Following values in engineering design and conception practices

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In this entry, we focus on values in engineering design and conception practices, and value practices as a specific way to enter the variety of work done in engineering and design studies on values. Our main intention is to show how STS progressively came to offer a differing view on *values* in engineering design and conception—to demonstrate that when it comes to technical objects and innovations, values are not something that happen only at their beginning (in their conception) or at their end (through uses and users), but are also shaped in and through engineering practices, including conception and design processes.

STS brought to light that in engineering, as in many other practices, values are also shaped in and through iterations and contingencies, where they emerge from daily interactions with people, objects, and materials. As such, values cannot be studied as a set of prefixed determinations. On the contrary, they are reshaped through—and often emerge from—the very processes of engineering conception. Departing from responsible innovation schemes that intervene only as general guidelines at the beginning or end points of these processes, STS approaches also ask what happens to ethical and moral values while things are being conceived and designed in specific places and times. In addition, STS proposes to consider engineering conception processes as collective agencements made up of humans and other-than-humans alike. Following the problems, frictions, and collective redefinitions of values helps overcome simplified narratives of values as individual and well-defined positions to instead consider how they emerge in the very process of conceiving new devices and solutions (Latour, 1987).

Regarding values more generally, STS has demonstrated through empirical and reflexive research that a simplistic repartition between calculus and rationality and subjectivity and values is not empirically true and has undesirable consequences (Latour, 1993). For example, STS scholars have produced detailed accounts of calculation and metric practices to demonstrate how they are historically situated and imbued with values, including criteria of morality. Within this enterprise, various works have demonstrated how objectivity is itself a value, which depends on a vast array of secured, material constitutions that allow calculus to happen (Callon, 2009).

A simple displacement proposed in STS can thus also be used for values (Latour, 2004). By displacing values away from 'matters of fact' (things that can be studied and prescribed from above) to 'matters of concern' (specific and situated understandings that are always already new) or even 'matters of care' (de la Bellacasa, 2012), we can better grasp how values can be described as emerging from different confrontations happening in the process of designing and conceiving technological devices.

As a general statement, then, we can say that STS has helped deconstruct the idea that science and technology exist in a social, value-laden, subjective context external to their rational shaping and on which they might have an impact, or to which it is important to ensure acceptance. When understood as a process, values do not appear as standing outside the design of technical objects but are instead reintegrated into the core of the activities that emerge from them.

In this entry, we start with a brief historical overview of the concept as developed within STS. We then go on to outline two main STS contributions to values in engineering and design. The first contribution is organized around more traditional sociological science studies approaches to values as elements—passed in and through institutions and training—related to the circulation of individuals. The second one relies more on material explorations in STS regarding innovative practices and the shapes that these contribute to giving to values. Together, these two strands help us to understand values as things that emerge socially and materially from several multiple encounters, not as individual and fixed subjective positions. We close our presentation with a brief indication of further work to be explored in these areas.

A historical review of values in engineering activities and their links to STS as a discipline

The dropping of the atomic bombs on Hiroshima and Nagasaki in 1945 challenged the image of science as being free of social responsibility. From the very heart of the physics community, a critical movement emerged in opposition to the connivance between science and the military: the Pugwash movement. The movement left a lasting impression on people's consciousness and fed into STS's initial steps and its questioning of the possibilities of social control over technology and its value-imbued character—asking if and how specific values should be inscribed in it, and by whom. This political positioning of the STS movement developed in the United States in the mid-1960s.

Since then, the movement has also contributed to developing formal tools assisting in shaping and understanding the values embedded in specific innovations, such as the 'Technology Assessment', an analytic and institutional tool aiming to orient public opinion on societal aspects of science and technology for decision-making. This kind of assessment tool took several shapes and directions, all aimed at ensuring, from a policy perspective, that the development of technologies would not disrupt societal values.

Drawing primarily on the work of Jacques Ellul (1964) and disseminated in American universities by the writer and philosopher Aldous Huxley and the historian Lewis Mumford (1967), who proposed that technology is best conceived as a continuation of society in its organization, politics, and values, the movement challenged the idea that science and technology are autonomous entities separate from their social context. On the contrary, STS scholars proposed to consider them as complex entities co-developed within societies: they are shaped by human values but also have the power to shape those values themselves.

Early STS scholars also made use of the history of technological changes (Hughes, 1983) and its critique of technological determinism, especially in regard to Taylorism, automation, nuclear energy, and computing. During the 1980s, the evolving STS movement and research field nourished the debates around technological development and its control by society. Convergences appeared between STS scholars and institutions who proctored the Technology Assessment, which lead to major scholar and activist trends including, among others, 'Constructivist Technology Assessment' and 'Inclusive' or 'Participatory Design' (Schot & Rip, 1998). These convergences continued to develop as ways to mitigate or intervene in the inscription of values into innovations.

Since these seminal works, many STS scholars have investigated the social and value-shaping dimensions of technologies. In doing so, STS scholars have proposed various conceptual frameworks—usually based on ethnographic descriptions—to observe if and how engineers' values are embedded within the technologies they conceive and develop. Using these frameworks, these scholars have investigated social representations—of problems, society, or users—and the meanings and values involved in engineering practices. For example, Gary Downey (1998) developed a broad investigation on Computer Assisted Design and Manufacturing in which he examined the values underlying the development of computer tools for engineering. In addition, on the design side, anthropologists have also engaged in similar fieldwork to follow design processes.

The philosophy and ethics of engineering became a place to reflect on this translation of value into technologies (Mitcham, 1997) as a research field that concerns everyone. Even if this field has been recently brought closer to STS (van der Poel & Verbeek, 2006), it can be considered a rich place to investigate not only value-shaping in and through technologies, but also the distribution of roles and responsibilities that determine which values those are.

Looking for values in engineering training and professional networks

From an STS perspective, values can be explored in the training and professional networks of engineers. These contributions aim at the historical and sociological study of values and offer a complementary, if not oppositional, stance to speculative inquiries into values in science and technology as mere concepts to grasp through philosophical means.

Both historical research and sociological inquiries into work organization, networks, tools, and formation, have provided a better—and more accurate—picture of what engineering is, who engineers are, and what they do in society away from the sometimes hagiographical professional discourses (e.g. stories where a genius like Edison or Zuckerberg is the only leader of a technological breakthrough). These mainstream representations of individuals foreshadow their actual networks, tools, training, and contexts and often go hand in hand with the technological promises and magical fixes that are attributed to technologies.

Scientific knowledge is a resource for engineers but it is not the main motor of technological development. Considering engineering as a simple and transparent step between scientific results and their applications in technological developments obscures what engineering training actually implies in terms of practices and their accompanying values. Therefore, it is important to follow practical knowledge in engineering, including specialized professional and, moreover, tacit knowledge (Trevelyan, 2013), which carries values that are rarely questioned.

Substantial work has been carried out on engineers' training, showing how professional organizations and institutions provide structuring devices (Davis, 1998) that work towards the preservation and perpetuation not only of a body of knowledge but also of values and definitions. Many universities, for example, aim to teach their students specific values and seek to offer ways to direct students toward social justice (Nieusma & Riley, 2010). While in training, engineers are engaged in professional identity-shaping, which includes values about what engineering is, what engineers ought to do, and what technology can or cannot solve alone.

In this perspective, values and cultural representations of what engineers do, where they should do it, and for whom they should do it are also circulated in the way curricula are shaped and put together (Shrum, 2010). Studying engineering schools' curricula and historical foundations helps to study how values are passed on. STS studies have shown that it is a long collective process in which not only knowledge but also attitudes, representations and values, are progressively co-shaped with practices and by people's circulations or entrenchment. Finally, this strand of research has also investigated gender and minority representation in engineering training, again in historical or more normative propositions aimed at amplifying diversity among engineering students (Faulkner, 2000).

Engineering professional identities and their values continue into professional life and/or are challenged by the transition between ideal spaces of practice and their real-world counterparts Once trained, engineers collaborate with various actors from diverse fields. These collaborations and professional circulations contribute to shaping and defining what engineers ought to do when confronted with multidisciplinary teams (Baird, Moore & Jagodzinski, 2000), implying that several professional practices also deal with regulators, activists, and users.

In their work, engineers are engaged with many different groups (Bijker, Hughes & Pinch, 1987) to give shape and meaning to artefacts and infrastructure. They also combine heterogeneous resources to establish stable and effective sociotechnical networks both to produce and maintain the artefacts that they contribute to developing; as such, they do what is called heterogeneous engineering (Law, 1986). In these processes, the very definition, not only of the problems that must be solved, but also of how engineering solutions should be designed and conceived (and by whom), is negotiated among several participants, and these places also imply that the values that are carried into these definitions are negotiated.

Through training and professional activities, engineers have circulated between various national and cultural spaces. Significant work has been carried out regarding colonial extensions through engineering practices. These circulations have been extensively considered through the lenses of colonial and postcolonial studies, where Western values are transported and imposed into countries and landscapes from the South, where they are opposed to local knowledge and production through the means of engineers' practices (Mitchell, 2002). Similarly, important questions are visible in 'brain drain' studies that show inequal repartitions between the global South and North, through the integration of Southern engineers into Northern teams, and the ways they may or may not carry along the values of their cultures of origin (Johri, 2012).

Values as practices in technological design and engineering

Aside from research on the values passed through the professional trajectories of engineers, this topic has also been considered from the perspective of engineers' practices. Engineering practices can be conceived as the places through which knowledge, representations, and values are made concrete and provided existence through artefacts.

STS has followed values in design and technology shaping. The *social construction of technology* (SCOT) programme was devised to show how (social) values are embedded into technologies, which paved the way for rigorous critiques of value-laden orientations in engineering realizations. To name a few examples, Winner (1980) studied how they impinged on bridge design while Summerton (2004) completed similar research on electricity networks. Meanwhile, Razzaghi, Ramirez and Zehner (2009) examined the realizations of Australian and Iranian societal values in product design while Zwart, Jacobs and van de Poel (2013) explored values in engineering models. Through engineering conception practices, a huge variety of persons and bodies, materialities, knowledge, forms of representation, and negotiations are engaged.

However, when studying (technological) objects, value inscriptions into projected artefacts during the conception phase has been less studied than the inscription of values into society through stabilized technologies. That is to say, the practical design steps of these objects have been less explored in terms of value production and circulation. Yet, focused accounts on conception and design steps help to understand the creation, shape, transfer, and transformation of values and their definitions while technical objects are tinkered with, constituted, tested, and implemented. Ultimately, values, while translated by a variety of actors, cannot be described as standing outside these processes. They are (openly or not) questioned and negotiated alongside problems, changes, and reconstitutions of technical objects (Akrich, 1992) as ethical or value concerns often emerge during these processes.

Engineering studies have covered a variety of topics (education, institution, circulation, and social position), but only a small number have investigated engineering practices, material engagements, and work among heterogeneous groups of actors. However, the shaping of technologies and their inscription into society are the processes through which values are negotiated (see SCOT) and translated, or inter-defined (see Actor–Network Theory). These approaches have covered broader assemblages of actors and activities, including controversies, uses, and regulations. However, they have often not seemed to regard engineering as a similar assemblage that warrants the same level of investigation.

On the contrary, design studies have studied engineers' practices of design. Mainly focusing on methods (e.g. design thinking, guidelines, user-centred design, immersive design, participatory design, creative design), people (design team, expertise, common ground), and practices (design process, decision, negotiation, legitimation), they have studied the design of review conversations, the construction of shared vision and values, and engineers' communication with stakeholders.

Material practices and the way they are organized and carried through are fruitful places to investigate the sociotechnical reconfigurations designed by engineers and the values they carry along the way (Bucciarelli, 1994; Sims, 1999; Suchman, 2000). Indeed, if engineers bring values when doing their job, they do not bring them in a material vacuum. Collaborative devices accompany these circulations, for example, intermediary objects such as industrial drawings, or prototypes (Vinck, 2003, 2011). These devices form new relations between existing elements and help to construct a shared vision in design work, including engineers' discussions with diverse stakeholders. These studies have offered alternative accounts where relations between design and values are complexified, as things are generally more complicated than a straightforward path from values to design or the reverse.

Design studies and design ethnography, however, have remained limited to design and have not considered development, industrialization, implementation, and most of the other engineering activities, like adjustment, improvement, and maintenance, in which values also are at stake.

Further work

A key location for value-shaping is an often dismissed part of engineering work—often not even taught or discussed in engineering literature—is the work of maintenance, repair, logistics, and alternative forms of innovation. If the design of new artefacts seems to be a primary place for emerging objects and their accompanying values, other spaces and temporalities can be considered to follow values as they are embedded in material artefacts simply by considering who decides and who does the work of maintaining or repairing specific innovations. Although related research fields, such as infrastructure studies, disaster studies, and repair and maintenance studies, have shed light on these dominant engineering activities, they remain marginal in engineering studies.

Another important area of exploration has been the role of social sciences in engineering design and conception processes, as these are often co-opted and used in a simplified way in an attempt to drive so-called technology acceptance. Here, the work of Callon, Lascoume & Barthe (2011) has been essential in bettering our understanding of how participatory initiatives are sometimes perceived by engineers and how they can occasionally be used to manage socio-technological controversies, such as nuclear waste. In sum, it is important to note that if STS offers tools to study engineering design practices from different disciplinary perspectives (sociology, history, anthropology), they also offer a space to explore and examine STS collaboration in engineering projects, where social sciences are considered as tools and plugins for engineering design.

In regard to participatory design, Clausen, Vinck, Petersen and Dorland (2020), have explored sensitizing devices for the facilitation of design and innovation activities by offering a repertoire of actionable collaborative strategies that allow stakeholders to intervene in and shape design and innovation processes. Engineers and designers working to design change in systems face challenges in how to navigate competing not only in terms of interests and values, but also staging efforts, as the theatrical metaphor of staging has become an inspiration to help think about design with a focus on the casting of the participants, the framing of the stage, and the resources it offers to them.

If participatory design is now a well-disseminated prescription, this approach originates from the Scandinavian design tradition, which has historically advocated democratically-oriented design and the direct involvement of people in co-design. This tradition was initially focused on designers' engagement with labour unions, when, for instance, new information technologies were introduced to the workplace. The idea was to balance the resources of the involved people—engineers, managers, and workers—so that those potentially affected could influence their design and implementation, giving voice to their constraints, goals, interests, and values.

Democracy, then, became a central element in the participatory design process. The idea was to give voice to marginalized people—not only workers and end-users—but also the multiple concerned and affected people. Influenced by Actor–Network Theory, design and engineering also became seen as a moral and political activity that expects to shape societies. This ANT influence contributed to better describing the sociotechnical settings (socio-material collectives made of heterogeneous entities, such as humans, non-humans, and their concerns) and, among other controversies, the process design projects are immersed in.

Finally, concerns regarding climate issues have become more and more embedded within technological design, where several questions have been opened including the environmental values in engineering design and conception, most notably through engineering consultancy.

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10 Key Readings (proposition)

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