Chapter 1
Turning Engineering Green: Sustainable Development and Engineering Education

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Abstract Since the 1970s, the relations between engineering and development have changed significantly. On the one hand, at a discursive or macro level, there has been a shift in regard to the kind of development to which engineering is meant to contribute, from furthering economic growth to an approach to development that is "sustainable" in one way or another. On the other hand, on a practitioner, or micro level, there has been a change in the kinds of competence that engineers are expected to have in order to be able to contribute to development, due to the emergence of new fields of "technoscience" blurring the boundaries between what was previously considered science and what was previously considered technology. Finally, in between, at an institutional or meso level, there have been significant changes in how engineering work and engineering education are organized. This chapter attempts to provide an overview of these changing relations between engineering and development and distinguishes between three ideal-typical educational responses: a technical, market-oriented approach; a scientific, academic-oriented approach; and a hybrid, socially oriented approach.

Keywords Development • Engineering • Environment • Education • Sustainability • Hybrid imagination

Introduction

Since the 1970s, there have been a number of significant changes in the relations between engineering and development. On a discursive or macro level, there has been an overarching shift in regard to the kind of development to which engineering

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is meant to contribute, from one that is primarily oriented to furthering economic growth and science-based material progress to an approach to development that is "sustainable" in one way or another. There have, however, been fundamental disagreements in regard to what a sustainable development might actually mean (Mitcham 1995; Jamison 2001).

Many, if not most, of those who make decisions and policies about development and engineering have tended to see sustainable development primarily as a continuation of economic growth by other means – a kind of "greener" or "cleaner" kind of growth – and have translated sustainability into the language of business and management, while others have seen the sustainability challenge primarily in professional, or academic terms, and have thus sought to develop new fields or subfields of sustainable science and technology within engineering and engineering education. Still others see the challenge as intrinsically human and political, requiring a fundamental reconstruction of science, engineering, and society, and have thus called for a more active integration of social and cultural understanding into the education of scientists and engineers (Jamison et al. 2011).

While the discourses of development have been getting greener, at least rhetorically, on a practitioner or micro level, there have arisen a number of other challenges to engineering and engineering education stemming from what has been termed "technoscience" – or a new "mode" of knowledge production. As Michael Gibbons and his coauthors characterized the situation in their influential account in the 1990s, scientific research and technological development are increasingly being carried out in a "transdisciplinary" manner (Gibbons et al. 1994). The boundaries that had previously distinguished scientific research, or philosophical-theoretical knowledge – what the Greek philosopher Aristotle famously referred to as *episteme* – from technological development, or practical-technical knowledge (Aristotle's *techné*) have been blurred or transgressed in many, if not most, fields of contemporary science and engineering. In such newer domains of knowledge production such as electronics and communications, health and agriculture, energy distribution and environmental protection, and, more recently, multimedia, the nanosphere, and synthetic biology – as well as in many traditional fields – there is no longer a clear line of demarcation between scientific "theory" and technological "practice." What Gibbons and his coauthors have called a new mode of knowledge production or "mode 2" is "knowledge which emerges from a particular context of application with its own distinct theoretical structures, research methods, and modes of practice but which may not be locatable on the prevailing disciplinary map" (Gibbons et al. 1994, p. 168). The coming of technoscience, or mode 2, thus raises important questions about what engineers need to know and how they are to learn and be taught.

In between the discursive and practitioner levels on what might be termed an institutional or meso level, there have been significant changes in how engineering work and engineering education are organized, due to the permeation of science and technology into ever more areas of our economies, our societies, and our everyday lives. For the most part, engineering is now carried out in less permanent structures than in the past, in temporary or ad hoc groups or networks, in which engineers collaborate with people from other parts of society. In both actual and virtual reality, university-based or academic engineers work ever more often together with corporate employees and government officials on particular projects in what has been called a "triple helix" linking the state, the market, and the academy in weblike relationships (cf. Etzkowitz and Leydesdorff 1997). To be able to work effectively in these new organizational frameworks requires new kinds of design skills and forms of communicative competence on the part of engineers, and most importantly perhaps, a more ambitious understanding of societal processes than engineers have previously received in their education.

In the Program of Research on Opportunities and Challenges in Engineering Education in Denmark (PROCEED), we have taken our point of departure in these three very different sorts of challenges that confront engineering and engineering education:

- The sustainability challenge, or the overarching need for scientists and engineers – as well as for humanity in general – to relate to the problems brought to light in the debates about environmental protection, resource exploitation, and climate change
- The technoscience challenge, the mixing in many fields of contemporary science and engineering of scientific knowledge and engineering skills in new combinations
- The various societal challenges, due to the permeation of science and technology into society, and calling for socio-technical competencies and a sense of social responsibility on the part of scientists and engineers

Experiences throughout the world, as well as in Denmark, have shown that it is difficult to meet these rather different challenges in a comprehensive way. Rather, a tension or contradiction has emerged that has served to pull engineering and engineering education in different directions – into a wide variety of efforts to foster a new kind of global or commercial engineering identity, on the one hand, versus a reinforcement of more traditional professional roles and academic identities, on the other.

The main response to the challenges has tended to be "market-driven" and has sought to convert the challenges into commercial opportunities in accordance with the new precepts of "academic capitalism" (Slaughter and Rhoades 2004). In regard to the educational curriculum, this strategy has meant that many engineering programs have come to include courses and instruction in such areas as marketing, innovation, and entrepreneurship, as well as various types of "on-the-job" training in an attempt to educate engineers who can help companies, countries, and continents compete successfully in the global marketplace.

A second response has been a professional or academic approach by which educators have tried to meet the challenges facing engineering in the contemporary world in a more traditional "scientific" manner. In relation to curricular construction, courses and even entire programs have been developed in new specialty areas such as sustainability science and technology, nanoscience and nanotechnology, industrial, urban, and even eco-design. In this response strategy, the ambition has primarily been to educate engineers who can be new kinds of professional experts while upholding a more traditional engineering identity. As a result, among different universities, as well as within many of the same ones, there is an ongoing tension or competition between the practical, market-oriented approaches and the scientific, academic-oriented approaches, which makes it difficult for students to receive a well-rounded and comprehensive education.

In this chapter, I will argue for the need for a third strategy that seeks to foster what I have come to call a "hybrid imagination" (Jamison et al. 2011). A hybrid imagination can be defined in this regard as the combination of a scientific-technical problem-solving competence with an understanding of the problems that need to be solved. It is a mixing of scientific knowledge and technical skills with what might be termed cultural empathy, that is, an interest in reflecting on the cultural implications of science and technology in general and one's own contribution as a scientist or engineer, in particular. It can be thought of as an attitude of humility or modesty, as opposed to arrogance and hubris, in regard to scientific and technological development, and, for that matter, to any kind of human activity. A hybrid imagination involves recognizing the limits to what we as a species and as individuals can do, both the physical limits and constraints imposed by "reality" as well as those due to our own individual limits of capabilities and knowledge.

A Paradigm Shift

In the course of industrialization in the nineteenth century and coalescing in the mid-twentieth century into what Stephen Cotgrove (1982) termed the dominant developmental paradigm, the theory and practice of "development" for a century and a half was generally characterized in material terms, as the promotion of economic growth and scientific-technological progress. Across the political spectrum, from conservatism to liberalism to social democracy, for both communists and capitalists, imperialists and anti-imperialists, the pursuit of material, "science-based" progress and economic growth served as a unifying goal for the development of human beings and the societies in which they live.

There were differences of opinion, to be sure, as to how economic growth and science and technology-based material progress could best be achieved, not least in regard to the role of the state and of government planning and policy. In most of the western European countries, as well as in the communist countries of Eastern Europe and the so-called developing countries of the Global South, the state was seen as a central actor, and economic growth was seen as a collective responsibility to be governed by a national state. In the United States, on the other hand, as well as in a number of countries most dominated by the United States ideologically and politically, the state's role was seen to be more limited. Economic growth was considered most effectively managed if it was left to so-called market forces; only those areas of development and engineering that were directly related to defense and to the military industries should be governed by a national or supranational state.

But in spite of these differences, there was until well into the 1960s an overarching discursive consensus, and practical convergence, throughout the world concerning the central importance of the pursuit of economic growth and scientific and technological progress for all of us, not least engineers.

The idea of sustainable development emerged out of the public debates of the late 1950s and 1960s, which challenged, from different perspectives, the pursuit of economic growth and material progress as the primary goals and priorities of human development (Jamison and Eyerman 1994). There were several forms in which this questioning took place. Most fundamentally perhaps, there was a moral or spiritual debate that was voiced by such people as Martin Luther King in the United States and Jacques Ellul in France and was accompanied by a resurgence of interest throughout the world in the Asian religious traditions of Buddhism, Taoism, and Islam.

What King termed the "poverty of the spirit" was part of a more general concern with the violations of human or civil rights that was so widespread in the technological society bemoaned by Ellul in his influential book, *La Technique*, from 1954, which was translated into English in the 1960s as *The Technological Society* (1964). The development of science and technology in pursuit of material progress had turned citizens into consumers, and, as a result, many contended that there was a need to bring a new kind of ethical or humanitarian concern into the making of science and technology (cf. Mitcham and Muñoz 2010).

As King put it, in his acceptance speech when he was awarded the Nobel Peace Prize in 1964:

> There is a sort of poverty of the spirit which stands in glaring contrast to our scientific and technological abundance. The richer we have become materially, the poorer we have become morally and spiritually…. Every man lives in two realms, the internal and the external. The internal is that realm of spiritual ends expressed in art, literature, morals, and religion. The external is that complex of devices, techniques, mechanisms, and instrumentalities by means of which we live. Our problem today is that we have allowed the internal to become lost in the external. We have allowed the means by which we live to outdistance the ends for which we live.

Another kind of debate concerned the impact that scientific and technological development was having on nature or what came to be referred to in the 1960s as the natural environment. While conservationists had been discussing the consequences that science- and technology-based economic growth was having on plants and animals, it would be Rachel Carson's book, *Silent Spring*, published in 1962, with its detailed exposé of the health and environmental implications of one particular widely used chemical in agriculture, the insecticide DDT, that would bring the environmental cause to public attention. It would also usher in a more activist and radical approach to environmental politics than had been characteristic of the older conservation societies which had been established in the late nineteenth and early twentieth centuries and tended to be located on the conservative side of the political spectrum.

What Carson and other environmentalists argued was that a full-fledged crisis was in the offing if science and technology were not changed into more environmentally friendly or ecological directions (Commoner 1971). Many of the new kinds of science-based products that had been produced in the immediate postwar era, especially the synthetic chemicals that were used in agriculture and food production and many health and household products as well, could not be broken down and recycled in nature as could the products they replaced and thus served to destroy the natural environment, as well as affecting human health.

There also emerged in the 1960s a more general questioning of the ways in which the broader society had been affected by the overarching concern with material progress and economic growth. The increasingly visible and horrific uses of science and technology in the war in Vietnam as well as the more general lack of a broader social responsibility in the ways that students were being educated brought on a wave of student revolts in the second half of the 1960s. Humanist scholars and philosophers, such as Hannah Arendt and Herbert Marcuse, who had fled from Nazism, saw in the scientific and technological pursuit of progress a new form of authoritarianism and wrote influential books about what Arendt called the "human condition" and what Marcuse called "technological rationality" and one-dimensional thought (Arendt 1958; Marcuse 1964).

As science and technology had become ever more integrated into the economy, and the state gap had emerged, not least in education, between what the British chemist-turned-novelist C.P. Snow termed the "two cultures" in a famous lecture in 1959. Snow's argument, which was echoed by many others throughout the world in the course of the 1960s was that both in education as well in the broader culture, scientists and engineers, on the one side, and humanists and writers, on the other, had come to form separate cultural identities in the modern world. Education and communication both in the professional and popular media had become polarized and overly specialized, and there was a need for both sides to know more about what the other was doing.

Reforming Engineering Education

One outcome of the debates of the 1960s was the emergence of teaching and research programs in science, technology, and society (STS) at universities throughout the world, to a large extent, to try to bridge the "two cultures" gap. The idea was to offer instruction about the social and cultural contexts of science and technology, as well as to provide meeting places for natural scientists, engineers, social scientists, and humanists for discussion seminars and workshops and eventually for carrying out research projects together. The field of STS, at least at the beginning, was part of a more general interest within universities to foster interdisciplinary studies.

A number of new universities were also created, often based on "student-centered" approaches to education that tried to transform the critical energy of the student revolts into more constructive directions. In Denmark, the new universities in Roskilde (1972) and Aalborg (1974) have ever since combined what has been called problem- and project-based learning, as opposed to the more traditional "book learning" that characterized the older universities. When applied to science and engineering, problem-based learning proved to be particularly effective as a way to connect university scientists, engineers, and their students more closely to the problems in the broader society and to help cultivate the sorts of communicative, managerial, and design skills that scientists and engineers would need if they were to be able to carry out their research and development work in a socially responsible manner.

In the course of the 1970s, there were also a number of centers set up outside the universities for appropriate, alternative, small-scale, and/or intermediate technologies, putting into practice the ideas that were propagated in such books as *Small is Beautiful* by E. F. Schumacher, an economist who had worked on development projects in India as well as for the British Coal Board, and *Tools for Conviviality*, by Ivan Illich. In the United States, a group of scientists and engineers left MIT to set up a "New Alchemy Institute" on Cape Cod, and for several years, they held courses and developed research projects combining organic agriculture, renewable energy, and other "ecological technologies." In the general spirit of "liberation" that filled the air at the time, many scientists and engineers throughout the world, but perhaps especially in the so-called third world or what is today called the Global South, sought to find ways to connect their scientific knowledge and technological skills to basic human needs. This was the expression used in many United Nations agencies in their activities and programs, as well as at the UN Conference on Science, Technology, and Development that was held in 1979 as part of the efforts on the part of developing countries to establish a "new international economic order" (Jamison 1994).

What I have previously termed the "cognitive praxis" of the environmental movements was based on a philosophy or cosmology of systemic holism derived from systems theory, cybernetics, and ecology (Jamison 1996). In the early 1970s, this new ecological worldview or paradigm was popularized in such books as Barry Commoner's *The Closing Circle* and in the book produced for the UN Conference on the Human Environment held in Stockholm in 1972, *Only One Earth* by Barbara Ward and René Dubos, as well as in *A Blueprint for Survival,* which launched the journal *The Ecologist*, and the extremely influential *Limits to Growth* that was produced by a group of experts reporting to the Club of Rome in 1972. Barry Commoner's four laws of ecology – "everything is connected to everything else," "everything must go somewhere," "nature knows best," and "there is no such thing as a free lunch" – provided a set of cosmological or worldview assumptions for the environmental movements that, in the course of the 1970s, became significant political actors in several northwestern European countries as well as in North America. In political campaigns directed against various kinds of air and water pollution, chemicals in food and agriculture, and especially against the development of nuclear energy, environmental movement organizations, together with students and teachers at universities, began to turn scientific knowledge and technological development green.

In the environmental movements of the 1970s, this ecological philosophy or worldview was combined with a practical or technical experimentation in new movement settings that included a wide range of production collectives and alternative communities. At these sites, environmental and energy activists could learn about "environmentally friendly" ways to produce energy, food, and the other necessities of life that were based on an ecological worldview. Activists and academics joined together to build solar energy panels and wind energy plants, grow organic food, and try to live more ecologically (Boyle and Harper 1976). In the Netherlands, "science shops" were established at several universities to provide meeting places between the academic world and the broader society, and in many other countries, the environmental movements fostered other forms of what the sociologist Alan Irwin later termed "citizen science" (Irwin 1995).

A kind of "grassroots" engineering emerged in many parts of the world, particularly in relation to the antinuclear energy movements. In Denmark, scientists and engineers created a national Organization for Renewable Energy (or OVE, *Organisation for vedvarende energi*) that helped people throughout the country to learn how to build their own wind energy plants and solar panels (Jamison 1978). OVE arranged courses at older as well as newly established folk high schools, and its members created centers for renewable energy such as the Nordic center in Thisted, which is still in operation. In 1978, the world's then largest wind energy power plant was constructed by students at the Tvind folk high schools on the Danish west coast, not far from where VESTAS is now based. Mobilizing a Danish tradition – Poul la Cour, a folk high school physics teacher in the nineteenth century, had been one of the first in the world to experiment systematically with wind-power-generated electricity production – the Organization for Renewable Energy has continued to foster "grassroots innovation" ever since. By the late 1970s, the movement had spawned a number of companies, one of which, VESTAS, is now the leading wind turbine producer in the world and one of Denmark's largest companies.

In the 1980s, as the political climate in North America and northwestern Europe turned to the right, environmental politics changed character, and the making of green engineering changed as well. This right turn in politics represented a mobilization of conservative traditions, or – as they are often referred to in the United States – neoconservative values. Traditional religious and nationalist concerns were fundamental to these neoconservative movements, which emerged, at least in part, as a kind of organized opposition, or "backlash," to the environmental and women's movements of the 1970s and the kind of knowledge they had embodied and articulated (Helvarg 1988; Rowell 1996).

At the same time, in the early 1980s, the environmental movement itself fragmented into a number of different organizations and institutions, both in terms of politics and knowledge-making. Green parties were formed in many countries and professional activist organizations, such as Greenpeace, grew in significance, while the broad-based, or grassroots, organizations that had led the campaigns against nuclear energy in the 1970s tended to lose members. Within universities and new environmental "think tanks" such as the World Resources Institute and the Wuppertal Institute, environmental and energy experts started to make more specialized kinds of knowledge in relation to renewable energy, organic agriculture, and eventually to climate change and other "global" issues as well (Jamison 1996).

As such, more professional and established forms of knowledge-making started to replace the kinds of appropriate or alternative forms of citizen science and grassroots engineering that had been so prominent in the 1970s. Many of those who had been active in the environmental and energy movements in the 1970s left the movement "space" behind to make careers in universities as well as in the wider worlds of government, media, and business.

In 1987, the report, *Our Common Future*, was published by the World Commission on Environment and Development, headed by the former Norwegian prime minister, Gro Harlem Brundtland, and with representatives from government, business, academia, as well as from environmental think tanks and so-called nongovernmental organizations. With its call for “sustainable development” – by which was meant a kind of socioeconomic development that took into account the needs of future generations for natural resources – the report signaled the coming of a new international political doctrine in which environmental concern was to be included into all other areas of socioeconomic and cultural development. But the quest for sustainable development would come to be a contentious process, with different conceptual interpretations and implementation strategies vying for support and influence in the years to come.

The Commercial or Market-Oriented Response

Following the fall of the Soviet empire, and the so-called Earth Summit in Rio de Janeiro in 1992 (the UN Conference on Environment and Development), where the ideas of the Brundtland report about sustainable development were translated into the Agenda 21 document, new approaches to greening science and engineering proliferated in the 1990s. Particularly prominent were the efforts to encourage more practical, market-oriented solutions to environmental problems. The general approach can be thought of as an incorporation of environmental concern into the world of business. In the course of the 1990s, there emerged a range of activities in such areas as environmental management, cleaner technology, eco-efficiency, environmental impact assessment, industrial and urban ecology, and green product development, which are explicitly commercial: this was engineering knowledge that was meant to be sold on the market.

These forms of knowledge-making became especially important in several European countries, where social-democratic governments, often with the support of green parties, pursued policies of “ecological modernization” as did the Clinton-Gore administration in the United States. In Germany, Great Britain, Denmark, Sweden, and the Netherlands, as well as at the European Commission, ecological modernization sought to combine environmental concern with economic growth. As climate change became a more integral part of environmental politics in the 1990s, it was the market-oriented approaches that tended to dominate the international deliberations, both in Kyoto, as well as within intergovernmental administrative and scientific advisory bodies, such as the Intergovernmental Panel on Climate Change (IPCC).

The rise of market-oriented environmentalism or green business was shaped by the broader neoliberal movement, which has provided the dominant story line of the past two decades, both in regard to science and technology in general, and environmental science and technology, in particular (Hoffman 2001). Much of the knowledge-making activity within green business tends to be organized in commercial networks, with university scientists and engineers working together with companies on specific projects. There are also a number of “movement intellectuals” in the commercial media as well as in private consulting companies who serve to articulate the underlying importance of meeting the sustainability challenge in commercial terms (Jamison 2010). The "cognitive praxis" of green business exemplifies the dominant approaches of academic capitalism in the promotion of commercially oriented technological innovation and green product development.

The cosmology of green business is based on a belief in a convergence between economic growth and environmental protection, and depending on the context, it has been termed ecological modernization, eco-efficiency, corporate sustainability, or green growth. In the words of Maarten Hajer, what was central to the political discourse of ecological modernization in the 1990s was "the fundamental assumption that economic growth and the resolution of the ecological problems, can in principle, be reconciled. Hence, although some supporters may individually start from moral premises, ecological modernization basically follows a utilitarian logic: at the core of ecological modernization is the idea that pollution prevention pays" (Hajer 1995, p. 27). In the course of the past 15 years, particularly in China and other Asian countries, this fundamental assumption is central to major national programs in "green growth."

In relation to engineering education, it has led to a wide range of courses and educational programs in such topics as sustainable innovation and environmental management, as well as more specialized areas, such as sustainable energy planning, mobility management, and sustainable design. Many of these initiatives, such as those at my own university, in Aalborg Denmark, are built on collaborative efforts between business firms and engineering teachers and involve internships and other forms of on-the-job training in companies as part of the educational program.

The Professional or Academic-Oriented Response

Already in the 1980s, Aant Elzinga noted how established epistemic criteria, that is, the ways in which truth claims are justified by scientists and engineers, were in a state of flux, as scientists and engineers increasingly found themselves in a condition of what he termed "epistemic drift":

> …the process whereby, under strong relevance pressure, researchers become more concerned with external legitimation *vis-à-vis* policy bureaucracies and funding agencies than with internal legitimation via the process of peer review. This may be seen as a process of erosion of the traditional system of reputational control.
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> (Elzinga 1985, p. 207).

Since then the traditional norms or values of scientists and engineers have been increasingly challenged by the transition to new ways or modes of doing research. To borrow a term from the French sociologist Pierre Bourdieu (2004, p. 65), the "habitus" of science and engineering, a way of life based in distinct academic disciplines and professional identities, which provided what Bourdieu characterized as a "collective capital of specialized methods and concepts," has been invaded by other forms of organization and ways of working.

Not all scientists and engineers have accepted the new world of academic capitalism. A good many of them have reacted quite critically to the changing contextual conditions and have sought to reaffirm a more academic or professional approach to science and engineering as a way to respond to the challenges. And while it certainly is valuable to uphold the importance of academic quality and professional standards, such responses tend to become anachronistic in that they all too often merely reassert the traditional norms of academic life and professional behavior, without recognizing that those norms and values have, to a large extent, become outmoded (Christensen and Ernø-Kjølhede 2006).

As part of this strategy, it has become popular to refer to the norms of science, which were influentially formulated in the 1940s by the American sociologist Robert Merton (1942). These have long been seen by many natural and social scientists, as well as engineers and large segments of the general public, as core values in science and engineering. The norms of communalism, universalism, disinterestedness, and, not least, organized skepticism continue to be seen as defining features of science, even though the practice of science has fundamentally changed since Merton characterized them. But the Mertonian norms continue to be propagated and considered to be part of the identities of scientists and engineers, particularly in relation to contentious issues such as sustainable development and climate change, where, among others, the Danish political scientist Bjørn Lomborg has been particularly successful in promoting the value of organized skepticism (Jamison 2004).

In relation to engineering education, the reassertion of professional values and norms has led to an educational strategy of academicization by which the various challenges facing engineering tend to be translated into new scientific or disciplinary programs for training in specialized areas of expertise. Such fields as ecological economics, sustainability science, and the various subfields of climate science – atmospheric chemistry, oceanography and hydrology, climate modeling, etc. – have spawned and become subjects of educational programs either as stand-alone disciplines on their own or as sustainability "minors" or electives that are added onto traditional science and engineering programs. What is stressed in these programs is the scientific credentials of the teachers and the adherence to the traditional academic values and professional norms. Particularly in relation to climate change, this skepticism has been a part of the political debate and, not least, criticism of the policy proposals of the "transdisciplinary" and highly networked scientists and engineers who have called for major expenditures on renewable energy systems and other green business ventures.

A Hybrid Imagination

In order to meet the challenges facing science and engineering in the world today, it is my contention that it is not sufficient to reaffirm a traditional faith in reason and truth and reassert the importance of a largely outmoded form of engineering professionalism. There is instead a need to foster a hybrid imagination, connecting science, technology, and society in new ways, by combining scientific knowledge and technical skills with cultural understanding as a part of what has been called the global justice movement.

Since the late 1990s, a new kind of political activism, often involving forms of civil disobedience and direct action, has emerged in relation to environmental issues and, most recently climate change, as a part of what has been characterized as a broader movement for global justice (Jamison 2010). In addition to political protests, which became most visible, in relation to sustainability issues, in the streets of Copenhagen at the end of 2009 during the COP15, there are a number of primarily local organizations in both the Global North and Global South that carry out a range of more constructive activities in relation to such areas as renewable energy, ecological housing and design, and organic agriculture. In recent years, there have been attempts to arrange gatherings, where the different component parts of the global justice movement can meet and discuss their concerns and exchange their experiences. These various "social forums," as they have come to be called, have taken place both at an international level (at world social forums, that have been held each year since 2000) as well as at more regional, national, and local levels, particularly in Europe.

There are a growing, but still relatively small, number of cases of collaboration between academics and activists in universities and local communities in trying to deal with climate change and other environmental problems in just or equitable ways (Hess 2007; Worldwatch Institute 2010). New forms of community-based innovation and knowledge-making can be identified in local food movements around the world, as well as in a range of not-for-profit engineering projects in such areas as sustainable transport, renewable energy, and low-cost, environmentally friendly housing. Such projects as the Alley Flat Initiative at the University of Texas in which students and teachers from the School of Architecture have designed low-cost, climate-smart housing in East Austin in cooperation with local housing suppliers and neighborhood groups show what can be done (Jamison 2009).

The Alley Flat Initiative emerged as part of a larger project on sustainable development, directed by architecture and planning professor Steven Moore. Moore had combined with his colleagues a number of course in different departments into a sustainability portfolio that students can acquire along with their degrees, a sort of green credential. He also established a design studio for masters students in architecture and planning taught not only by Moore but also by Louise Harpman and a visiting professor, Sergio Palleroni, who had previously carried out community-oriented architectural projects with students at the University of Washington. Looking for a specific focus for the studio, the students spent time in East Austin, the area of the city that in the early twentieth century had been segregated through the provisioning of infrastructure as an African-American, Latino, and industrial area. Like many such areas in many American cities, east Austin became threatened by so-called gentrification when Blacks and Latinos cleaned up industrial brownfields over six or seven decades, making the area attractive to more wealthy whites.

The motivation behind the initiative was to find a way to learn architecture by doing something useful for the community, and after looking through maps, and reading about the history of the area, the students came up with the idea of designing climate-smart alley flats or second houses along the alleys – what used to be called "granny flats" because they were where grandparents lived – that could help the residents pay their escalating property taxes and fight off gentrification and also contribute to the transition to a low-carbon society. As described on the initiative's website:

> The initial goal of the project was to build two prototype alley flats – one for each of two families in East Austin – that would showcase both the innovative design and environmental sustainability features of the alley flat designs. These prototypes were built to demonstrate how sustainable housing can support growing communities by being affordable and adaptable. The first of these prototypes celebrated its house warming with the community in June of 2008 and the second prototype was completed in August of 2009. The long-term objective of the Alley Flat Initiative is to create an adaptive and self-perpetuating delivery system for sustainable and affordable housing in Austin. The "delivery system" would include not only efficient housing designs constructed with sustainable technologies, but also innovative methods of financing and home ownership that benefit all neighborhoods in Austin.
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> (AFI 2011)

Unfortunately, however, such activities fall well outside of the mainstream and remain quite marginal at universities throughout the world, although, in recent years, several universities in the United States have established programs in engineering for sustainable community development (Lucena et al. 2010). In some of these programs, there is a similar kind of institutional outreach that was so characteristic of the "movement" activities that took place in the 1970s, but most of them have a difficult time establishing themselves at universities. The increasing encroachment of a commercial and entrepreneurial value system at universities makes it difficult for concerns with social justice and cultural change to be given the attention they deserve in science and engineering education.

Conclusions

As such, the greening of engineering and engineering education can be seen as an ongoing process of contention between three very different approaches or strategies. The dominant approach can be considered a part of what has been termed the new "mode" of knowledge production or "mode 2," in which the borders between the academic and business worlds are increasingly transgressed. On the other hand, there is an academic or professional approach to engineering and engineering education that is based on a more traditional conception of science-based, expert knowledge. In this approach, education tends to be carried out in accordance with the more traditional scientific disciplines and engineering fields.

A third approach that explicitly connects the quest for sustainable development to concerns of global justice and fairness is comparatively weak at the present time. Since the challenges facing engineering in the world today, and not least the sustainability challenge is so all-encompassing and multifaceted, I have suggested that it will be necessary in this emerging third approach to engineering education to foster a "hybrid imagination," mixing natural and social, local and global, academic and activist forms of teaching and learning in new combinations.

At a time when the global economy is in a state of crisis and the need for sustainable development is growing ever more urgent, much will depend on the ways in which science and engineering education and universities more generally respond to the challenges they face. All too many efforts around the world today in regard to greening or sustainable development are more rhetorical than real, more concerned with branding and image-building than with substantive integration of contextual knowledge into educational programs. There must be more room or space at universities for students and teachers to undertake "not-for-profit," community-oriented activities in relation to their education. In a world in which universities have become ever more subjected to "market forces" in order to contribute to their "global competitiveness," cross-disciplinary and cross-cultural education and knowledge-making is, to put it mildly, not particularly encouraged, well supported, or understood. If scientists and engineers are to meet the challenges that they face in a meaningful way, however, it will be crucially important in the years to come to see to it that our universities can help to foster hybrid imaginations, perhaps especially among science and engineering students.

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