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ABSTRACT Engineers have two types of stories about what constitutes 'real' engineering. In sociological terms, one is technicist, the other heterogeneous. How and where boundaries are drawn between 'the technical' and 'the social' in engineering identities and practices is a central concern for feminist technology studies, given the strong marking of sociality as feminine and technology as masculine. I explore these themes, drawing on ethnographic observations of building design engineering. This is a profoundly heterogeneous and networked engineering practice, which entails troubled boundary drawing and identities for the individuals involved – evident in interactions between engineers and architects, and among engineers, especially around management and design. Many engineers cleave to a technicist engineering identity, and even those who embrace the heterogeneous reality of their actual work oscillate between or straddle, not always comfortably, the two identities. There are complex gender tensions, as well as professional tensions, at work here – associated with distinct versions of hegemonic masculinity, with the technical/social dualism, and with what I call 'gender in/authenticity' issues. I conclude that technicist engineering identities persist in part because they converge with (and perform) available masculinities, and that women's (perceived and felt) membership as 'real' engineers is likely to be more fragile than men's. Engineering as a profession must foreground and celebrate the heterogeneity of engineering work. Improving the representation of women in engineering requires promoting more heterogeneous versions of gender as well as engineering.

Keywords engineer identities, gender, heterogeneity, technical/social dualism

'Nuts and Bolts and People'

Gender-Troubled Engineering Identities

Wendy Faulkner

In conversation with a friend who has been an engineer for some 40 years, I was surprised to discover that he had worked in quite different sectors, and on quite different technologies, from toy manufacturing to road bridge maintenance. He explained, 'It's all engineering really – all nuts and bolts.' Then he paused for a minute and added, as if to correct himself, 'Well, nuts and bolts and people.'

Rather beautifully and unexpectedly, this exchange captures a widespread tension about what constitutes engineering – a tension between what sociologists of technology would call a 'technicist'[1] understanding of engineering practice and a heterogeneous or sociotechnical one. I have

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encountered this tension routinely in the course of ethnographic fieldwork amongst professional engineers. For instance, engineers commonly report that their biggest surprise when starting their first engineering job after graduating was how little of their work time was spent on 'actual' or 'real' engineering. When I ask what they mean by 'real engineering', they typically reply 'calculations and drawings' or just 'sums'. The emphasis on calculations is hardly surprising. As Louis Bucciarelli (1994: 108) has demonstrated, the core of university-based engineering education is a mathematical approach to analytical problem-solving in which problems are 'reduced' to their physical properties and social complexity is pared away. This training stands in stark contrast to the huge importance of 'social' expertise in engineering jobs, which engineers soon learn is actually vital to their work. Some, like my friend, come to view these aspects of the job as the more challenging and rewarding; others cleave to a 'nuts and bolts' identity. But virtually all the engineers I have met oscillate between or straddle, not always comfortably, technicist and heterogeneous engineering identities. In short, there is a deep technical/social dualism at the heart of engineers' identities as engineers.

The question 'what is engineering?' is of key sociological interest, precisely because the boundaries placed around what counts as engineering are typically about how much of 'the social' is admitted. Social studies of engineering have long grasped the paradox between the heterogeneous nature of engineering practice and the technicist orientation of engineering education.[2] They have provided rich case studies of 'life on the constructed social boundaries between science and society and between labour and capital' (Downey & Lucena, 1995: 167). But is this the full story? In this paper, I seek to 'write gender in' to this account. The technical/social dualism is a central concern for feminist technology studies also, since it maps so readily onto the entrenched gender dualism of masculine instrumentalism and feminine expressiveness, to (re)produce a strong marking of sociality as feminine and technology as masculine (Faulkner, 2000b). Yet the connection is rarely grasped. Although there exists an interesting literature on engineering identities,[3] scant attention has been paid to gender in relation to engineers' identities or to engineers' boundary work around the technical/social dualism.

This paper seeks to redress this gap. It draws on ethnographic fieldwork in two UK offices of a building design engineering consultancy company. This involved job-shadowing six engineers over the course of 5 weeks, two of whom – Karen and Fraser – I followed for more than a week each, offering many opportunities for extended conversation. During this fieldwork, I was able to observe closely the routine office-based practices of some 20 engineers, plus several meetings with external partners. This experience provided a very rich picture of just how profoundly heterogeneous building design engineering is.

The paper sets the scene, first by outlining my framework for thinking about gender in/of engineering, and then by discussing the heterogeneous nature of building design engineering. The body of the paper examines

closely some of the troubled boundary work around engineering identities that flows from this heterogeneity.[4] It looks at 'horizontal' boundaries *between* engineers and architects, and at 'vertical' boundaries *among* engineers, especially around design and management. In both cases, the troubled identities reflect very real and rather intractable professional and organizational dynamics. But they also reflect very real, and rather complex, gender dynamics. These dynamics help explain both the persistence of technicist engineering identities and the tensions between these identities and heterogeneous ones. I conclude that this evidence represents a challenge to 'women into engineering' campaigns and to the engineering profession: we need to foreground and celebrate the heterogeneities in gender(s) and in engineering.

Genders in/of Engineering

My fieldwork on building design engineering was part of a larger study entitled 'Genders in/of Engineering', which sought to bring a gender perspective and analysis to a detailed investigation of engineering practices, cultures and identities.[5] The study was founded on the conviction that we need to know more about men and masculinities in engineering if we are to understand better the continuing poor representation of women in engineering. By using ethnographic methods, my study addressed the premise that the retention and progression of women engineers is impaired not only by well-rehearsed structural barriers (for example, lack of flexible work practices), but also by more subtle, 'taken-for-granted' gender dynamics. In particular, the study identified a number of subtle dynamics by which people come to 'belong' (or not) in engineering communities of practice.

I use the plural 'genders' in the title of the project not only to capture the 'fact' of diverse masculini*ties* and feminini*ties* within engineering, but also to conceptualize gender as multi-faceted or multi-dimensional – encompassing symbols, cultures, practices, identities and structures. I see all of these facets as potentially interacting, though often in contradictory ways. Time and again, the study revealed that *actual people and practices in* engineering diverge significantly from the conventional (symbolic) gendering found in *images of* engineering – hence 'Genders *in/of* Engineering'. Such mismatches highlight the coexistence of forces for fluidity and forces for stability. In the course of the study, I have come to see gender *norms* as a major force for stability, one consequence of gender norms being that particular activities and behaviours are *perceived and felt* to be more 'gender authentic' for particular groups at any given time and place.

I have coined the term *gender in/authenticity* to capture the normative pressures of 'the way things are' – pressures that lead people to expect the gender norm (in this case, the man engineer) and to notice when they see something different (the woman engineer). There is nothing remarkable about a man choosing to be an engineer. Most of the men I interviewed provided little or no account of their choice; either they never gave it much thought or it was all pretty obvious to them. By contrast, virtually all the

women interviewed *had a story to tell* about why they made the choice – in much the same way as women who don't have children have a story to tell as to why: it demands an explanation. The reactions of outsiders are a constant reminder that being a woman engineer marks them as unusual.

I must stress that I use the term 'gender authenticity' in a non-essentializing way. The term is not meant to imply that 'the way things are' can or should never change: far from it. Much of the evidence produced in the larger study profoundly challenges the *presumed* non-congruence of gender and engineering identities for women. The point is that gender in/authenticity issues are consequential: they *perform gender work*. Thus, the perceived gender inauthenticity of the woman engineer does not end when she chooses a career in engineering. It means that women engineers face (in) visibility problems men engineers never experience (as men) – that they are visible as women, not as engineers, and so have routinely to (re)establish their engineering credentials.[6] This is not trivial. For instance, when the managing director at the pre-bid meeting described later in this paper insists, 'We put our key men forward', he is part of *and at the same time reproducing* a tradition in which it is 'normal', even 'natural', to choose men for high-profile engineering jobs.

Finally, I understand gender to be pervasive in the social institutions that structure our choices, and ever present in the 'social ether' that shapes how we see, talk about and act in the world. Since gender is intricately interwoven with engineering, as it is with any other social institution, gender and engineering are *co-produced* or co-constructed.[7] For example, the nerd stereotype is of men who are passionate about technology but a-social; the fact that these two are posited as *mutually exclusive* – to be technical is to be not-social – is one of the more powerful symbolic ways in which engineering appears gender inauthentic for women, given the strong association of women/femininities with caring about people. I suggest that the co-production of gender and engineering, together with the concept of gender authenticity as I am using it, provides a useful framework for understanding gender trouble surrounding engineering identities.

Heterogeneity in Engineering Building Design

The design of buildings is a networked and staged design process involving collaboration between a heterogeneous array of partners, each of whom is vital but none of whom could do the job on their own. Major building projects start with a tendering procedure in which architectural and engineering companies team up to bid for the work. The clients commissioning a building also participate in the design process, so as to ensure that user requirements are incorporated. The design itself is developed in two main phases: the concept design, which establishes the main features of the building; and the detailed design (implementation), in which every last element is specified and commissioned. Architects and engineers work closely through both phases. Several engineering disciplines contribute to the design of a new building: structural, mechanical, electrical, civil, geotechnical and other specialists.

Because of the complexity and scale of any major building, and the range of expertise required, control is a major preoccupation. A building *contractor* is responsible for managing the construction, liaising with an army of *sub-contractors* who build or install the different elements of the building. Specialist *suppliers* are selected and commissioned by engineers during the detailed design. *Quantity surveyors* (cost consultants) work with the design team to ensure the building is as economical as possible. Often a separate company is brought in as *project manager* during the implementation phase. In addition, each partner usually has one or more members of staff charged with managing the project internally. Much of the detailed design takes place during the construction of the building, involving frequent on-site visits by the engineers. In large projects, especially where the client is a public sector organization, the implementation of the design can be very political.

Key to controlling the design process is managing the knowledge flows involved – both *certified* and *embodied* knowledge.[8] The first thing that struck me when I joined the company was the heaps of architectural-type drawings on every available surface. Drawings act as *the* boundary object[9] between the partners; as one junior woman engineer explained, 'it's how we communicate … how we know what to QS [quantity-survey] and how to build it'. Another early impression was that it is rarely quiet in these open-plan offices. At any one time, at least half of the engineers present are talking – either on the phone or to colleagues. In addition to these informal exchanges, the progress of a building design project is structured around a series of formal meetings, both internal and external.

Building design engineering is heterogeneous, not only in terms of the diverse array of partners involved, but also in the expertise required.[10] Some of this expertise is gained from university education – most obviously first principles, formulae and procedures specific to the discipline, plus analytical problem-solving. It also requires generic skills, such as presentation and communication skills, and the ability to find things out. Building design engineering also requires sophisticated management skills in various management disciplines and in handling delicate interpersonal situations; these are largely gained on the job, and include project management, accounting, line management, team building, and the ability to build and maintain networks of contacts. In addition, much of the specific expertise required can only be built up on the job: an appreciation of different types of client/user requirements, knowledge about specific products, relevant factors (for example, regulations), and useful contacts (suppliers, contractors, clients and other engineers). Above all, building design engineers, like other engineers, build up and rely on a huge body of cumulative experience of 'what works and what doesn't', from which they are able to make 'sound' judgements, not only about the design but also about the management and 'politics' of complex projects.

This brief overview indicates the depth and breadth of expertise required of building design engineers; the more senior and experienced the engineer, the more heterogeneous their expertise. It highlights two things.

First, building design engineering involves considerable 'people skills'. This is an explicit organizational driver in recruitment. One of the company's directors, Tom, has a mantra: 'Ignorance I can cure; personality I cannot'. And he means it: I once heard him recommending someone for a job on the basis of her enthusiasm alone, and holding back a man (with proven ability in detailed design) because his 'attitude' was wrong. Of course, some engineers have better people skills than others, but *all* of those I encountered are capable and effective in this regard.[11] As a minimum, they can work in teams and communicate across the divergent expertise, priorities and perspectives in design teams. They can do these things because they have to: failure can seriously undermine the company's business. We should remember that the great majority of these engineers are men. This reality, therefore, represents a largely un-trumpeted challenge to the 'to be technical is to be not social' stereotype of engineers, and to the widely held assumption that women engineers have better people skills than men engineers.[12]

Second, in every type of engineering job, the expertise required is *both* 'technical' and 'social'. Feasibility, for example, is simultaneously about what is practically doable and what is commercially viable. As has long been argued in technology studies, the knowledge mobilized in the course of engineering design is never 'just technical' with 'the social' bolted on (Hughes, 1983, 1986; Law, 1987). Rather, these two dimensions are in a very practical sense *inseparable* – hence the use of the terms 'sociotechnical' (unhyphenated) and 'seamless web' in technology studies to denote the inseparability of nominally 'social' and 'technical' aspects. Since the two are inseparable in everyday engineering practice, the boundaries drawn between them are inevitably arbitrary – as we will now see.

Troubled Boundaries between Engineers and Architects

Without exception, the building design engineers I met distinguish the professional orientation and interests of engineers and architects around a dualistic boundary: architects want a building that 'looks good' while engineers want a building that 'works' – by which they mean a building that stands up and that people are happy to inhabit and use. Karen is typical. On our first meeting, she explains to me that she took a joint degree, taught half by architecture and half by engineering faculty, which she describes as being 'more design than sums'. The next things she tells me about herself is that she has a particular interest in energy-efficient and sustainable building design, adding 'we engineers understand more about it than architects'. In a later interview, Karen says she might have become an architect but 'I felt more of an engineer. I was a bit too practical for architecture … I need more to justify a space than "it's the right aesthetic" – it has to fulfil its function, it has to make people comfortable, it has to use the appropriate amount of energy, etc.'

In practice, the distinction between design and technology is misleading: there is considerable overlap in what the two communities actually do

and know. Architects spend a significant proportion of their education learning about building technology. As Karen discovered, there are 'some very talented architects and they are problem solvers too. Trying to get all the required spaces to fit and relate to each other while maintaining the "vision" is a difficult job.' Notice how her respect for architects is grounded in their ability to be *like engineers* (heterogeneous problem-solvers). By the same token, she argues, engineers need to be like architects: 'To be a good engineer you need to be creative' – for example, in how you integrate building services into a building – and 'You need people who can have those design conversations [with architects]'.

The distinction typically drawn between engineering design and architectural design is that between *form* and *function* (see, for example, Walsh et al., 1992: ch. 1). When engineers use the term in relation to architecture but not engineering, they are privileging the aesthetic version of 'design' over the functional. I sense that one reason for this is that 'form' and architectural design are generally more *visible* to outsiders than are 'function' and engineering design. In conversation one day, two engineers told me they saw the engineer's role as 'enabling the architect to be creative'. I asked, 'Well isn't there also creativity in engineering design?' They accepted this but argued that, for the most part, the ingenuity and originality which go into the engineering design of a building are not visible to users.

For this reason too, building design engineers, like architects, derive huge pride and satisfaction from seeing the finished building.[13] Conversation frequently turns to publicly visible buildings. On one such occasion, at a meeting to prepare a bid to design sustainable offices, the engineers and architects chat about the 'Gherkin' building in London, a notable 'green building'. Karen asks, 'Is there any assessment of the Atrium and how it will work? [since] *air doesn't do that!'* Eilidh, the other engineer present, laughs, explaining that the particular architects behind this building 'love arrows: blue ones for cold air and red ones for hot … *They think they can change the laws of physics!*' Karen joins in, lamenting the marketing of 'stupid ideas that don't work'. Perhaps realizing that the architects present don't really understand what the problem with air is, she then explains, grinning, 'They behave as if you can make air do what you want it to do! [But] cold air pushes hot air up. Hot air doesn't rise – *it's a myth!* It's displaced by cold air, which is denser and needed to drive it. In a room full of hot air there is no air movement.' She is laughing openly because, like many engineers, she identifies strongly with apparent certainty that flows from their reliance on science, and relishes the fact that such expertise distinguishes her from non-engineers.[14]

The technicist professional identity Karen is expressing in the exchanges above is associated not only with science but also with a kind of practical materiality – something I encountered repeatedly among both men and women engineers. Their educational grounding in mathematics and science allows engineers to claim an identity in the material and (mostly) predictable phenomena governed by the 'laws of nature', backed up by a faith in cause-and-effect reasoning. And this same materiality and scientificity enables them to claim, as the central contribution of engineering design, that it creates

technologies that 'do the job'.[15] This is a very empowering identity, *in the very literal sense* that buildings are empowering: they enable us (users) to do things. This is why engineers in all sectors celebrate the visible outcomes of their work. And it is why engineers' practical and scientific expertise *feels* very empowering to them, especially when contrasted with a lack of scientific or practical expertise in others.

The apparent certainty and materiality associated with science and technology can also be very powerful *symbolically* – with significant gender connotations, at least historically. As feminist scholars have demonstrated (Merchant, 1980; Easlea, 1981; Noble, 1991), achieving control and domination over nature was a central plank in the Baconian project – and a central justification, at the time, for excluding women from that project. Similarly, Ruth Oldenziel (1999) has demonstrated that the strong association of engineering with industrial technology (machines), with science and with corporate might, served to code engineering as heavily masculine during the period of its professionalization. In short, the establishment of both science and engineering involved the emergence of new versions of what Bob Connell (1987, 1995) terms *hegemonic masculinity*. The 'mastery of nature' remains a powerful emblem of technology, both within engineering (for example, Florman, 1976: 121–26) and in wider culture (for example, Caputi, 1988).

Elsewhere, I have suggested that engineers' shared pride and pleasure in the technologies they build can be read as a vicarious identification with the power of technologies, perhaps even a kind of *symbolic compensation* for a felt lack of power in other aspects of their lives (Faulkner, 2000a).[16] It has been suggested that this might explain the particular appeal of engineering to men – to the degree that performances of masculinity 'demand' a sense of mastery over something (Edwards, 1996), and that men 'have a problem' with interpersonal relationships (Hacker, 1990: ch. 4). Tine Kleif and I found that this hypothesis does hold for some men (Kleif & Faulkner, 2003). However, many of the women engineers I have encountered also like science and maths 'because there's always a right answer', and many also get excited by 'big bits of kit!'. The fact that the theme of power resonates with hegemonic versions of masculinity does not prevent women engineers from enjoying the felt power of built technologies as much as men do. This may be a significant symptom of gender change.

To recap: the need for 'conversations' between the collaborating specialists creates contradictory impulses about what counts as 'real' engineering. On the one hand, all the partners in a networked design process have to be able to 'meet in the middle', as it were, in order to collaborate. They must acquire what Collins & Evans (2002) call *interactive expertise* in each other's specialisms in order to converse meaningfully across those specialisms – which is why their work overlaps to some extent. On the other hand, engineers have an occupational interest to preserve their roles in the design process by foregrounding the 'core' scientific and technical expertise that only they, as engineers, can bring. I have suggested that there are other subjective dynamics at play here too – engineering identities are strongly tied up with the actual and felt power of built technologies, and

with the apparent certainty afforded by their use of maths and science. While these subjectivities are strongly associated historically and symbolically with available masculinities, they are no longer confined to men.

Boundary Spanning

Many engineers maintain a fairly clear division of labour in relation to the architects (and clients) they work with. John, for instance, has no desire to 'get embroiled' or 'take a position' in a rather tortuous workshop with clients and architects for a major office development. The aim of the meeting is to resolve conflicting requirements of form and function: to keep a clean sweep of stone flooring in the foyer but still provide sufficient air conditioning (which demands floor vents) plus access to maintain it. The role he takes is fairly passive, responding to request for 'facts' – about how much air conditioning they need, what vents are available on the market and the like. After the meeting he tells me, 'I take a fairly pragmatic view: just tell us what you want and we'll design it.' This pragmatic attitude may well be common among mechanical and electrical (M&E) engineers, since the building services they design are largely not visible. The structural engineers I observed are more likely to engage in deliberations concerning aesthetic form, since their design choices frequently impact on the appearance of the building. Notwithstanding disciplinary differences, some engineers span the boundary more effectively than others. Karen is one such. The part of her job she likes best is the 'upfront' roles – bidding for new work, developing the early concept designs and project-managing – all of which means she must be able to work effectively at the interface between engineering and architecture. She says her job 'is as much about people and relationships as sizing stuff'.

In the same spirit, Karen chose mechanical building services over other subjects, like structural engineering or controls, 'because they didn't involve people like building services do!' She is often animated about this aspect of building services engineering, including the very real difficulties associated with engaging the end user in making the building 'work'. During the preparation of the sustainable office bid, she launches into a minor speech on the subject:

> They [the client] need to think about the control system. Sustainability ends when you put people in! You need to train staff to ensure that the building is operating correctly. We mustn't leave once it's built. … If you don't get buy in, the buildings won't operate properly, and it will overheat. You probably need some automatic features [but] if it's all automatic, they'll also complain. You need people to like being there. And you need a facilities manager. … The way the industry hands over a building is crap! That's why all these low energy buildings get such bad press. For example, you can introduce digital displays in the building about water and energy use – so people know. It increases awareness and ownership. It all comes back to the process and how people buy in and own it. … It's all about people: designing buildings people can use!

Eilidh echoes the sentiments in a playful exchange: 'The world would be great if it weren't for people!' I read this comment as an ironic dig at the

technicist version of engineering, and a recognition that the 'people aspects' of engineering are far more challenging and difficult to resolve than the 'nuts and bolts'.

Like Karen, Eilidh spans the engineering–architecture boundary. During the same meeting, she comments on the landscape architect's concept of a 'pavilion' (that the landscape will be created first, then 'populated' with buildings): 'It can sound very soft and not very commercial.' Karen picks up:

> We need to get the message across that this is a hard commercial development. People assume that sustainable buildings are more expensive, but actually it involves taking money usually spent on M&E [building services] and spending it on the façade. And this is why you need a team approach.

Eilidh then asks Karen, 'What about the engineering?', which seems to be a question about 'nuts and bolts':

> Certainly, they should be looking at CHP [combined heat and power]. You don't need heat pumps if you don't air condition. Otherwise you zone the building where you can't avoid this. And you look at using river or ground water where needed, like, for toilet flushing.

Eilidh then turns to the architect and landscape architect, triumphantly: 'It's useful to have this discussion in front of [the client] to show we know the subject, to show we're not soft engineers who can't deliver!'

Eilidh makes frequent use of the hard/soft dualism. There is a clear value hierarchy in these quotes: hard is associated with being effective commercially, with the 'nuts and bolts' of engineering and with 'being able to deliver'; soft is associated with 'aesthetics', with the people aspects of design and, perhaps, with idealism in relation to sustainability. The symbolic gendering of this 'hard/soft' dualism is fairly self-evident (see Faulkner, 2000b). What I want to emphasize here is how Eilidh is building a space in which the importance of *both* 'hard' and 'soft' issues – and the need for *both* 'hard' and 'soft' expertise – is acknowledged.

Eilidh and Karen are proud of having that heterogeneous mix of expertise, and receive considerable organizational support for it: the engineering and architect companies both see Karen and Eilidh as their key assets in the sustainable office bid. Nonetheless, there are hints that the very heterogeneity of their expertise, and their role as boundary spanners potentially weaken their membership as 'real' engineers. Eilidh recently worked in a university mechanical engineering department, where 'they all talk about boilers all the time, and I felt very soft'. Now she works for a design company; 'I feel like a car mechanic there!' And as we leave the meeting, Eilidh and Karen wring their hands at the news that the joint degree Karen took is being disbanded.

Troubled Boundaries Among Engineers

The identity work performed by engineers is wrought with tensions and contradictions. Karen is clearly a 'nuts and bolts and people' type of engineer.

Yet she sees maths, science and practical technology as central to her engineering identity. As noted earlier, the mathematical competence, so emphasized in engineering education, is often all but absent in engineering practice. I was treated to many playful asides about this. Karen laughs with me in flicking through a report she wrote, 'See, I did some sums there!' And James, on the second day I shadow him, exclaims suddenly 'This is the first calculation you've seen me do!' I feel such jokes indicate a realistic irony, even wistfulness, about the inadequacy of the technicist version of engineering. They serve to challenge and reproduce simultaneously an image of engineering that is at odds with the actual work. The loss of 'technicist' identity is a readily recognized lament.

Several questions ensue: What do individual engineers feel about the contrast between the actual heterogeneity of their work and the technicist focus of their education? How do they position themselves in relation to the (implied) technical–social scale? And what are the implications of different positionings in terms of 'getting the job done', career progression and perceived membership as 'real' engineers? The cases of Karen and Fraser provide interesting insights on these questions.

Karen

Karen's joint degree has not held back her career as an engineer. In her fifth year in the company that she joined after graduating, she was responsible for the design of the mechanical building services in a major iconic building, incorporating many principles of sustainability. She subsequently won a prestigious national prize for this work, became chartered and got a major promotion – signalling that she is ready to bring in new business, undertake concept design and run projects unaided. So, Karen has clearly established her engineering credentials. Having done so, she now feels she has earned the right to concentrate on these more upfront roles.

Karen claims her personality is suited to these roles. She says, 'the arty-architecture bit of me, comes out' not only in how she approaches design (integrating engineering and architectural requirements), but also because 'I am creative in how I present myself, because I draw everything.' She also likes interacting with people and is very organized:

> I need to be out and about meeting people, talking to people. I don't like being stuck in the office in front of my computer all day. I also find that increasingly. … I prefer the buzz of being the one that has to front the job, make sure things are happening and deal with the external team and the client when things are either going well or not so well! I am a very organized person and the task of planning and managing the process sits well with that.

Like many others, however, she feels some ambivalence about this:

> There are weeks when I feel I've done no engineering at all. The person I am now is a project manager/design manager. … Every now and then I get a craving to do some sums. It used to bother me more. The feeling of 'not producing anything' has made me unhappy at times.

Karen juxtaposes the 'upfront' roles with the more 'backroom' job of detailed design, in a way that echoes the technical/social dualism. She has a sense that the upfront roles are less 'real' engineering, perhaps because they are further away from the materiality of 'producing' things. And she feels some sadness about moving away from the more narrowly technical aspects of her work (and perhaps identity) – hardly surprising, given that she has trained in and so values this aspect of engineering expertise.

Yet Karen wants to be able to leave behind the work of detailed design, on the grounds that people should be allowed to concentrate on the jobs that realize their particular strengths and interests. Unfortunately for Karen, this view is not shared by her manager, Tom, in the regional office to which she recently moved. Tom esteems Karen highly: 'She's very clever, very innovative, very likeable; got all sorts of qualities which are terrific in an engineer.' But he is troubled about her role. Karen explains:

> Tom used the term 'captain and cabin boy' when I joined – i.e., we all have to do a bit of everything, from basic stuff through to management stuff. … Problem is, I don't really want to be the cabin boy anymore – again been there, done that – and I've worked very hard to progress to a point where I don't have to do that role anymore. … I think that this may become a problem. … I'm more than happy to do the concept design and get things kicked off and then run the job, but the thought of spending the next several years tied to my desk detailing and personally putting tender packages together fills me with dread. … I definitely see my future as a project/design manager and not sure that I can do this within [the company].

Five months later, Karen left the company in which she had such a brilliant early career, for a job in project management – a move that, though still in mechanical building services, she sees as leaving engineering.

It would be quite wrong to view Karen's story as a tragedy. For Karen, this will probably prove a good career move, and her obvious talent is not being lost to the design of new buildings. What her story does illustrate, however, is how perceptions of what counts as 'real' engineering can have a material bearing on who is and is not deemed to *belong* in engineering – and, thus, on who gets to stay and progress. In part, as Karen rightly perceived, she did not 'fit' in the particular business model of the regional office (the captain and cabin boy). By contrast, the head office where she had previously worked operates with a different business model: chartered engineers are *expected* to move into managerial roles and detailed design is conducted almost exclusively by junior engineers. In this setting, Karen's preferences would be unremarkable. In addition to this, I suspect that Karen's fragile membership in the regional office was also due to the culture and ethic of her colleagues, many of whom appear to celebrate a 'practical', 'nuts and bolts' version of engineering. On one occasion, there were gasps of astonishment when Karen admitted that she'd never 'sized' a gas pipe – *'You've got this far and never sized a gas pipe?!'*[17] Thus, although she was widely respected, it seems likely that some of Karen's colleagues were unimpressed by her disdain for practical and backroom jobs.[18]

Fraser

Fraser seems to be more in line with the culture and ethic in the office than Karen. Like her, he specialized in mechanical engineering building services and is in his early 30s. He also has a demonstrated talent for management and upfront roles. He is currently project managing the company's design of electrical and mechanical building services for a major office development. This means he plays a pivotal role between the dozen or so company engineers doing the detailed design and the wider network of partners involved in the project. It is the first time Fraser has done so much 'people management' and financial control, which he is finding a challenge. In his own time, he has developed a detailed plan for the design process – breaking down the jobs into tasks, with estimates of the number of drawings required for each and milestones for completing them. From this he worked up a spreadsheet of the hours per month needed from everyone on the job. These two documents were bound together with selected drawings marked up to show areas of flexibility. The whole document is half an inch thick. Fraser gave copies to all staff on the project, 'so they own it and know where their work fits in and have personal targets'. Over a period of two weeks, I witnessed him handle a number of quite delicate interpersonal interactions, within and beyond the firm.

The heterogeneity of Fraser's work does not sit entirely comfortably with him, however. Coming out of an on-site design team meeting one day, he expressed deep disdain for the role of the contractor manager who chaired the meeting. When I commented how impressed I was at the man's ability to 'keep it all in his head', Fraser's immediate and pained response was, 'But that's *all* he does is manage!' There is a similar theme in a later comment: 'They [the contractors] will never get blamed because all they do is management contracting; the subbies [the sub-contractors] do the work.' By implication, then, the *real* work is designing and building, not managing.

So for Fraser, there is a tension between engineering and management, where for Karen it is between backroom and upfront roles. But both of them experience the move into management as a move *away* from engineering. Fraser is clearly even less happy about this than Karen. He laments that he now gets to do less and less engineering (that is, design), and that engineering does not attract as much kudos as management. On more than one occasion, he expresses unprompted a heartfelt view that 'The people who are doing the design are just as important as those managing: both are essential and both should be paid the same!' Companies tend to reward managers more than designers in terms of pay and status because, as many senior managers report (like Tom), it is easier to find engineers who are good designers than engineers who have the needed management skills.[19] But the pay disparity is understandably resented by those who see 'real' engineering as being about design.

Science and technology are both part of Fraser's engineering identity, as with Karen. The science connection surfaces in the way he frequently dualizes 'facts and politics'. For example, he tells a client about a report he

is producing for them: 'I prefer not to do verbose reports – stick to the facts really.' On the big office project, a political conflict had erupted between the concept architects' requirement to maintain a consistent external appearance to the building and the users' requirement to have blinds they can see through. Façades engineers had produced a report which the client felt did not address their concerns adequately, so Fraser then revised it in a way which in turn upset the façades engineers. He explains, 'they say I haven't been correct, but they don't understand the politics'. Fraser's use of the word 'correct' is common among engineers: it signals 'facticity', an argument or finding that cannot be challenged. Like other engineers, Fraser takes comfort in certainty and seeks to maintain a very clear line around what is 'known' or unchallengable and what is not.

Fraser presents the 'technological' part of his engineering identity in terms of being 'a nuts and bolts person'. For example, in a telephone conversation with a contractor to whom the company is bidding in order to pair up for a major hospital project, Fraser says they need to talk 'with the people responsible for managing and delivering the thing as well as the nuts and bolts'. He then suggests 'an informal meeting with everyone chipping in …, that's what I like. I'm more of a nuts and bolts person, than sitting talking about the thing. It's all about delivery at the end of the day.'

The story of this bid is interesting for what is illustrates about the troubled boundary between management and design. There are two internal teleconferences – with three directors and two senior engineers, Fraser and Roger, from different offices of the company – to brainstorm their strategy for the bid and prepare the PowerPoint presentation. Everybody present recognizes that management and design need to be *integrated* if the design is to be 'delivered'. Yet the distinction between management and design runs right through the preparatory discussions for this bid, with 'delivery' emerging as an ambivalent, boundary term (as in Fraser's quotes above). The management challenges in the hospital project are considerable, since it will need inputs from several offices around the UK. But while the team members know they must have a convincing story to tell about this, time and again they come back to the need to demonstrate their 'design depth' – especially because the people they have to persuade in this bid are contractors. Tom emphasizes this: 'At some point, we will talk about design and delivery, and we will want depth in the meeting. … They will talk nuts and bolts. They'll want to know what your [waving to Fraser and Roger] duct drawings look like. … They'll respond quite well to that discussion in my experience [of contractors].' And later he cautions that the presentation must not be too long, so as to leave plenty of time to 'talk engineering!'

The other senior engineer, Roger, has extensive experience of project management but, like Fraser, holds on to a 'nuts and bolts' engineering identity – perhaps because he comes from a contracting background. He recently ran the mechanical and electrical design of a big hospital, and is asked to lead this side of the bid. Unlike Karen, Roger does not relish the role. He replies: 'Good designers don't necessarily do well upfront. … I'm not necessarily the man for the job. I'm not comfortable with strangers. My confidence is in my technical ability.' The healthcare director then suggests,

'I could be the project director, delivering some upfront bullshit, alongside Roger as the bid manager' – to which Tom responds, 'You're just a sharp instrument for Roger.' Re-reading these quotes, I feel the references to the healthcare director's role as 'bullshit' and 'just a sharp instrument' are intended to play up the importance of Roger's design strengths and play down these more upfront roles, *in order to win him over*.

In some ways, the relationship between the directors and senior engineers is similar to that between engineers and architects. The two must be able to work effectively together, but without losing their respective strengths – the directors, their 'upfront bullshit', business experience and networks of contacts; and the senior engineers their day-to-day, 'hands on' control and knowledge of design projects. Accordingly, the directors involved would find it hard to 'talk engineering' in specific detail with the contractors; they need the two senior engineers to present as 'nuts and bolts' people in the context of the bid. But if the company *is* to deliver the eventual hospital design, it needs Fraser and Roger to be what they in fact are – 'nuts and bolts and people' people!

We see here the fluidity of boundaries within engineering. In practice, management and design are thoroughly overlapping activities in engineering, in spite of the distinctions frequently drawn between them. A similar story could be told about the relations Roger and Fraser have with their respective staff – where their staff, and not they, would be cast as the 'nuts and bolts people'. In both cases, engineers portray themselves as *more technical than colleagues senior to them*. The directors and the senior engineers are both managers, albeit they occupy somewhat different management roles. And the directors and senior engineers are both still 'doing engineering', still using their 'core' engineering expertise, in these management roles. For example, Tom routinely reviews the designs of his staff and makes presentations of their work to architects or clients. In such ways, engineer managers have what Collins and Evans call *referred expertise*.[20] So the distinction between design and management is one of degree, not kind.

Gender Trouble around 'Real' Engineering

Karen and Fraser have much in common beyond their shared discipline and age. Both are relatively senior, respected by their peers and managers alike; both are hardworking and ambitious; both do a lot of upfront and managerial work and have good people skills; both have engineering identities routed in science and technology; and both lament the loss of 'real' engineering work to some degree. The main difference between them is that Fraser is still trying to hold on to some of detailed the 'nuts and bolts' work and has a strong sense of this as central to his engineering identity, whereas Karen is moving away from the nuts and bolts of detailed design and doesn't foreground this in her engineering identity. As a consequence, Karen had to leave the company in order to continue doing the type of engineering work she enjoys, whereas Fraser is likely to stay and progress through the ranks.

In drawing a comparison between the two, I do *not* wish to imply that Karen is typical of women engineers and Fraser of men engineers: I could have reversed their names, since there are plenty of men engineers who

happily gravitate away from backroom roles and women engineers who prefer these roles. Nor am I saying that their respective engineering identities necessarily relate to their individual gender identities: I do not know them well enough to say. Rather, I believe the cases of Karen and Fraser illustrate how *gender symbols* (in the social ether) *co-produce* (alongside professional drivers) *engineering identities* – following from the conceptual framework outlined at the beginning of this paper.

Most obviously, the 'nuts and bolts' identity takes its marker from hands-on work with technology; it is modelled on the technician engineer – virtually none of which in the UK are women. This engineering identity therefore resonates with a working class 'muscular masculinity' involving physical mastery. The blue collar associations of the 'nuts and bolts' identity paraded by Fraser and his colleagues may be more of a draw for engineers in the UK, where the class composition of engineers is generally more mixed than in other countries (Whalley, 1986), and where a considerable proportion of men engineers come in to professional engineering through apprenticeships. In addition, the blue collar associations are particularly salient in the context of a bid to building contractors, who generally have a much more working class composition and culture than do design engineering groups. Yet, even in countries where fewer engineers come from a blue collar background, it seems common for men engineers to celebrate a 'nuts and bolts' identity. In their extensive study of engineers in the USA, Judith McIlwee and Gregg Robinson (1992; also Robinson & McIlwee, 1991) found that men engineers often engage in 'ritualistic displays of hands-on technical competence' *even when the job does not require this competence*. Women engineers do not generally participate in this 'engineering culture', as they call it, and can lose out in career terms as a result.

So, the traditional association of men with engineering tools still marks professional engineering as masculine and makes the 'nuts and bolts' identity feel 'manly'. This does reflect a real, if diminishing, gender difference. 'Tinkering', with car engines and the like, has long been a typical route into engineering for men (for example, Mellström, 1995). Although a growing proportion of the men now entering engineering do not come from a tinkering background, and although some women opt for hands-on work, still considerably more men than women engineers have been socialized into a hands-on relationship with technology. As many women engineers testify, this can seriously undermine their confidence and their sense of belonging, especially when they first enter engineering degrees (Faulkner, 2005).

(The term 'practical' seems to me very gender-troubled in this context. Many of the women engineers I have met, including Karen, tell me unprompted that they are 'not practical' – by which they mean they do not have a strong background or interest in 'hands-on' aspects of engineering. This often comes up as a feature distinguishing them from other colleagues. At the same time, women and men engineers at all levels of the hierarchy routinely foreground and celebrate a 'practical' engineering identity. Practical in this context means that as engineers they come up with solutions that 'get the job done'.)

Significant though the 'hands-on' theme certainly is, the gendering of engineering identities is rather more complex than this, on a number of counts. For a start, women and men engineers both foreground technicist engineering identities, and science is an important marker of these identities for women and men alike. I sense that most women engineers foreground science more than 'nuts and bolts' in their engineering identities. This is not terribly surprising. The gender norms surrounding science are less strong these days than those surrounding 'nuts and bolts' technology, in the obvious sense that there are considerably more women scientists than women technician engineers. Yet, as we have repeatedly seen, there is a strong emphasis on materiality – designing things that work – among all engineers. This practical materiality is, thus, a unifying theme of both the 'nuts and bolts' and the 'laws of physics' versions of technicist engineering identities – and so cuts across the heavy masculine coding of the former.

Another source of gender complexity is that the two versions of 'real' engineering with which I opened this chapter are associated with two prevalent versions of masculinity. Where the technicist engineering identity takes its marker from science and technology, the heterogeneous identity takes its marker from corporate authority and business.[21] It is modelled on the senior manager or entrepreneur – of which few are women. Senior management is also a materially powerful role, like engineering, but here the power wielded is based on financial or organizational clout rather than physical power. A man engineer who moves into management may lose his credentials as a 'nuts and bolts' engineer in the eyes of engineering colleagues, even unsettle the blue collar associations, but he does not lose his credentials *as a man*. If anything, he gains in this regard, since the authority wielded by managers, and the money made in business, are widely applauded markers of achievement in men (Connell, 1987, 1995) – what Michael Kimmel (1994) has called *marketplace manhood.*

Why, then, does Fraser parade a technicist engineering identity even when his job is so heterogeneous? Why is he so reluctant to embrace an identity more consistent with his growing management role? This is something I have seen in other men engineers. Many oilfield engineers I studied voice disdain (albeit often jovially) for the 'collar and tie' men in management roles. Two of these men independently told me they dislike a career model that moves engineers from being specialists to generalists, destined for management. Like Fraser, these are men whose gender identities are closely tied up with technology. It is quite possible that if their ambitions could be met by staying in more narrowly technical roles, they would not opt to go into management. However, as well as being ambitious, all three of these men get excited (feel vicarious pleasure in) the 'money power' of the businesses they work for – and this is precisely what management gets them closer to. So they are torn between the attractions and rewards of management and their reluctance to leave behind what they see as 'real' engineering and the particular masculinity that goes with this.

Of course, such ambivalence is not unique to the engineering profession. People in many occupations (if not most) have to move progressively

into management roles and away from their original specialist skills if they want to progress their careers. There is no a priori reason to believe that women or men are any less likely to experience a sense of loss about the specialist work, and/or the identity that attaches to it, as they shift from specialist to management roles – *unless* their gender identities are tied up in some way with the specialty. Clearly, this does apply in the case of Fraser and others. But I believe a further gender dynamic may be operating here – namely, that the gender symbolism surrounding management is itself somewhat ambivalent. Remember Fraser's sense that management is not the 'real' work, and his disdain for people who 'only' manage.

I believe there are two dualisms embedded in these sentiments: hard/soft and technical/social. Note that the skills required for management are universally referred to by engineers as 'soft' skills – or 'fluff' – in contrast to the 'hard' skills required for engineering. There is a strong association here with people skills. But management is also an arena of 'hard' commercial reality – readily cast as hard-nosed, hard-hitting and so on – as Eilidh's quotes remind us. It is difficult to escape the gender connotations of the hard/soft dualism here. Moving into management and business roles is likely to feel, and be perceived as, more 'gender authentic' for men engineers, *to the degree that* these jobs carry real authority over others and/or deal with commercial, profit and loss aspects of running the business. Moving into management and business roles is likely to feel, and be perceived as, more 'gender authentic' for women engineers *to the degree that* these roles draw heavily on interpersonal skills, as in team management or customer relations.

The conventional gendering of the technical/social dualism creates tensions for men engineers doing or contemplating management roles in so far as 'the technical' and 'the social' are presumed to be mutually exclusive. It means that identifying with 'the technical' (masculinity) means distancing oneself from 'the social' (femininity) – or at least playing down its importance, as Fraser does in relation to management. It also means that roles like management are perceived as *just* social, not technical. I encountered this perception widely, among women and men engineers, even though all of the engineer managers I observed still use 'technical' expertise – as a sociologist, I could not do their job! Nonetheless, for a man whose gender and engineering identity is tied up with technology, a move into management potentially undermines both his gender and his engineering identities.

The technical/social dualism also creates tensions for women engineers. On the one hand, it means that moving out of narrowly technical roles is likely to feel, and be perceived as, more 'gender authentic' for them than for men. On the other hand, it means that those women who move away from the more narrowly technical aspects of engineering are likely to be in greater risk of losing their membership as 'real' engineers than are men who make the same move. Two older women engineers have commented on this to me: they say that women engineers who've become managers are more likely to stop calling themselves engineers than are men who have made the same move. Significantly, this very issue can serve to reinforce a technicist identity among women engineers. After all, engineering attracts women who

'love technology' and all women engineers perforce make a huge investment in being (and being visible as) engineers. It is perhaps not surprising, in this context, to discover that many women engineers *choose* to stay on the 'technical' side (quite apart from the others who get 'left' there).

If we look at the types of management jobs that women and men engineers end up in, we see evidence of an interaction of the gendering of these two dualisms – technical/social and engineering/management – in a pattern Mike Savage calls 'women's expertise and men's authority' (1992). It seems engineering is typical of other occupations in that men disproportionately occupy positions of power and authority, where they are involved in high-level line-management and control of organizational resources, while women are disproportionately in the management of support roles which demand specialist expertise (for example, in charge of IT systems).[22] Women also tend to get stuck in lower-level management jobs, such as project or team management, which can be dead-ends in terms of progression into more powerful seats of management: there is a glass ceiling in engineering management as elsewhere (Evetts, 1996, 1998). We should note here that occupational identities do not necessarily map onto the jobs people end up in. Thus, women engineers disproportionately occupy specialist engineering roles rather than management roles *irrespective of* any fragility in their membership as 'real' engineers. And men engineers disproportionately occupy management roles *irrespective of* any reluctance some may have about losing a technicist engineering identity.

In sum, it seems the gender authenticity issue never quite goes away for women in a male-dominated occupation – even though women engineers clearly are building new co-constructions of gender and engineering identities. The upshot of all this is that Fraser's membership as a 'real' engineer is likely to remain more solid, and Karen's more fragile, as they both move progressively from design into management. And Karen's move into management is more likely to be seen as – and sadly, in the case of her recent job move, to feel like – a move away from engineering, in spite of her obvious credentials on that front. In this significant regard, we *can* see Fraser and Karen and 'typical' of their gender.

Conclusions

We can now return to our opening challenge – to 'write gender in' to accounts of engineering identities. A key question is: *Why do engineers so often foreground a technicist engineering identity in spite of the lived heterogeneity of their actual work?* As we have seen, the unique professional contribution that engineers make in a networked design process is the 'core' expertise in analytical problem-solving and first principles they get from engineering education. These are professional factors, but there are also two critical gender factors operating here.

First, technicist engineering identities are as strong as they are partly because they converge with available masculinities in at least two important ways: they evoke a sense of hands-on 'nuts and bolts' work (even though

they rarely do this themselves); and they make engineers feel powerful (they make 'buildings that work'). Thus, many men engineers cleave to a technicist engineering identity because it feels consistent with versions of masculinity with which they are comfortable. While most women engineers also take pleasure in and identify with the material power of the technologies they build or use, the majority nonetheless identify more readily with the science base of engineering than with hands-on engineering. Significantly, whereas these women are, in effect, creating new gender identities as women engineers, their male colleagues do not have to do equivalent gender work.

Second, the conventional gendering of the technical/social dualism simply cannot be ignored if we are to understand the strength of technicist engineering identities (and, by this token, the continued male dominance of engineering). The conventional gendering of the technical/social dualism makes it easier for men to identify with the 'nuts and bolts' of engineering and casts people skills as 'soft', for women. The tendency to see 'the technical' and 'the social' as mutually exclusive reinforces some men's resistance to embracing a heterogeneous engineering identity. In any case, presenting as a 'nuts and bolts' person is rather more 'gender authentic' symbolically for a man than for a woman in our culture; just as moving away from the 'nuts and bolts' is rather more 'gender authentic' for a woman than a man. Little wonder that women's membership as 'real' engineers is often more fragile than that of male colleagues.

Notwithstanding the pull of the technicist identity, engineers routinely experience contradictory impulses concerning how much of 'the social' is admitted as part of their identities as engineers, and as part of what counts as 'real' engineering. A second key question, then, is: *Why are the tensions surrounding the two versions of 'real' engineering so apparently intractable, and what are they about?*

Again, there are gender dynamics operating alongside professional and organizational ones. Professionally and organizationally, there is a tension between the need for engineers' 'core' expertise in maths, science and technology, and the need for them to also be able to collaborate and communicate effectively with the other specialists and actors in a networked design process. In a similar way, there is a mutually dependent but partially overlapping relationship between those engineers who do more design and those who do more management.

The gender tensions operating around technicist and heterogeneous engineering identities are different for men and women engineers. For men engineers, tensions can flow from the fact that the two versions of masculinity which these two engineering identities map onto are *very distinct*: one associated with technology, the other with business. Although they are both in some sense hegemonic masculinities – therefore highly 'gender authentic' for men – they are not necessarily compatible for all men, as Fraser's story illustrates. For women engineers, tensions can flow from the very 'gender inauthenticity' of the woman engineer, which means that women engineers have a constant struggle to prove that they are not only 'real engineers' but also 'real women'.[23] In this context, moving away from narrowly technical roles is a case of 'damned if you do, damned if you don't'.

The central conclusion of this study is that *engineering as a profession must find ways to foreground and celebrate heterogeneous understandings of engineering and heterogeneous engineering identities*. There are two really strong reasons for this conclusion.

First, that is what engineering is! Every aspect of engineering is heterogeneous; even the most apparently technical roles have social elements embedded inextricably within them. Moreover, *good* engineering (as in engineering which is effective) demands the thorough integration of these elements, in ways that *transcend* conventional dichotomies. Witness, Eilidh's vision of the integration of 'hard' and 'soft' elements in sustainable building design; the hospital bid team's understanding of the need to integrate management and design if the hospital is to be 'delivered'; and the common view that 'good' (effective) management requires a combination of 'hard' and 'soft' skills. The crucial and radical challenge is to convey that all engineering is, of necessity, *both* technical and social. This is not an easy message for some engineers to hear, given how commonly engineers paint 'engineering' roles as *just* technical and 'management' roles as *just* social.

Second, foregrounding and celebrating more heterogeneous images of engineering can only serve to make the profession more inclusive. Engineering encompasses a wide diversity of roles, in which the relative weight of technical and social elements (among other things) varies along a spectrum. Within this 'broad church', individuals tend to gravitate to roles that suit their particular skills and personality. As we have seen, some are more comfortable with the 'upfront' roles and others with the 'backroom'; some are more comfortable interacting with contractors and suppliers, and others with architects and clients. If the profession does not promote an identity for itself that welcomes this broad range of interests and aptitudes, then it will fail to attract some very valuable talent. And if the profession remains a 'mono-culture', in which only people from one spot on the technical/ social spectrum really feel they belong, then it will lose some very valuable talent – as Karen's story illustrates.

So, promoting heterogeneous images of engineering will create space for a more diverse range of people to become engineers. If such moves are to be more *gender* inclusive, however, they must also challenge the gendering of 'the social' as feminine and 'the technical' as masculine – and thus promote new 'co-constructions' of gender *and* engineering simultaneously. In the words of the American scientist-come-historian Evelyn Fox Keller many years ago (1986), we need to learn to 'count past two'. Counting past two is not about getting more women who have good people skills into engineering (though that is not in itself a bad thing); it is about challenging the very dualisms that (re)produce women and men as necessarily different, and engineering as necessarily technical or social. As my ethnography of building design engineering demonstrates, *heterogeneous engineering requires heterogeneous genders* – in the sense that it requires various mixes of stereotypically masculine and feminine strengths.

The need to count past two may be analytically obvious to readers of science and technology studies and of gender studies, but the anti-essentialist message presents a serious challenge for practitioners and activists seeking to

improve the representation of women in engineering. Many 'women into engineering' campaigns draw on the conventional gendering of the technical/social dualism, by playing down the technical content of engineering and playing up the social content.[24] As Norwegian scholars have argued, appealing to women on these ground leaves intact the stereotypical equations between women and people skills, men and technology (Rasmussen, 1997; Lagesen, 2007). In playing down the technical content of engineering, such campaigns may also be seriously misleading, giving a false impression about engineering. Furthermore, my own and other scholars' recent work (Webster, 2005; Lagesen, 2007) reveals that those women who are likely to enjoy engineering *like* the technical and scientific aspects. Yet very few recruitment campaigns speak to this. Finally, promoting an image of engineers and engineering as *both* technical and social should have an impact on the retention and career progression of women engineers as well as on their recruitment. When women engineers (or men for that matter) do not count as real engineers, when they neither feel they belong nor are perceived by colleagues to belong in this way, engineering – and all of us who benefit from its labours – are the poorer.

Notes

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1. I use the term 'technicist' here not only to convey an understanding of engineering practice as narrowly technical, but also to capture a normative sense-that these narrowly technical aspects of engineering *alone* ought to be the 'real' work of engineers, or that they are the bits that 'get the job done'.
2. For a range of relevant case studies, see: Downey (1998), Law (1987), Vinck (2003), Bucciarelli (1994), Forsythe (1993).
3. See, for example, the review of engineering studies by Gary Downey and Juan Lucena (1995). Peter Whalley (1986) addresses *class* and occupational identities and boundaries in British engineering. More recently, there has been a growing body of internationally comparative research exploring intersection of *national* identities and professional identities of engineers in various countries. See Meiksins & Smith (1996) and Downey & Lucena (1997, 2004).
4. This is of course just one case of a more general phenomenon captured by Gieryn's (1995, 1999) concept of *boundary work*, which has been so helpful in illuminating the constructed nature of arbitrary boundaries around many areas of science or technology. The key analytical point I am drawing from this work is that how and where boundaries are drawn at any one time and place is often consequential, not 'accidental'.
5. Faulkner (2000a) indicates the framing of this larger study. In total, 66 engineers were interviewed and/or observed; where not attributed, later claims are derived from this fieldwork. See Faulkner (2005) for a synoptic account of early findings.
6. Karen Tonso's detailed ethnography of engineering students (1999, 2006, 2007) has been especially illuminating on this (in)visibility. She also shows that women engineers are (hetero)sexually visible in a way that their male peers never experience. My own work confirms both these phenomena. See Faulkner (2005), also my webcast lecture, 'Engineering Workplace Cultures: Men's Spaces and (In)visible Women?', of 3 November 2005 at <http://stadium.open.ac.uk/berrill/>

7. This framework has been elaborated and reflected on in: Cockburn (1992); Ormrod (1995); Berg & Lie (1995); Berg (1997); Lerman et al. (1997); Lohan (2000); Wajcman (2000); Faulkner (2001).
8. I am using the term 'certified' loosely here to distinguish knowledge that is written down or drawn, electronically or on paper (but not necessarily in any formal sense 'certified'), from knowledge that is 'embodied' in the expertise and interactions of the engineers. The significance of this distinction has long been emphasized in studies of expertise: see, for example, Williams et al. (1998).
9. See Star & Griesemer (1989). Here as elsewhere in engineering (Henderson, 1991; Ferguson, 1992), I observed how often engineers think and communicate by sketching, and how important visual knowledge is.
10. In an earlier project (Faulkner, 1994), I developed a typology of the technical knowledge used in the course of innovation, drawing on similar work (Gibbons & Johnston, 1974; Vincenti, 1990). The expertise listed in this paragraph encompasses but extends far beyond the scope of these typologies, precisely because I am including the more 'social' expertise.
11. There was one exception to prove the rule, an experienced engineer with a nervous disposition, who is now only given work 'where he doesn't have to speak to people and go out'. Tellingly, it has been very difficult to find sufficient work to keep him occupied.
12. This assumption has not been upheld empirically in my study: I have seen many male engineers with truly excellent people skills, and many women engineers who struggle on this front.
13. The tangible artefact is a common source of pleasure for engineers in all disciplines. (See Faulkner, 2000a; Florman, 1976; Hacker, 1989, 1990.)
14. Humour ridiculing the lack of 'technical' knowledge among others is a common feature of engineering communities (Hacker, 1990: ch. 4, Mellström, 1995: ch. 5). Elsewhere (Faulkner, 2000a), I have argued that the shared pleasure in engineering expertise is part of what marks engineers out as inhabiting a 'separate reality' (c.f. Murray, 1993).
15. I am not suggesting that engineering always *provides* certainty. As most engineers readily acknowledge, uncertainty is endemic. The point is that engineers see their roles as seeking to *reduce* uncertainty to acceptable levels, and see their uses of science and technology as enabling them to achieve this. It is the palpable success of modern technologies that gives them comfort in this. See Kleif & Faulkner (2003) for a fuller discussion.
16. This argument builds on the work of the late Sally Hacker (1989, ch. 3; 1990, ch. 4).
17. Sizing here refers to the calculation needed to establish what diameter of pipe is needed for a particular purpose. Karen asked how to size a gas pipe or duct because, as it happens, she'd never had to do it for gas before. She acknowledged their astonishment in her reply: 'I know, but how do you do it?'
18. As an illustration of how she isn't practical, Karen told me she had knocked back a request to do a 'plant inspection', on the grounds that 'I'll miss things and won't do it again'. See discussion in next section on gender-trouble surrounding the term 'practical'.
19. Many engineering companies have a 'dual ladder' career structure, which in principle allows engineers to gain promotion in recognition of their more technical expertise without moving into management. This is clearly an attempt not to alienate their 'core' designers too much since they can't deliver the business without them.
20. Thus: 'to manage a scientific project at a technical level requires not contributory expertise to the sciences in question but *the experience* of contributory expertise in some related science' (Collins & Evans, 2002: 257, emphasis in original).
21. For engineers who work in the public sector, heterogeneous engineering identities are likely to take their marker from seats of political power rather than business.
22. See Evetts (1996, 1998) and Otterly (2005) on women in engineering management; Wajcman (1998) is also relevant. For the gender segregation of management work in other sectors, see Savage (1992), Halford et al. (1997) and Crompton (1999).
23. The point here relates to the issue of women being visible as women and invisible as engineers. It is frequently manifest in the way women engineers position themselves, and are positioned, in engineering workplace cultures. See note 6.

24. Vivian Lagesen (2007) provides a fascinating recent example, at the NTNU in Norway, which equates men with squares and women with circles, and which 'takes a bash' at the hacker stereotype. Significantly, Lagesen demonstrates that playing to such stereotypes is generally seen as crass by the very people who are being targeted.

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