not grown significantly over the past three or four years. It is stable. Scholars come and go, but the overall number on the listserv stays about three hundred.

If interest in the journal grew quickly, or we felt overwhelming pressure for more workshops and other meetings, then perhaps. I actually think it depends on the extent to which Engineering Studies scholars can begin to claim the field as an emergent discipline. This goes back to the question of critical participation we discussed earlier. My sense is that an interdisciplinary field can begin to call itself a discipline when the new images it nominates begin to travel significantly beyond the boundaries of the field and become taken for granted in the arenas of study. The interests of Engineering Studies researchers would then become something akin to a "mission" for an Engineering Studies discipline. Maybe one day, but we're not seeing it now.

A related reason for not developing a professional society now is that the benefits to members from joining a professional society are evolving. Publications are moving online. Increasingly, we have electronic publications, such as the two series at Morgan & Claypool. The print publication is losing its importance, especially for early career scholars, and the PDF is becoming increasingly important. Print publishers such as Oxford University Press and Springer are selling PDF's of individual chapters from book collections, undermining, I think, the

The main justification for joining a professional society used to be the print journal. Now many scholars obtain PDFs through their university libraries, which makes the reduced registration rate one gets at annual meetings an increasingly important benefit of joining. Perhaps the main benefit. I'm seeing in the 4S, for example, that if members don't plan to attend a given meeting, they seem much more likely to allow their membership to lapse than they might have in the past. So the shift to electronic publication is arguably providing a disincentive to establishing new professional societies.

Zhang: In China, the development space for a new discipline relies mainly on institutionalization within professional societies. Professor Li Bocong wanted me to update you about the institutionalization of Engineering Studies in China—development of its infrastructure, as you put it. In his judgment, Engineering Studies depends upon three disciplines: history of engineering, philosophy of engineering, and sociology of engineering. As you know, the philosophy of engineering in China developed several years ago. The Society for Dialectics of Nature/Philosophy of Nature, Science and Technology has established a section on the philosophy of engineering. The Chinese Sociological Association has founded a section on the sociology of engineering. This year, the Society for the History of Science and Technology will establish a section on the history of engineering.

In this sense, Professor Li is very positive. In his judgment, the basic picture of Engineering Studies in China has been drawn through the three sections.

Considering the differences you have described between Engineering Studies in Europe and the U.S., on the one hand, and China, on the other, how do you view these developments in the infrastructure of engineering studies in China?

Downey: All this is enormously exciting and encouraging. Please convey my hearty congratulations to Professor Li Bocong and all the other scholars who have been involved in these important additions to the scholarly infrastructure for Engineering Studies in China.

Your description reminds me of the early days of STS during the 1980s. I found it fascinating to watch historians of science and technology, philosophers of science and technology, and sociologists of science, scientific knowledge, and technology reaching across disciplinary lines to read one another's work. They were looking for help addressing questions they could not wholly answer with their sub-disciplinary viewpoints alone. One justification then for a separate field called STS was that historians, philosophers, and sociologists were clustering around variants of a common question: What are the relations between the so-called knowledge,

non-technical dimensions, and how do these relations change over time? A similar process appears to be happening now with Engineering Studies in China.

Seeing this connection leads me to two follow-up questions. The first is: What are the chances of Engineering Studies gaining status as a separate discipline in China? Or more specifically, what are the chances of Engineering Studies research in China nominating new images through critical analysis, images that might travel beyond the boundaries of these subfields and become taken for granted in the arena of study? If I were interested in building a separate Chinese Society for Engineering Studies, designed to combine these sub-disciplinary developments, I would focus attention on audiences they shared beyond the boundaries of their fields as currently defined.

My guess is that such has a greater chance in China in the near term than it does in the U.S. and Europe because of the link to the study of large technological projects. I tend to be an optimist, but it seems reasonable to speculate that historians, philosophers, and sociologists of engineering might find themselves collaborating to address the myriad of researchable questions that emerge with large technological projects. One can picture the history, philosophy, and sociology of technology in the Three Gorges Dam project as complementary and additive. A key question is how to formulate collaborations in research and teaching that might have a chance of scaling up new images of large technological projects.

Zhang: That's right. Some projects are super-large, raising many complex questions.

Downey: When I attended the sociology of engineering conference in 2011 at what was then the Graduate University of the Chinese Academy of Sciences, I was struck by the extent to which the sociological researchers focused on such issues as peoples displaced by dam construction—the disenfranchised. Just making visible and documenting the experiences of such people, let alone using that to formulate new images of the projects as a whole, can constitute an importance approach to critical participation in a constructive way. Is that what those scholars intended? I never had the chance to ask. To what extent are researchers interested in or committed to participating critically in the projects they study, both to advance knowledge production and expression and to formulate and advance alternative images that might travel? Such provided another important source of legitimacy for early developments in STS, and I'm trying to make it a focus of attention for Engineering Studies in the U.S. and Europe.

My second question about the three new sections of professional societies is: To what extent are these Engineering Studies researchers studying people who get identified as engineers and what they do, including but

University of the Chinese Academy of Sciences is no longer exclusively a graduate university. At the sociology of engineering conference in Beijing, I saw drawings and photographs of the new campus, then under construction. The senior administrator who presented them explained that the Chinese Academy of Sciences had developed so many new research institutes that it needed a larger campus for first-year graduate students. They come to the main campus before going off to do their research.

I did not know that the main campus would also become a new site for undergraduate engineering education and the word "Graduate" would be dropped from its name. From an INES point of view, if you add undergraduate engineering education to an existing graduate university, it raises many researchable questions: How? Why? Why engineers? How will these engineers be trained and where will they work—at the research institutes, for example? The questions are especially interesting given that we have the Beijing institute of Technology nearby; we have Tsinghua University, Jiaotong University, Dalian Institute of Technology, and a multitude of regional and local technological universities and institutes. The major universities are producing engineers at both the undergraduate and graduate levels. How did the Chinese Academy of Sciences become interested in undergraduate engineering education, and how is it carrying this out? What makes it similar to or different from other sites for the formation of engineers? What are the implications of their formation for engineering work and its implications in China?

And for Engineering Studies scholars at the Chinese Academy of Sciences: what part(s) can you play in their education? Will you be seeking to help these engineers become better engineers? What would that mean in China?

Notes:

[1] Downey thanks Teun Zuiderent-Jerak for introducing him to the concept of knowledge expression.

[2] Council has since approved annual support for the *Ethnografilm* festival founded by Shrum in 2014 to be held each April in Paris.

[3] Downey's understanding is that Marguerite Avery, then of MIT Press, suggested the idea to Trevor Pinch, who embraced it and created a subcommittee of the 4S publications committee to begin researching possible directions."

[4] The committee was also considering the name '4S Founders' Award' until Council members indicated a preference for 'Building STS.' Some Council members also expressed concerns about how to distinguish such an award from both the Mentoring Award and Bernal Prize, the Society's highest award.

[5] Downey uses the term "image" to refer generally to events of representation, ranging in scale from ideas to realities, meaning to reference, ideals to materiality. Dominant images name that which is given to someone or taken-for-granted by them as true or real. The 'someone' is essential, meaning that truth or reality always has an audience.

[6] The term 'perspectives' has devolved into an anachronism in anthropology, a vestige of structure-oriented analysis. More on this later in the interview. Like other social sciences, it shifted its focus to agencies and, more recently, materialities.

[7] Years later, George Stocking, an historian of anthropology in the department, told Downey that his defense marked a turning point in the department from structure to agency-based analysis. He reports that he thought, "Thanks a lot."

[9] Downey and his co-author, Kyonghee Han (Yonsei University) elaborate this point in the book *Engineers for Korea* (Morgan & Claypool Publishers, 2014).

[10] The majority of graduates in engineering-related fields in France have worked in the private sector since at least 1900. Downey is speaking here to the commitments and hierarchy of value built into engineering formation.

[11] Downey's former student, Juan Lucena, developed modules on Mexico, Colombia, and Brazil. Another former student, Brent Jesiek, has worked with Yi Shen and Zhu Qin on the emergence of engineers and engineering in China. Matthew Wisnioski, a colleague at Virginia Tech, has developed a module on engineering in India. As part of the Global Engineering series Downey edits with Morgan & Claypool Publishers, other scholars are producing books on Canada, Portugal, Colombia, and India. Downey is currently working both on an introduction to the course and, with Chang Kuo-Hui, a former student, and Shih Po-jen, a current student, on the emergence of engineers and engineering in Taiwan.

[12] Downey also produced a series of multimedia lectures and made them available online for free. See his website, www.downey.sts.vt.edu.

[13] Brent Jesiek, an STS scholar and engineering education researchers at Purdue University, USA, has long served as INES Web Editor. Atsushi Akera, historian at Rensselaer Polytechnic Institute, later joined as an active co-organizer.

[14] Downey wants also to credit Brent Jesiek and Jen Schneider. Jesiek built the journal's first manuscript management system using OJS, the Open Journal System used today by many open access journals. Schneider served as the journal's first Managing Editor. A specialist in communication studies, she helped construct the many documents that constitute the infrastructural core of the manuscript management system.

[15] This interview took place during a conference of the Forum for the Philosophy of Engineering and Technology held at Virginia Tech in Blacksburg, Virginia, USA.

[16] Downey points out that during the year after he took office as 4S president, the theme of critical participation evolved into the language of making and doing. A committee is at work building a new meeting format. Downey and Pablo Kreimer, the ESOCITE chair of the upcoming joint meeting are organizing an opening plenary focused on this theme.

[17] Downey also wants to call your attention to the Springer series "Philosophy of Engineering and Technology," edited by Pieter Vermass, as well as the numerous publications by participants in the annual Forum on Philosophy, Engineering, and Technology.

[18] Downey notes that, in his research on engineering education, he appropriated the continental term "formation" to focus on how education and training combine to add identities to persons, thus forming them.

[19] Downey adds that the advocates of engineering tend to assert that it helps everyone all the time, resisting the specificities that would force them to portray the technical work of engineering as necessarily political at the same time.