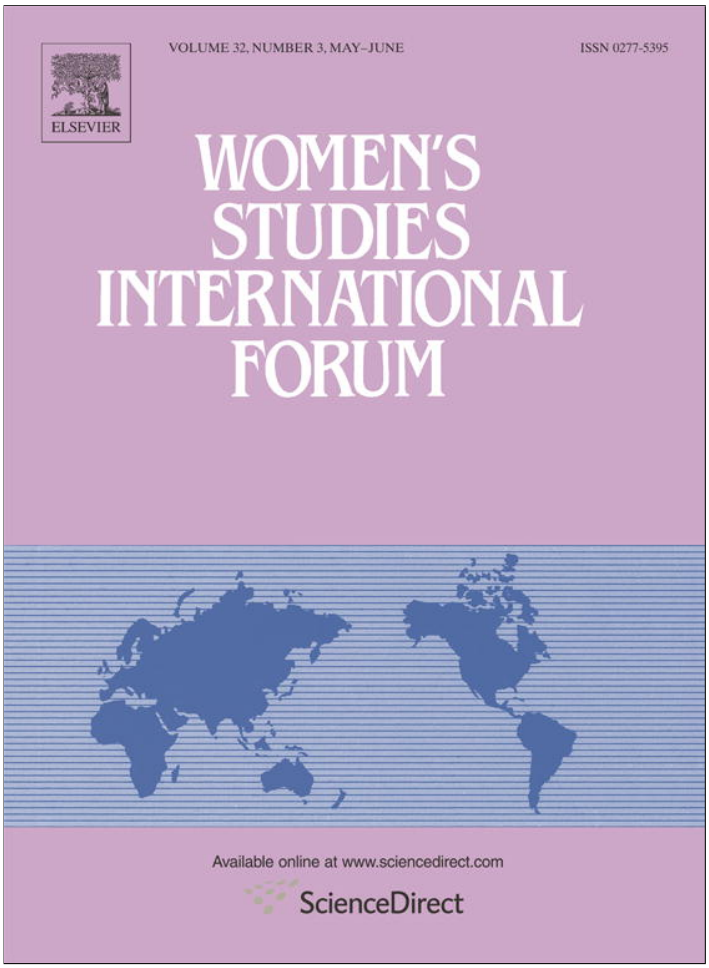

Women's Studies International Forum 32 (2009) 219–226

Contents lists available at ScienceDirect

Women's Studies International Forum

journal homepage: www.elsevier.com/locate/wsif

A located realism: Recent development within feminist science studies and the present options for feminist engineering

Maria Udén

Division of Gender, Technology and Organization, Department of Human Work Sciences, Luleå University of Technology, S-971 87 Luleå, Sweden

SYNOPSIS

The article states that in order to be meaningful gender studies in engineering need to conceptualize feminist understandings into the web of routines created and maintained in engineering practice. Its theme is the area in-between laboratory settings and human–machine interfaces. This huge area includes civil engineering, energy production, mechanical engineering and more, but has hardly been addressed in feminist writing on technology. The works of Evelyn Fox Keller and Karen Barad are investigated. Their respective approaches to language differ, as do their stances with regards to the possibility of universal knowledge. As an experiment, agential realism is applied to a fictive case of a collapsing structure, and found to make sense as feminist conceptualization of such an event. But engineering takes place in complex and disruptive processes that produce situated experience. Therefore, feminist concepts of embodiment and plurality remain crucial. The author recommends a located realism.

Introduction

From the 1980s onwards scientists such as Evelyn Fox Keller have reached world wide audiences with contributions to the development of feminist theory. Feminism in the natural sciences has since been a source for the development of feminist and gender studies perspectives in engineering. Against this background, in this article I will look into the present options for further development of feminist and gender studies perspectives in engineering. The problem area that intrigues me the most is the space in-between on the one hand the laboratory setting, and on the other hand social organization and human–machine interfaces (that occurs in for example systems development, urban planning and shop floor organization). This 'in-between' area of engineering practice has consistently been the least addressed in feminist writing on technology. This is not motivated by its minor effects on the conditions for human life, or on our planet, or because of insignificant economic impact or financial turnover. The area is huge. It includes the major parts of civil, mining, and chemical engineering; metallurgy, power production and distribution; electricity and electronics, and much of mechanical engineering etc.

This brings us to the difficulty addressed in this article. To be meaningful, gender studies in the engineering fields need to conceptualize feminist understandings into the web of routines that engineers create and maintain by doing their job. The challenge is to remain in contact with that which is central in engineering without losing touch with feminism and the other way around.

This study will not investigate the reasons as to why the natural sciences have generated more proficient and widely spread feminist scholarly publications, and have become the resource for gender studies in the engineering sciences rather than the other way around. A comparative overview of any set of feminist and gender studies publications from on the one side engineering, on the other natural science will demonstrate this as a fact. Evidently, in the social sciences and the humanities, feminism and gender studies have reached substantially further in developing theories and methods, and have grown larger groups of audiences and partakers than in both science and engineering. The subsistence and advancement of feminist engineering (to the degree that such a phenomenon does or will ever exist) is thus dependant on connecting to the more developed feminist fields in the social sciences and the humanities, their discourses and their tools.

0277-5395/$ – see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.wsif.2009.05.014

This dependence is, above being a historical fact, the expression of a need for intellectual resources at this point, that engineering science cannot provide. Why then, are the natural sciences of particular interest? It cannot be foreseen that neither the social sciences nor the humanities have the same relation to the material as engineering, if material is understood as *matter* and not least *materials*. For engineering their purposeful utilization is central. This relation to the material is close to that of science, but has specific characteristics in being explicitly instrumental. Engineering can be defined in many ways, but in comparison between engineering and the social sciences and humanities, and in contrast to the natural sciences it occurs that the *purposeful utilization* of material opportunities is engineering's significant pursuit. Therein rests also a relation to energy.

The plan of the article is to first develop the notion of engineering and the dilemma of addressing material reality and social construction together. Thereafter I describe the article's theoretical stance and in doing so I review and discuss the works of Evelyn Fox Keller and Karen Barad. A large part investigates and discusses the implications of their respective theories and to a certain degree of other feminist philosophy such as that of Rosi Braidotti. Chosen concepts from Barad's writing such as the agency of all relata are discussed in relation to their possible meaning in engineering practice, together with Keller's emphasis on plurality. One instrument for advancing the investigation is making engineering reality present, specifically as topical sections in the text.

Sexed equations and the emphasis on social construction of reality

Utilization requires reorganization. For instance, in mineral processing rock is fragmented and processed in order to produce separated and defined fractions of minerals. To obtain this result energy is needed, and the increasingly refined fractions are transported in and between plants and, some minerals finally to smelters. Here, material opportunities are utilized through a reorganization of materials that goes into their structures and even composition. The transport sector on the other hand, and the many engineering specialties maintaining and developing it, is concerned with a completely other type of reorganization namely the relocation of intact (hopefully) bodies from one point to another. The different sources of energy exploited for the purposes of this sector, are currently debated daily. Of course, en masse the relationships which engineers have to the material (matter, materials, energy), develops indirectly and through the execution of symbol processing or if put in other words, procedural handling of representations. These representations can be numbers, graphical representations in many varieties, and formulas, algorithms, etc. The point being that the focus of this processing remains on utilization. For instance, on some part of the chain from rock to minerals to metals to electronic components, finally put together with other components to computers. The symbol processing compels reduced costs and risks compared to what actual trials would bring about, if such had to be executed for each and every project. The theories which lay within procedures and symbols bring about widened horizons of achievability, and their execution differentiates engineering from other professions and trades (see for instance Berner, 2006; Kline & Lassman, 2005). For better or worse, the methods for natural resource exploitation and for production, construction and communication that signify the global society today would not have existed without symbol processing for technical purposes.

In my case commencing postgraduate studies meant repositioning from engineering to gender studies. This was in the early 1990s. My aim was to develop a technology analysis on feminist ground. From the start the process was inspiring. Feminist researchers and theorists lay before me tools for making the particularity of engineering graspable beyond the self-evident picture of engineering practice which my engineering education had imprinted on me. Yet, as my studies progressed I came to experience much hesitation in formulating the direction I was heading for. The relation between matter and ideas is complicated and it is not obvious that feminism and engineering can go together. In 1996 Alan Sokal published a paper, which he later revealed was a parody of social constructivism. He followed this up in a book co-written with Jean Bricmont, in which the critique on 'social constructivism' was made explicit and detailed. A comment by Norris (1999) reveals the case. Sokal's hoax gained "jubilant acclaim" from scientific colleagues (Norris, 1999: 78). What were these acclaims about? Solely celebrating revenge for being questioned, the way scientists are from the mere existence of sociology of knowledge? This can be part of an explanation. At the same time, scientists are people who in their scholarly practice cannot escape dealing with matter or energy. They are therefore dependant on a fundamental acceptance of matter, as well as energy, as real.

Without spending much effort on reviewing feminist theory or research practices, Norris (1999) gave his article the title *Sexed equations and vexed physicists*, drawing attention to feminism and its role in the story. "Sexed equations" refers to Sokal's and Bricmont's (1998) ridicule over "[Luce] Irigaray's idea that $E = Mc^2$ is a 'sexed equation'" (Norris, 1999: 88). Norris agreed to that being an "especially absurd statement." Being a feminist and scientist/engineer in the midst of this turmoil, that is finding feminism an enabler towards a clearer view of reality, makes a confused state, additionally more as in the eyes of a fair share of feminists, feminist advancement has suffered as much as served from 'post modernism', 'social constructionism' or should we say lack of frames for addressing materiality. As much as feminism carries an urge for breaking free from and reforming a reality whose inevitability it questions, it contains a struggle with materiality. Moreover, what outside observers apparently have failed to understand is that the prime focus of feminist critique is in fact social constructions, above all. To feminists, social constructions matter. Both R.W. Connell and Judith Butler, two of the more prominent feminist theorists in the period of and prior to the Sokal hoax, repeatedly asked why matters of social construction are referred to as 'just' or 'only': "Arguments about gender are plagued by an assumption that what is biological or 'natural' is somehow more real than what is social. /…/ The oppression of women and gays is a matter of human agency, not of nature" (Connell, 1987: x).

Practice and language: the philosophy of Charles Taylor

I tend to maintain that *practice* is decisive for the existence of any branch of science or engineering rather than the

possibilities to logically define the branch itself or its constituents. The latter point of departure has been endorsed by for example Roy (2004). In *Interpretation and the Sciences of Man*, Charles Taylor (1985, paper originally published in 1971) maintained that intersubjective meaning is constituent of human societies. This is not the same as converging beliefs and values; it is not equal to consensus. Instead, intersubjective meaning is expressed in social practices and institutions. These are partly constituted by certain ways of talking about them. The range of social activity is "carved up in a certain way, by a certain set of distinctions which our vocabulary marks" (Taylor, 1985: 23). "At the same time," writes Taylor (1985: 29), "there is reaching out for other forms which still have the 'abstract' quality of ideals which are subjective in this sense, that is, not rooted in practice."

The deployment of feminist and gender theory in engineering is indeed a pursuit at present better described as an ambition than a practice. The vision and expectation is to be able to present methodological alternatives; alternative practices. This is expressed in for example Suchman (2007) on technology design and the human–machine interface, Rydhagen (2002) on feminist sanitary engineering, Mörtberg et al. (2003) foremostly on ICT and democracy. To a degree, the reaching out for other forms of engineering (feminist or gender studies informed) appears abstract even to those of us who are involved in the pursuit of forwarding these ambitions. For possibly reaching into engineering and its enormous fields 'in-between' I find the works of physicists Evelyn Fox Keller and Karen Barad of particular importance.

The strategies of Evelyn Fox Keller and Karen Barad

Evelyn Fox Keller has maintained that, given that human interaction with nature certainly involves language on the part of humans, the success of that interaction nonetheless remains something quite other than a social construct. "Whatever force [language] may have, that force can, after all, only be exerted on language-speaking subjects" (1992: 33). To conceal by declaring it all a social construct, the effective interaction with nature and matter that science gives us instruments to carry out, is an extraordinary denial. Yet, because of feminism's basic identification of social construction as integral to reality, a particular problem needs to be addressed:

> [N]o representation can ever 'correspond' to reality. At the same time, however, some representations are clearly better (more effective) than others. The question that has plagued much recent philosophy is how to make sense of this latter statement in the absence of a copy theory or truth (Keller, 1992: 5).

In science and engineering, representations can be words but, also for example equations, diagrams or flow sheets. The meshing of representations with opportunities offered by material reality leads to what Keller labels 'effective knowledge,' that is: knowledge that generates epistemological and technological success. With respect to any kind of feminist engineering ambitions, this is an extremely important observation. *The Century of the Gene* (Keller, 2000) is a recount of a scientific topic at the same time as it is a condensed expression of the view on language that Keller has developed as a scientist and feminist:

> But over the long run, as everybody knows, language does evolve, in science as elsewhere. Indeed, our understanding of the natural world could scarcely progress without such evolution (Keller, 2002: 144).

The learning from Keller is that science does systematically interact with language, and specifically that this interaction is far from naïve on the part of the scientific community. Nor is it neutral in terms of values promoted or otherwise harmless in terms of the results it produces. "In this sense," she writes, "*good science* typically works to bring the material world in closer conformity with the stories and expectations" (Keller, 1992, italics original) While Keller on the one hand addresses research and development leading to production of nuclear weapons, and how this has status as effective and successful science, the expression "good science" could be ironic or cynical. On the other hand however, this expression may also mean that science will be shaped by any set of standards, if only the chance is given. This conviction is demonstrated while she reconstructs the work of Barbara McClintock (Keller, 1983) and in her own approaches to contemporary biology in *The Century of the Gene* and other publications. This experimental line of work takes on diversity and detail. Keller's feminist ethics include the conviction that plurality and richness in perspectives and styles of research is the only path possible for women to gain genuine access to science, and it states that science does not have privileged access to knowledge about nature (Keller, 1987). In focusing on language however, Keller leaves out much of the interaction scientists (and engineers) involve themselves in. The somewhat younger Karen Barad has prioritized differently. She holds that feminists and scientists alike have struggled with over-emphasis on social constructions as fundamental for the human world, and she is the most prominent writer to catch the sense of frustration the Sokal hoax expressed, opening an article as she did, with the straight forward assertion that: "Language has been granted too much power" (Barad, 2003: 801). The words are from *Posthumanist performativity: Toward an understanding of how matter comes to matter*. It reflects a need for access to relevant language for fostering relevant research, and a feeling that getting to this is hindered by a dominant intellectual trend. Barad names the academic route at fault 'representationalism' referring to the belief that we have access to representations while not to that which they represent, while Norris (1999) speaks of 'the strong programme' and refers to sociology of knowledge. This however is details, but it can be noted that contrary to Norris Barad knows that the problem is shared by feminists and scientists alike. She makes this an explicit issue. Barad's punch line is that any relation, be it of physical, linguistic or other kind can be understood within the frame she introduces, *agential realism*, and which she builds in order to "not merely offer a unified theory of cultural and natural forces but inquire into the very practices through which they are differentiated" (2007: 66). Characteristically, she centres the building of agential realism on how light emerges in laboratory set-ups.

Intra-action as a key notion of Barad, is disclosed around a well known disruption in this realm.

> [I]n contrast to the usual "interaction," which assumes that there are separate individual agencies that precede their interaction, the notion of intra-action recognizes that distinct agencies do not precede, but rather emerge through, their intra-action (Barad, 2007: 33).

To put it briefly, whether we get to know light as particles or waves is not about light being particles or waves but how it makes itself known to us, which depends on the apparatus we set up in order to get knowledge of it. A key notion is that the materiality of the apparatus itself is not merely the embodiment of human concepts:

> Crucial to understanding the workings of power is an understanding of the nature of power in the fullness of its materiality. To restrict power's productivity to the limited domains of the social, for example, or to figure matter as merely an end product rather than an active factor in further materialisations is to cheat matter out of the fullness of its capacity (Barad, 2007: 66).

Relying on Niels Bohr she thus puts forth that concepts are actual physical arrangements rather than ideational: "*theoretical concepts* (e.g., position and momentum) are not ideational in character but rather *specific physical arrangements*" (Barad, 2007: 147). It can be noted how this harmonizes with Taylor's notion of relation between language and practice. Besides Bohr's philosophy and advancements in physics, Barad relies on Foucault's philosophy of power and, especially in the early development of her agential realism on Butler's analysis of culture (1989, 1993, 1999) as a patch for the materialisation of human bodies. Hence, her methodology validates *becoming* rather than 'being' or even 'doing.' Phenomena are the primary epistemological units; "relations without pre-existing relata" (Barad, 2003: 815).

Implications for engineering

Barad's agential realism is developed through investigation of selected cases from theory on physics laboratory practice, and the use of detectors in medical practice (1998; 2003; 2007). She has also demonstrated agential realism on shop floor studies (2007). None of these lack relevance for engineering. But the space in-between science as it is practiced in laboratories and clinics on the one hand and the human–machine interface on the other, as for instance social organization of work, is huge and through the years it has been the least likely to be addressed by feminists. If the purposeful reorganization of matter is engineering's significant pursuit, this is where the grand part of this reorganization happens. Thus, if Barad's methodology can contribute to advancement here, the achievement will be noteworthy. I will here apply Barad's analytical concepts *apparatuses*, *agency*, *power*, and *objectivity* to a schematic example, and thereby make a first test of the feasibility of Barad's methodology. Let us look at typical, everyday engineering experiences such as those of soil, construction, and civil engineering. According to agential realism values are indeterminate before their measurement. That means soil does not exist in the terms which soil mechanics brings, until the engineer is brought in for example to investigate its strength in order to prepare a decision on what method to use for the foundations for a building, bridge or other construction. Furthermore, soil makes itself known to the civil engineer in the terms of mechanics as these are ways in which the civil engineer has capacity for getting an understanding of soil. This is not to say soil does not exist before it is the subject of scientific investigation. It does: in myriads of intra-actions. In this case here, just not with engineers.

Take the case of a construction. It can be for example a building, a bridge or antennae. Say that this construction collapses because the land it is built on gives in. Let us see what happens with the understanding of what takes place if viewed through the application of Barad's notions. The first is *apparatuses* — specific material-discursive practices that produce differences that matter. Here what is produced would be the construction standing on its foundation. To obtain this result and finally shatter it, the human *agency* is far from the only agency — among other agencies we find that of the soil, the wind and the materials and parts constituting the construction. *Power* is repeatedly applied to bodies — the weight of the construction applied to the foundation, water falls and flows, transporting material, affecting even the very structure of the soil. The wind applies strain on the construction, snow and ice weighs it down if the climate is such, and so do vehicles crossing if the construction is a bridge. *Objectivity* is permanent marks left on bodies — marks are made on the soil when the construction is raised, and afterwards, marks are made on the construction from wear, including smaller cracks as a result of minor subsiding, and many other processes. In the collapse the construction's destroyed parts are separated from each other, marks are made on the land which failed and where the construction part falls; potentially marks on human bodies, other constructions, vehicles, etc. The description can be made richer and more intricate. But this is sufficient for our purpose. The exercise makes sense.

Differences between the respective approaches of Keller and Barad

The difference in the approaches Keller and Barad have taken to language is evident. Moreover, their epistemological stances differ at the point of generalization and the possibility of universal knowledge. A main point of feminist critique of mainstream science in the 1980s and 1990s, was the search for singular forces and simple explanations to complex problems; a striving symbolized by the idea of 'the great unification theory.' "In the realm of theoretical physics," Keller (1985: 30) wrote, "the modern physicist searches for the laws of nature; he seeks communion with the nexus of authority to which material nature is subservient." Keller's critique was in that instance typical for the times, and the strategy has remained significant for feminism in all disciplines to this day. With agential realism Barad (2007: 66) reinstates the great unification theory in a feminist style calling it "a unified theory of cultural and natural forces." The benefits of the new approach are not definite, and I will show why. As demonstration of the capacity of agential realism Barad presents

an account of a shop floor organization which she has collected from another researcher, Leela Fernandes (Barad, 2007: 226–230). What Barad misses out by counting the possibility of describing the shop floor organization in the terms of agential realism; as a manifestation of agential realism's capacity, is that even though the theory she has developed from physics investigations can in retrospect be used as structure for the description of the organization of a shop floor, it could not in the first place have produced the data from which the description is produced. Knowledge in physics theory or acquaintance with the corresponding laboratory work is not sufficient or even needed, for the production of guidelines for humane shop floor working conditions (or even for inhumane conditions that are however economically prosperous for the shop owner). Barad (2007) emphasises that her account of Bohr's work goes beyond the mere analogy or metaphor level. She claims that this is the level where scholars reviewing Bohr's work mainly stay, and she rejects this latter practice as unscientific. Nonetheless, in the advance of agential realism she is not consistent to acknowledge that the shop floor, the body, or whatever other items (or phenomena) she mobilizes for its development, deserves the same careful account as does the light explored in Bohr's apparatuses, or the piezoelectric crystal investigated in one other set. As a result, Barad contradicts her own request for stringency. Withholding the request for stringency and respect for physics solely, she creates, or rather confirms, an existing hierarchy putting physics above all other knowledge. The social organization manifested on the shop floor; the human body, become metaphorically treated as if they were light or crystals. In this detail, Evelyn Fox Keller's methodological emphasis on plurality remains the more convincing strategy. Moreover, it is a more probable strategy to yield success even when making use of Barad's central winnings, than the application of a one-size-fits-all scheme. In the articulation of engineering experience produced in this paper, I have rather followed the quest of Keller, and tried to develop language that is likely to produce a science that is effective in a feminist sense, than implemented Barad's concepts as meta measures. My judgement is that the one does not replace the other. At this stage, while Barad's work has recently become more widespread, it is nevertheless necessary to examine her contribution more thoroughly.

A reformed view on agency

Returning to the example of soil, construction and civil engineering, everything from wind, water, worms, bacteria and field-mice to substances, particles and crystals, interact in the processes determining the history of the structure. To use Barad's vocabulary they intra-act creating phenomena, establishing each other as well as being created themselves. This view on agency might appear far-fetched, and is hardly compatible with the primacy we usually give to human will and human sense of meaning as determinant for agency. But, I would claim that this understanding is profoundly in line with what is taught to engineering students more or less from the start of the engineering education. The reason is that the ability to foresee and determine the behaviour of (in this case) soil over time is crucial, or for example erosion of rock, the ageing of materials, etc. This ability leans on contextual understanding. To an engineer soil or bedrock is not atoms and elementary particles other than in relation to very specific practices, or even silicates and carbonates, but rather the way in which these have been first generated, then layered and with time rearranged to new composition, in that manner presenting the circumstances with which to interact in constructing a bank, a building or a road. There is an interconnectedness about this kind of thinking, along with contextual awareness, that resonates with feminist theory on science and technology, as it evolved during the 1980s and 1990s. This is a definite point where feminism as transdisciplinary effort is of importance for feminism in engineering. From feminists in the social sciences and humanities, we have learned that universalism and the ideal of unity excludes and omits people from the possibilities to take place within society and language, and so from coming into being. We have learned that we need not strive for unity among us, or even within us to make sense or earn the right to speak (see in particular Butler, 1999; Braidotti, 1994; Hooks, 1981). Engineers such as I might like to pretend that things are clear-cut, straight-on and no-fuss when we build communications networks, roads, drill rigs, textile factories or power plants, or when we make steel. The truth is, when applied, engineering is never beautiful in the way a mathematical formula or a piece of classical music can be. Philosopher Rosi Braidotti's honour of accounting for each and every detail, regardless how disruptive it is to the whole, instead of turning to the broad strokes of sweeping formulations, speaks well with engineering practice — as it turns out in practice. What can be learnt by engineers from this feminist philosophy is that such a situation is not by any means a fault or burden. Braidotti writes:

> [I]n a globally linked world 'we' are indeed in *this* together. But this pan-human factor need not result in new universalizing master narratives /…/ The polylingual voice of the multi-located subjects of the global nomadic, diasporic, hybrid diversity are producing concretely grounded micro-narratives that call for a joyful kind of dissonance (Braidotti, 2006: 93).

While Braidotti addresses a global situation in this quote, the statement could describe almost any engineering project I can think of, even the most local, and including my schematic soil and construction fictive example above. The utilization requirement circumscribes effectively any aspirations for disregarding disruption. Also the results of feminist post-colonial technology projects tend to demonstrate this vividly. The learning here is profoundly that methodically, there is no one-size-fits-all solution, except keeping eyes, ears and minds open. Extrapolating knowledge from one situation to another is not universally possible, and this goes for technical as well as organizational strategy. For instance, while Yoko Arisaka (2001) holds forth the leading engineer Susan Murcott's (1991, 1998) understanding of traditionally Buddhist ethos and the extensive local participation she enabled in the development of location adapted technology, as explanation for the success in two feminist household water projects in Nepalese and Burmese locations, Birgitta Rydhagen (2002) warns against expectations that populations in poor communities shall be more prone to environmentally friendly and

locally based solutions of everyday matters than their richer neighbours are. Herself an eco-feminist Rydhagen eventually found it unethical to disregard the wish for usual commercially available flushing toilets, when this was pronounced by inhabitants in a South African community where she was engaged in a water and sanitation project. The situation made Rydhagen reflect upon her mission. Middle class households are not expected to take part in the design of their areas' plumbing systems. What is implied in expectations that more vulnerable populations shall allocate from their scarce resources to doing so?

Hands-on feminist interventions in technology production are typically staged in projects of local scale and in poorer communities, as those mentioned above; local/household water and sanitation, or communications access projects. Thus, the power balance between the feminist scholars and engineers and the (future) users of the technical designs developed typically is asymmetrical to the disadvantage of the users. Furthermore, the feminist technologist probably has a sort of monopoly at the location, as the economic viability of the type of endeavour does not answer to commercial business models. The necessity of ethical considerations draws attention to local circumstances and all their variations. However, also in large scale projects the location-bound character of knowledge and the contradictions intrinsic in human and particularly post-colonial interaction are manifest. An analysis developed by historian May-Britt Öhman (2007) reminds us that extrapolating know-how won in one setting to another, is difficult. The case investigated by Öhman (2007) started when, after the colonization period had ended, the Tanzanian nation planned for exploitation of some of its water resources. In competition with British interests, the Swedish hydro power company Vattenfall earned a contract to exploit the Great Ruaha River. Since Sweden was not a former colonial master it contributed to the attractiveness of Vattenfall's offer, writes Öhman. However, if the Tanzanian leadership gained something of political or symbolic value, and also financial support from the Swedish Development Agency and the World Bank, certain engineering capacities were lost with the decision to go for the Swedes, in short the ability to technically envision the river as anything more than a hydro power source. While the initial wish from the Tanzanian leadership was a technical design that made use of the to-be exploited river's resources both for irrigation and hydro power, the first goal was eventually left without execution. Öhman argues that this had to do with the foundational knowledge of Vattenfall being accumulated in the organization during its first years of operation as public authority building hydro power in Sweden. With plentiful access to water including ground water, irrigation has historically never been the issue in this Nordic country as in many parts of the world. Water was no major constraint for agricultural production in Sweden during the first half of the 20th century when the Vattenfall know-how was established, and by no means in the remote sub Arctic region where its first grand projects took place. Thus, while the British as colonial power had developed knowledge on how to combine irrigation with other use of a river's resources, the Swedes had not, and the Tanzanian's did not have the capacity to compete against either. The Tanzanians got hydro power but not irrigation. To speak with agential realism, the analysis developed by Öhman brings forth how a specific natural setting, intra-acts with those that take on to reorganize its rivers into hydro power production systems. The landscape that is so re/created is not the only constituent of the phenomenon emerging in the intra-action. There are many. Among them are a corps of engineers, and the organization Vattenfall. Finally, the location of the primary intra-action (Sweden) has consequences for the further activities carried out by Vattenfall.

Engineering and the agency of all relata

Returning to Barad's contest of boundaries and the reformed view on agency in agential realism they can be recognized from other renowned feminist theory as that of Donna Haraway (2004), and indeed that of Keller's. Especially in some later contributions Keller (2000; 2005) contests the human centred view of agency and, already in her publication from 1992, *Secrets of life, secrets of death* she declared that scientists interact with nature. Interaction cannot take place between one active part and one that is dumb. Nevertheless, where Donna Haraway (2004) has certainly made us reflect upon the possibility of animals and machines not only having agency but co-constructing the agency we possess as humans, and Keller has indicated that the interaction scientists are involved in, as counter parts involves that which is beyond those in one way or another human-like agents, Barad's emphasis on the agency of *all* relata composing a phenomena uniquely resonates with the way in which engineers already think. Thus, her theory fills an empty space, the existence of which possibly has contributed to the comparatively weaker development of feminist theory and gender studies in engineering. Her definition of knowledge as a possibility for *any* body is especially of interest here: "knowing is a matter of differential responsiveness" (Barad, 2007: 149). This is a crucial thought for engineering as the instrumental character of this profession, i.e. the imperative to make things work, creates co-workers out of materials, machines, structures, components, tubes, combustion, explosion, electricity, compression, beams, arcs, pressure, tension, land, rock, water, solids and fluids, emulsions, acids, electric circuits, fibre, radio waves, computer programs, etc, etc. Furthermore, the concepts of becoming, of intra-acting; the notion of the one mutually making the other in each renewed moment rather than stably just being there resonates well with engineering knowledge. For engineering students, learning about soil and bedrock, and how they respond to pressure, rainfall and excavation, is learning that they have a history that makes a difference to their responses. For active engineers this learning about mutual and ever present processes continues. As a result of engineering's instrumental relation to the material aspects of existence, an awareness of ongoing history is ever present in it. Not only do we as engineers and technical professionals presume that all materials and all matter have a history, but we also know and expect that what we produce will go through historical processes. The fact that not only human use but nature's processes will inevitably affect what we produce is one of the very foundations of our knowledge, and in this sense engineering excellence is more or less measured as the ability to counteract or allow forces of change (to the desired degree). This is why it is relevant for a

PhD student in an engineering faculty to study "Maintenance Performance Indicators," or for a research group to engage in "better understanding and control of degradation phenomena and failure modes," to mention a couple of examples from the polytechnic university where I work.

The future of feminist engineering studies

Above I have maintained that the future options for feminist and gender studies perspectives in engineering depend on the success of conceptualizing feminist understandings into the web of routines created and maintained in the symbol processing that signify engineering, and that the focus of this processing is utilization of material opportunities. The differences between the respective approaches to language found in the works of Evelyn Fox Keller and Karen Barad, and the fact that Barad does not build on Keller's work, imply a new situation in feminist science studies; the development of different schools within the study of physics. With this, feminist science writing has entered into a second round. Though I am personally sceptical about universal knowledge claims (I find it risky to mistake principles for knowledge), it is significant that Barad has brought dimensions of materiality that are crucial in engineering, to the common arena of feminist methodology. Her particular contest of conceptual boundaries includes certain concerns hitherto silent in feminist theory, but central in engineering. With the help of agential realism the huge area in-between lab and organization, the only two science and engineering settings hitherto regularly addressed by feminism, unfold. This is significant, because endeavours that form not only the lives of individuals and populations locally, but globally, take place in this area in-between. At this stage there is an opportunity to follow up a general interest in becoming and enacting in feminist methodology, perhaps stronger than ever accentuated in agential realism. Implicitly there is an offer in the air that was not there before, of the times being helpful to developing conceptual tools, and for creating stories where the central dimensions of engineering's interaction with nature and matter can be accounted for in meaningful terms. But, before concluding this topic, I find it necessary to address the transdisciplinary relations within feminism. My point would be that even if feminists in the social sciences and humanities must strive eventually to find a resolution to problems of addressing materiality, the lack of frames for doing so has been a hindrance to a degree beyond compare for the development of feminism within the engineering sciences. This is because the core practices of engineering remain impossible to address as long as language or social construction are the only factors attributed existence. Even when starting from a pool of common, let us say everyday language, there are differences in the purposes that concepts and words must serve as part of feminist engineering endeavours, as compared to the roles the same concepts have in especially feminism in the social sciences and the humanities. As result of the less developed state of feminism in engineering, this has effects regarding the way in which theory and practice can reasonably be directed and formed. Being the dependant part in a relation, one inevitably reflects upon what strategies are in reality feasible. A question is to what degree feminism in other disciplines would gain from advancement in the conceptualization within feminist engineering. Can the potential gains become reciprocal?

Feminist gains

In the above rudimentary experiment with Barad's agential realism soil was made a theme. Soil is central, particularly in one of the very significant engineering specialities, that of civil engineering. The ability to foresee and determine the behaviour of soil is crucial in grandiose projects as construction of hydro power plants and their gigantic dams, and soil is an ever present topic in the everyday doings of urban planning, projecting of roads and railroads, etc. At the same time, a number of quite other trades and professions interact intensely with soil for their own reasons (farmers and gardeners of course, but also archaeologists, for instance.). However, I want to especially highlight that every person has experience of soil without any professional reasons at all. The reason that we all have this experience regardless of and beyond professions and education, is that we live on and by it; we know soil as that which we walk upon, as dirt and dust, transported with the wind from continent to continent, soil to cultivate, soil as slopes that change each year with the flow of rivers and waves, as land suddenly flushed away with storms and rain; the good of soil that gives us crops and the threat of soil as the foundation of houses and villages that vanish; soil sinking down and collapsing when permafrost melts and the sea level rises. In sum, the experience of the same natural and material environment as that with which engineers work is shared by literally all people in this world. How the interaction with soil permeates social organization, our modes of thinking, or the arts is not for engineers to tell. Nonetheless, as soil is a condition for our lives it might prove helpful for those to whom it is to say these things, to have access to language that catches up till now silent aspects of our experiences and relations to it. Soil leaves marks on our bodies and our cultures.

To conclude: what is gained, as seen from a *feminist* perspective, not only engineering perspective, if we are now able to speak of marks in human bodies with the same set of distinctions as used for speaking of marks on what ever other body? I should clarify that I do not imply that harm done to a machine, or to 'property' for that matter, would be the same as harm done to a person, to an animal, or a natural habitat. Rather, my agenda is the opposite. I suspect that applying the same conceptual frames when speaking of the events of marks on human bodies, and on all bodies might in certain contexts, be the necessary condition for effectively distinguishing before ourselves what they are. This would come from that until a shared set of representation is developed and taken into use, these events will not be handled within the same practice. This statement may appear utterly abstract, but there are plenty of everyday expressions for how this idea is put into work. One procedure that should be fairly well known is when the quality of a service or product is included in the evaluation of tenders, together with the requested price. This is commonly arranged through awarding points to each identified quality criteria in accordance with a beforehand developed system that weighs the impact of quality to that of price. Another example is when environmental impact is included, in the same manner (as in Sterner, 2002).

One could regard this type of temporal homogenization as a unification effort, but the distinction between this type of procedure and a search for a 'great unification theory' should be clear; while it is designed to practically handle a process where many different aspects must be considered for the result to be viable, its starting point is the recognition of difference. Regardless if all phenomena can be accounted for by one and the same theory or not, it is not as one and the same that they emerge in the situations where engineering is actually executed. This is why the feminist theories of the 1980s and 1990s, and the post-colonial feminist approaches to technology, holding forth embodiment, location, plurality and being situated, must not be abandoned at this point by a possibly emerging feminist technologist corps. The approach that I suggest is a located realism. Its methodology is to employ Evelyn Fox Keller's works as a frame for Karen Barad's advancements. One of its positive outcomes is to secure Keller's double theory on language and agency. This theory appreciates, as we know, a plentiful agency outside language that does not negate the effectiveness of language.

Acknowledgement

An anonymous reviewer requested a better definition of my own contribution. For this I am grateful and it gave me the impulse to formulate the concept located realism.

References

Arisaka, Yoko (2001). Women carrying water: At the crossroads of technology and critical theory. In William S. Wilkerson & Jeffrey R. Paris (Eds.), *New critical theory: Essays on liberation* (pp. 155—174). New York: Rowman & Littlefield Publishers.

Barad, Karen (1998). Getting real: Technoscientific practices and the materialization of reality. *Differences*, *10*(2), 87—128.

Barad, Karen (2003). Posthumanist performativity: Toward and understanding of how matter comes to matter. *Signs: Journal of Women in Culture and Society*, *28*(31), 801—831.

Barad, Karen (2007). *Meeting the universe halfway: Quantum physics and the entanglement of matter and meaning.* Durham: Duke University Press.

Berner, Boel (2006). Rationalizing technical work: Visions and realities of the "Systematic Drawing Office" in Sweden, 1890–1940. *Technology and Culture*, *48*(1), 20—42.

Braidotti, Rosi (1994). *Nomadic subjects: Embodiment and sexual difference in contemporary feminist theory.* New York: Columbia University Press.

Braidotti, Rosi (2006). *Transpositions.* Cambridge and Malden: Polity Press.

Butler, Judith (1989). Foucault and the paradox of bodily inscriptions. *Journal of Philosophy*, *86*(11), 601—607.

Butler, Judith (1993). *Bodies that matter: On the discursive limits of "sex".* New York: Routledge.

Butler, Judith (1999). *Gender trouble: Feminism and the subversion of identity.* New York: Routledge.

Connell, R. W. (1987). *Gender and power: Society, the person and sexual politics.* Cambridge: Polity Press.

Haraway, Donna (2004). *The Haraway reader.* New York: Routledge.

Hooks, Bell (1981). *Ain't I a woman: Black women and feminism.* Cambridge MA: South End Press.

Keller, Evelyn Fox (1983). *A feeling for the organism.* New York: Freeman.

Keller, Evelyn Fox (1985). *Reflections on gender and science.* New Haven: Yale University Press.

Keller, Evelyn Fox (1987). The gender/science system: Or, is sex to gender as nature is to science? *Hypathia*, *2*(3), 37—49.

Keller, Evelyn Fox (1992). *Secrets of life, secrets of death: Essays on language, gender and science.* London: Routledge.

Keller, Evelyn Fox (2002). *The century of the gene.* Cambridge, MA: Harvard University Press.

Keller, Evelyn Fox (2005). Ecosystems, organisms and machines. *BioScience*, *55*(12), 1069—1074.

Kline, Ronald R., & Lassman, Thomas C. (2005). Competing research traditions in American industry: Uncertain alliances between engineering and science at Westinghouse Electric, 1886–1935. *Enterprise & Society*, *6*(4), 601—645.

Murcott, Susan (1991). *The first Buddhist women: Translations and commentary on the Therigatha.* Berkeley: Parallax Press.

Murcott, Susan (1998). Report in Crabgrass: Report from the Field 5:3.

Mörtberg, Christina, Elovaara, Pirjo, & Lundgren, Agneta (Eds.). (2003). *How do we make a difference? Information technology, transnational democracy and gender.* Luleå: Luleå University of Technology.

Norris, Christopher (1999). Sexed equations and vexed physicists: The two 'cultures' revisited. *International Journal of Cultural Studies*, *2*(1), 77—107.

Roy, Deboleena (2004). Feminist theory in science: Working toward a practical transformation. *Hypathia*, *19*(1), 255—279.

Rydhagen, Birgitta (2002). Feminist sanitary engineering in Vioolsdrif, South Africa. *Gender, Technology and Development*, *6*, 249—267.

Sokal, Alan D. (1996). Transgressing the boundaries: Towards a transformative hermeneutics of quantum gravity. *Social Text*, *46/47*, 217—252.

Sokal, Alan D., & Bricmont, Jean (1998). *Fashionable nonsense: Postmodern intellectuals' abuse of science.* New York: Picador.

Sterner, Eva (2002). Green procurement of buildings: Estimation of life-cycle cost and environmental impact. Diss. 2002:09. Luleå: Luleå University of Technology.

Suchman, Lucy (2007). *Human–machine reconfigurations: Plans and situated actions.* Cambridge: Cambridge University Press.

Taylor, Charles (1985). Interpretation and the sciences of man. In Charles Taylor (Ed.), *Philosophy and the human sciences* (pp. 15—57). Cambridge: Cambridge University Press.

Öhman, May-Britt (2007). Taming exotic beauties: Swedish hydropower constructions in Tanzania in the era of development assistance, 1960s–1990s. Diss. Stockholm: Department of History of Science and Technology, Royal Institute of Technology.