Philosophy of Engineering and Technology 21

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Engineering Identities, Epistemologies and Values

Engineering Education and Practice in Context, Volume 2

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Philosophy of Engineering and Technology

Volume 21

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ISSN 1879-7202 ISSN 1879-7210 (electronic)
Philosophy of Engineering and Technology
ISBN 978-3-319-16171-6 ISBN 978-3-319-16172-3 (eBook)
DOI 10.1007/978-3-319-16172-3

Library of Congress Control Number: 2015939348

Springer Cham Heidelberg New York Dordrecht London

Printed on acid-free paper

Springer International Publishing AG Switzerland is part of Springer Science+Business Media (www.springer.com)

Preface

And some time make the time to drive out west
Into County Clare, along the Flaggy Shore,
[T]he ocean on one side is wild
With foam and glitter, and inland among stones
The surface of a slate-grey lake....
Useless to think you'll park and capture it
More thoroughly. You are neither here nor there,
A hurry through which known and strange things pass
As big soft buffetings come at the car sideways
And catch the heart off guard and blow it open.

– Seamus Heaney, "Postscript" (1996)

We live today in a world progressively in the process of becoming an engineered artifact. We engineer not only roads and buildings but communication systems and biologies. In such a world, thinking about engineering is increasingly important – and yet incredibly difficult.

Among themselves, engineers are continuously trying to figure out what and who they are: skilled workers, project managers, applied scientists, designers, entrepreneurs, and more. Additionally, there are a host of competing interests that would enroll engineering for their purposes: military interests, nation-building interests, commercial interests, social interests, environmental interests, and more. Finally, multiple disciplines attempt to take the measure of engineers and engineering: history, sociology, philosophy, and more.

There is no simple resolution to the tensions inherent in this complexity of contextualizations for the engineered constructions in which we progressively live and move and have our being. The best we can do is take an intellectual drive through diverse intellectual landscapes, with a willingness to let what poet Seamus Heaney calls "big soft buffetings" come at us sideways, opening the mind. Open to its contexts, the mind is at once:

- More reflective in negotiating the pressures that enfold it
- Better at spanning different engineering visions and practices

- More insightful when conciliating the corporeal powers of engineering with the ethereal truths of poetry or art
- More resistant to commercial, political, and military distortions of human and professional responsibilities
- Better at constructing a more just world – one in which lives well-lived and well-examined transcend mere existence

To contribute to this opening up, not so much of the black box of what takes place behind the scenes in engineering, but of our own thinking about engineering, is the central effort of our collective reflection.

The two books we offer – *International Perspectives on Engineering Education: Engineering Education and Practice in Context. Volume 1* and *Engineering Identities, Epistemologies and Values: Engineering Education and Practice in Context. Volume 2* – are the result of an extended dialogue or bridge-building between humanists and engineers with whom we have been involved both individually and more recently as a group. Steen Hyldgaard Christensen, the editor-in-chief, studied literature and history of ideas at Aarhus University in the 1970s, and since 1987 has taught humanities for engineering and business students at what was originally a technical vocational college in Herning, Denmark (which in 1995 became the Institute of Business and Technology, and in 2006 Aarhus University). Since 2003, Christensen has been facilitating processes of collaboration between engineers, social scientists, and humanists in a series of book projects. The first, with coeditors Martin Meganck and Bernard Delahousse, was on *Profession, Culture and Communication: An Interdisciplinary Challenge to Business and Engineering* (2003); the second, with the same coeditors, was *Philosophy in Engineering* (2007); a third, again with coeditors Meganck and Delahousse, was *Engineering in Context* (2009), the precursor of the present two volumes.

Martin Meganck has a doctorate in chemical engineering and is a former Dominican friar who studied theology and currently teaches ethics for engineering students at KU Leuven in Ghent, Belgium. Bernard Delahousse was an English language scholar who taught at an engineering college in Lille, France, and served as head of the school's international office. Delahousse has retired, but participates now as coauthor of one of the chapters in Volume I. Christensen got to know them while serving as the international officer at his institution, which is now part of Aarhus University.

For each book, Christensen and his coeditors organized a gathering of potential authors. Two days of deliberations by participants lead to a table of contents, after which Christensen and his coeditors orchestrated the logistics of book production: first draft submission, final draft submission, index submission, proofreading, etc.

In 2008, Andrew Jamison was drawn into the process, as a contributor to the project that became *Engineering in Context*. But even before that book was published, Jamison, with Christensen and several other contributors to these volumes, asked the Danish Strategic Research Council to fund a four-year Program of Research on Opportunities and Challenges in Engineering Education in Denmark (PROCEED). This ambitious, interdisciplinary project took place between 2010 and 2013.

PROCEED was organized as a strategic research alliance between four universities: Aalborg University, Aarhus University (including the former engineering college in Herning), Roskilde University, and the Danish Technical University. The research was divided into five thematic projects: "Challenges and Responses in Historical Perspective," "Curriculum Design and Learning Outcomes," "Modeling and Simulation in Engineering," "Engineering Practice and Design Competence," and "Integrating Contextual Knowledge into Engineering Education" (cf. PROCEED 2010). The alliance included engineers, social scientists, philosophers, and historians; numerous chapters in these books are based on research and teaching activities that were part of the program.

Prior to the initiation of PROCEED, another project took shape that has also influenced the present two volumes. Christensen, Jamison, and Carl Mitcham teamed up to organize an interdisciplinary reflection on relationships between "engineering and development" that involved American, Chinese, and European perspectives. Christensen invited ten Europeans, Mitcham ten Americans, and Li Bocong, from the Graduate University of the Chinese Academy of Sciences (with whom Mitcham had been working since the early 1990s), ten Chinese scholars. Together these scholars met at the Colorado School of Mines in April 2010 in a workshop supported by the CSM Hennebach Program in the Humanities for an exercise in reflective, cross-cultural learning. PROCEED served as a cosponsor of the workshop by funding travel by some of the European participants.

Mitcham – a key node in the Christensen network from 2006 on – organized the CSM workshop around a series of "tutorials" designed to stimulate dialogue. Mitcham and his colleague Juan Lucena led tutorials on engineering and development from an American perspective (Mitcham for the North and Lucena, originally from Colombia, from the South); Christensen and Jamison offered a tutorial on engineering and development from a European perspective; while Li Bocong and Yanming An introduced a Chinese perspective. By the end of the meeting in Golden, CO, a table of contents was developed for a book that was eventually published in 2012 under the title, *Engineering, Development and Philosophy: American, Chinese and European Perspectives*, edited by Steen Hyldgaard Christensen, Carl Mitcham, Li Bocong, and Yanming An. The book appeared in the Springer series *Philosophy of Engineering and Technology*.

As a further contribution to the American-Chinese-European collaboration project, Li Bocong arranged another workshop on "Engineering and Sociology" in Beijing, China, in the fall of 2011. Li had long been concerned that engineering in the West was too focused on an individualistic professionalism, and he sought to stimulate reflections that would broaden the contexts of understanding in both the West and the East. It was thus in Beijing, around the pleasures of extended Chinese meals, and in a country undergoing a historically unique engineering construction, that there emerged the germ of an idea that has grown into these two volumes on *Engineering in Context*.

Another contributory linkage to these publications can be found in the European Ethics Network (EEN) from the 1990s. The EEN brought together ethicists from 40 European universities and had a broad set of objectives. One of these was creating a book series with core materials for professional ethics in the fields of biomedicine, business, press, and engineering. A kick-off conference in Barcelona, under the title "Rethinking Professional Ethics," was the starting point of a series of collaborations among ethicists involved in engineering and technology from mainly Western European countries. An immediate and tangible result was the publication of Philippe Goujon and Bertrand Hériard-Dubreuil's edited volume, *Technology and Ethics: A European Quest for Responsible Engineering* (2001). The engineering ethics team of the Catholic University of Lille (France) was the motor and the pivoting centre behind the book, and Christelle Didier and Martin Meganck were members of the editorial team. Mitcham contributed an afterword comparing American and European efforts in this area. The ethics journal *Ethical Perspectives* served for some time as the official organ of EEN and is the only *ad extra* visible remainder of that EEN period. A less visible outgrowth, however, is a continuing set of ties among ethicists in different professional fields. When the *Profession, Culture and Communication* project sought a continuation in *Philosophy in Engineering*, the ties between research groups and individual researches resulting from the EEN experience were useful in identifying new partners. The presence of Christelle Didier in the current editorial team has its basis there.

Still one more contributing stream to our collaborative effort, one that draws again on the work of Li Bocong, among others, is the 2012 Forum on Philosophy, Engineering, and Technology (fPET) held in Beijing, China. fPET-2012 was a follow-on to an earlier fPET-2010 hosted at CSM in Colorado. The fPET conferences grew out of previous workshops held in 2007 and 2008 known as the Workshops on Philosophy and Engineering (WPE). The fPET conferences, like the WPE workshops before them, have provided opportunities to bring together scholars from a variety of cultures and disciplines, all sharing a common interest in trying to better understand the human activities we call engineering, the people we call engineers, and the creations we call technology. At the latest meeting in Beijing, approximately 15 countries and 5 continents were represented. Philosophers, historians, and other humanists, along with social scientists and engineers, participated. The range of presentations included philosophical, historical, cultural, and ethical analyses of engineers, engineering, and technology. These events have proved invaluable as catalysts for ideas, scholarly exchanges, and collaborations. In fact, almost half the contributors to the present volumes have been participants in one or more of these events. Byron Newberry, another member of the current editorial team, whose background is in aerospace and mechanical engineering, served as cochair, along with Li Bocong, of the fPET-2012 meeting. Newberry also contributed to the earlier *Engineering in Context* book.

These different strands come together in the current set of two books. An international editorial kick-off workshop was initiated by Christensen and organized with the help of Louis L. Bucciarelli at MIT in May 2012. The main purpose was to define the objectives, structure, and content of the volumes. After introductory presentations by workshop host Bucciarelli, Gary Downey, and Jamison, an intensive process of discussions began. And, as the French say, *Du choc des idées jaillit la lumière*: at first confrontational ideas finally result in understanding and constructive proposals.

We hereby present the final result of a long writing and editorial process. We trust that our readers will find the work worthwhile and they may be inspired by it to do even more to think and rethink engineering contexts so as to transform engineering into a truly humanizing enterprise.

As those two books are meant to be a contribution to furthering the dialogue between engineering and philosophy in order to explore ways in which the humanities can contribute to self-development in engineering education through appreciation of the multiple contexts within which engineers increasingly work, these groups of academics are the primary audience for our books. Moreover, we believe that the very process of creating these volumes, bringing together as it has a host of scholars from a diversity of disciplinary and cultural perspectives, marks a major milestone on the path toward creating a sense of identity and shared culture, while recognizing the value of differences, and building a vibrant community of scholars dedicated to bridging the gaps between engineers, humanists, and social scientists.

However, the book is also addressing a wider academic audience and may actually function as a means to achieve greater self-understanding for both teachers in engineering disciplines and for practitioners. Educational policy makers, both on a political and an institutional level, may also find valuable matter for reflection and inspiration in this book. We believe that, not least, the process of globalization compels engineering educators to rethink and recontextualize engineering education in order to educate a better and more rounded type of engineer. We finally hope that the book may inspire students of engineering as well as students of the humanities and social sciences who are interested in the challenges and complexities that a rapidly changing and globalized world pose for higher education in general and for engineering education in particular.

Herning, Denmark — Steen Hyldgaard Christensen
Lille, France — Christelle Didier
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1 October 2014

Acknowledgment

The editors would like to express our heartfelt gratitude to the two anonymous reviewers who provided thorough assessments of our two volumes, respectively. The comments, suggestions, and criticisms provided by these two scholars were both detailed and insightful. As a result of their feedback, we added new material on topics that deserved more attention (particularly with respect to issues of gender, race, and class), made significant improvements to several chapters, reorganized some of the chapters for better coherence and flow, and have tightened up some of our introductory sections. Our manuscript has been made stronger due to the care and diligence of these reviewers.

Contents

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General Introduction
The Engineering-Context Nexus
A Perennial Discourse

Steen Hyldgaard Christensen, Christelle Didier, Andrew Jamison, Martin Meganck, Carl Mitcham, and Byron Newberry

In 1982, Barry Barnes and David Edge published *Science in Context: Readings in the Sociology of Science*, which significantly influenced the sociology of science. The volume collected 18 previously published articles from the 20-year period 1961 to 1981 – articles almost exclusively by social scientists – to promote reflection on relationships between the subculture of science and the wider culture that surrounds it. Although the editors did not present it as such, the program for understanding

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"science in context" can be read as responding to the challenge of C.P. Snow's 1959 "two cultures" lecture, which identified a debilitating split between scientific and literary intellectuals. For Snow, there really were two cultures that approached the world from antagonistic perspectives. For the social scientists collected by Barnes and Edge, however, scientific culture is always part of culture in a more expansive sense. The two cultures are really one, and science needs to be understood precisely as an aspect of what it may indeed partially oppose.

In the spirit of that earlier title, the present two companion volumes focus on *Engineering Education and Practice in Context* (EEPiC, read as "epic"). This project differs, however, not only in its concern with engineering instead of science but also in being composed of more than 40 original articles contributed by a much more interdisciplinary group: social scientists, yes, but also engineers, philosophers, historians, and even scholars from the fields of classics, communication, and film studies. Additionally, among the more than 60 contributors are representatives from 16 countries on the 6 inhabited continents. The volumes direct attention to four primary contexts of engineering: formal education, the design process, workplace and institutional experience, and civil society. Yet like Barnes and Edge, these new volumes postulate an integral if sometimes contentious relationship between engineering cultures and their larger cultural contexts.

Comparing work on science with the present work on engineering, there emerges what may be termed a contextualization-decontextualization paradox. Scientists qua scientists think of their work as decontextualized and, therefore, have trouble recognizing the ways in which it is also contextualized. Engineers qua engineers think of their work as contextual and, therefore, tend to overlook the ways in which it is decontextualized. Scientists, for example, see formulas such as $F = ma$ and $E = mc^2$ as independent of context and universally true, failing to appreciate their knowledge production can reflect particular cultures (as, in these cases, a mathematical rhetoric enacted in distinctive social institutions). By contrast, engineers engage with contexts in which they deploy those same formulas in particular projects. But it is precisely because they think of themselves as so context dependent and sensitive that engineers also so often presume they can go into any situation and provide appropriate solutions; they often too readily believe all their solutions are inherently contextual, even when this fails to be the case. The existence of such a paradox suggests the need to use the *Science in Context* project as defined by Barnes and Edge as a foil with which to exploit difference.

Beyond Science in Context

The science in context argument is in an important respect nihilistic. The significance of natural science, which the sociology of science aims to disclose, is that natural science has no special significance. Its reputed claims to significance are unmasked, demythologized, and demystified. The sociological argument, as succinctly summarized by Barnes and Edge, is that "There is no way in which [natural scientific] expertise can be guaranteed by reference to reason rather than habitual inference, nature rather than culture" (p. 11). Natural science is a social institution like any other; it rests on purely social foundations and its reasons are no more privileged than those of politics, economics, or the military.

Yet as Barnes and Edge also admit, "to conceive of expert knowledge solely in terms of advocacy" is to ignore the normative question concerning which advocates are most credible or authoritative. The normative question is not one that can be "reduced to a matter of what beliefs are immediately expedient, or immediately relevant to vested interests" (p. 10). Among natural scientists and nonscientists alike, the problem of credibility has customarily been resolved by granting natural science a measure of rational authority – although a rational authority that social scientific analysis questions.

The social scientific analysis of science in context is nevertheless faced with three problems. First, social science is not generally granted the same social recognition as natural science – that is, as the astronomical, physical, geological, and biological sciences. So its claims with regard to the natural sciences often carry little weight. It is not clear what influence the analysis of science in context can ever really have.

Second, even if the social sciences were magically to acquire social prestige and power, it is not clear how more careful and detailed sociological studies – which are repeatedly recommended by Barnes, Edge, and others, in order to give a better understanding of what really happens with science – would escape the acidic analysis that they apply to the natural sciences. That is, the sociological analysis addressed to the natural sciences would seem necessarily to apply as well to the social sciences. The social sciences, too, would have to be conceived as social constructions.

As a result, third, the social sciences can "offer no obvious solutions to the normative problems involved in the evaluation of [scientific] expertise" (p. 12). It is not just that the normative question is, as Barnes and Edge later claim, "of no sociological interest" (p. 194); normativity is not an issue that it is even possible in principle for sociology to address. The sociology of science reveals science to be without distinctive authority and thus at the mercy of political, economic, and military powers – powers that are not troubled, in their real-world exercise of power, by any alleged lack of authoritative rationality. This is what Barnes and Edge refer to as "the tragedy of the expert" (p. 237). Experts can never deploy the methods of expertise, which exist within a community of experts, to legitimate such expertise to the wider public. "If science itself is called into question, then the scientific expert can only retire gracefully" (p. 234). Scientific experts appear dependent on irrational acceptance by the public, with an irrationality that can at most and only on occasion be meliorated by programs of public participation – although Barnes and Edge acknowledge the "power" present in science, especially as reflected by the close linkages of science "with 'the higher levels' of government and industry" (p. 248).

The science in context project is thus fraught with implications the engineering in context project seeks as much as possible to avoid. To this end, we offer three observations. First, by way of a brief historicophilosophical gloss, note that while the idea of the social construction of science can be manifest among scholars without serious immediate harm, the idea has been applied elsewhere with quite harmful results. Insofar as the administration of U.S. President George W. Bush refused, when making decisions about how best to reduce teenage pregnancy, respond to climate change, and the invasion of Iraq to grant any privileged status to scientific knowledge, both natural and social, he adopted a social constructivist stance. To the realist objection that one needs to respect reality, one of Bush's senior advisers is reported simply to have replied, "When we act, we create our own reality" (Suskind 2004). Such application and its results surely provide a good reason to revisit the normative question and defend the rationality of engineering as well as of science.

Second, and more positively, as if offering a means for addressing the normative question, our engineering in context project, is inherently more interdisciplinary. It involves not just sociologists and historians but also engineers and philosophers – along with scholars in the further reaches of the humanities and the social sciences. Indeed, while science in context sought to broaden the reach of science, the broadening went no further than to describe science as not just a "source of knowledge and competence [but as] a repository of theories, findings, procedures and techniques which it makes generally available both directly, via expert intervention and consultation, and indirectly, via its interaction with technology and with specialized institutions in the economic and political structure" (p. 2). What is lacking is recognition of science as a font of social, ethical, and even environmental problems.

To recognize science or engineering as a source of problems – especially environmental problems – is not to deny that it can also contribute to solutions or, better, responses. Indeed, to adopt and adapt the naturalistic pragmatism of John Dewey and to recognize something as a problem is implicitly to imagine a better state of affairs. For Dewey, engineering is ultimately and properly subordinate to the enhancement of life and the qualitative enlargement of human experience. Insofar as science and its sibling engineering fail to accord with this transcendent end – an end that is subject to continuous reimagination and reinstitutionalization in culture – it calls forth its own reconceptualization, regulation, or delimitation along with parallel and complementary extensions and expansions.

It is precisely this that best functions as our own context for the study of engineering. We are studying engineering not simply to promote sociological understanding but in pursuit of better engagement between engineering and society – and the better education of engineers. Moreover, although to some degree a socially constructed or contingent end, it is an end for which we are willing and able to develop rational arguments. Only insofar as we can give good reasons for such ends – not just insofar as such ends are popularly accepted – should we wish to defend and built upon or toward them.

Thus the EEPiC project includes a strongly reflexive element. In the Barnes and Edge volume, for instance, there was no discussion of the meaning of context. By contrast, our two volumes both explicitly and implicitly address different meanings of context. On the explicit side, some chapters grapple overtly with the issue of context, whether trying to elucidate its meaning, to highlight its importance, or in at least one case to reject it. On the implicit side, ideas about contexts were built in via the selection of authors and topics, along with the organization of the volume sections. For example, while Barnes and Edge relied heavily on the problematic concept of culture, for which it assumes an anthropological meaning (see p. 193), here the question of culture is itself placed in context by the presence of contributions from multiple cultures and cultural perspectives, not to mention disciplines and disciplinary perspectives. In addition, chapters in the two volumes are organized in sections designed to explore particular contextual facets, whether historical, ideological, or institutional.

We should note, however, that it is not the objective of these volumes to definitively demarcate the meaning of context in engineering. For our purposes, context is not an end-in-itself but rather a means to an end. In the spirit of further reflexivity, the contingent but nonetheless rationally defensible (and inherently normative) end of the engineering in context project is to foster a better understanding of and engagement with engineering. This engagement will be intentionally provocative and argue for an end that is not explicitly given but implicitly found embedded within it: the transcendence of engineering, what has been called postengineering (see Mitcham 2009).

Remaining for the present in the European tradition, there exists a long-standing or sedimented distinction between liberal and professional education. From the perspective of liberal studies, the contrast is one between education and training, even vocational or technical training. From the perspective of professional studies, the contrast is between useless discussion or mere theory and useful or practical learning. It seems clear that engineering education accords primarily with professional or practical studies. Yet this is not to deny its possible involvement with liberal or even useless studies. We need to move beyond simple dependence on engineering. We must not become so effective at and engrossed with engineering that we forget that engineering is not everything. We need to exercise again the classical humanities disciplines of self-moderation.

Two Volumes and Their Complementarities

In summary, in relation to science in context, which it references as an ancestor, the two EEPiC volumes aim to be more interdisciplinary and original, more critical and reflexive, and more openly normative. Taken as a whole, this collection of original scholarly work is unique in its broad, multidisciplinary consideration of the changing character of engineering education and engineering practice in and from the perspective of multiple contexts.

Volume 1 on engineering education includes analyses of the history, structure, and ideologies of engineering education, challenges and critical perspectives, along with discussions of new pathways in 25 contributions by 50 authors from engineering, social sciences, and humanities. Key overlapping questions examine such issues as:

- What are the different approaches to engineering education?
- Are differences competitive or complementary?
- What special challenges are emerging for engineering from concerns for sustainable community development, energy ethics, sustainability, and demands for innovative design?

- What new efforts are being made to reform engineering education from the perspectives of design, engineering education research, and case-based learning?
- What is the role of the social sciences and the humanities in engineering education?

The chapters of Volume 1 are grouped into four sections, roughly following a see-judge-act logic. Part I historically frames engineering education in the United States, Western Europe, and a selection of locations elsewhere (India, Brazil, Slavic Europe). What appears initially simply descriptive is interwoven with a reflexive/interpretative layer. Part II groups a series of more fundamental reflections on the hidden and overt ideologies in engineering and engineering education. Parts III and IV collect contributions on experiences and approaches for reform and innovations in engineering education.

In Part I, the institutional history and evolution of engineering education in different geographical/cultural contexts is the carrying canvas. Regional, cultural, and historically bound aspects form one approach. Although these historiographical descriptions focus on regional and cultural differences, some common themes emerge. One is "academic drift": vocational-oriented training programs tend to be swept into more academic structures, inducing changes in professional profile and educational culture. A shift of focus from local toward more global perspectives can also be observed throughout the contributions. Insertion in the global economy seems to induce more pragmatic and neoliberal entrepreneurial tendencies in engineering education.

Part II shifts from institutional history to the asking of critical questions regarding theory and practice in engineering education. Like all institutionalized programs of education, engineering schools explicitly or implicitly assume and promote beliefs about how engineers should behave, not just in technical terms but in their social relationships. As previous scholars have noted, there are deeply ingrained ideas in the American context about positive relationships between engineering and business. The chapters in this section invite consideration of some alternative perspectives by calling attention to how engineering education functions differently in China and how the engineering-business nexus may not be experienced as unquestionably rational by members of nondominate social groups.

The framework of Part III extends an exploration of the limitations of received ideologies in engineering education by considering specific cases in the emergence of alternative futures. Hence the majority of chapters in Part III contribute to the construction of a counter-hegemonic discourse or "heterotopia," to use a term of Baillie et al. (2012). Some themes that come into view are engineering mindsets that get in the way of engineers seeing social justice, social justice in the context of global energy consumption and use, critique of the prevailing "weed out" culture in undergraduate programs as an impediment to diversity, developing a hybrid imagination in prospective engineering students, and questioning the ideology and codes of knowledge behind the dominant construction of the epistemological core in engineering education and more.

The chapters in Part IV focus on the renovation of engineering education. Different in their structures and approaches, the innovations that are discussed in this section have in common to refuse reducing education to a mere transmission of knowledge from a master to passive students. Instead, they rely on the active participation of the students and their personal experiences. Most importantly, rather than discussing which content should be added to enrich engineering education, some chapters focus on how to teach with pedagogical methods such as problem-based learning, and how to combine engineering teaching and engineering education research. Others propose a more radical transformation of engineering education through a definition of engineering not only as problem solution but also a contribution to problem definition or a new understanding of engineering knowledge, as the products of contextualized experience.

Volume 2 on engineering practice advances contextual analyses of engineering identity, epistemologies, and values in 23 contributions by more than 30 authors from engineering, social sciences, and humanities. Key overlapping questions examine such issues as:

- What does it mean to be an engineer?
- How are engineering self-understandings enacted in the professional world?
- What is the distinctive character of engineering knowledge?
- How do engineering science and engineering design interact in practice?
- What are the prominent norms of engineering?
- How do they interact with the values of efficiency or environmental sustainability?

The reflection on engineering identities in Part I fans out in the following sections: Is there anything like "engineering knowledge" (Part II)? Is there an inherent normativity in engineering, and how does it connect with the norms and values of the surrounding world (Part III)? The concluding Part IV gives a further exploration of the idea of context itself: in practice, a sharp delineation between "text" and "context" may appear difficult if not impossible. This can either lead to fundamentally questioning the very concept of context or to the vision that engineers can make their own context.

How do engineers distinguish themselves from scientists? From business people? From technologists? How do engineers define themselves professionally, and how are those professional identities uniquely shaped within particular national contexts. How do those outside of engineering perceive engineers? Is there a common unifying element between the diverse types of engineers? And how do gender-based stereotypes of and within engineering serve to limit equitable participation in the field? These are the types of questions that are grappled with by the chapters in Part I of Volume 2, in an effort to gain a clearer understanding of the *identities* of engineers. In addition, a final chapter provides a statistical overview of the scope of the engineering occupation worldwide.

Another field – expounded in the chapters in Part II – where the contextuality of engineering appears, is in the epistemology of engineering: the knowledge engineers need or use in their work cannot be clearly defined and demarcated. There are many uncertainties, as well in the available knowledge itself as in the evaluation of possible outcomes. Data may be lacking or hidden in an overload of information of indistinct relevance. And the boundaries within which engineering projects are to be solved are subject to negotiation with economic or political instances and societal groups and stakeholders of many kinds. Part II of this volume gathers reflections on engineering epistemology. What kinds of efficiencies are pursued by engineers? How do they situate themselves in the tension between pure science and design practice? And how can the many layers of engineering knowledge be reflected in modern curricula of engineering education?

In Part III, the central issue is the values that carry engineers and engineering (which is nowadays our common world) and cultural norms that are or should be at work in professional practice engineers. Some authors question the ambiguous influence of professional associations on the consideration by engineers of ethical issues. Others wonder how the culture of the engineers, the way they look at the world, shapes and is shaped by their relationship with the world of politics. Still others discuss the influence of social values on the attitudes of engineers and those of economic and political issues on how the problems they are asked to solve are formulated.

Do engineers create their own contexts or are they created by contexts? The authors in Part IV, the final section of Volume 2, all take explicit aim at the notion of context. Aptly titled "Competing Contexts in Engineering," the chapters present contrasting views of what context might mean or even how important the concept might be. One author argues that engineers create their own contexts. Another argues that the very idea of context is too static and should be abandoned in favor of more dynamic ways of characterizing engineering. Other chapters seek useful ways to differentiate context, whether by scale (from the micro to the macro) or by vantage point (internal versus external to the engineering activity). A final chapter explores the challenge faced by engineering practitioners with respect to reflexively incorporating an understanding of context in their work.

Contexts, Challenges, and Paths to Transformation

The notion of context in engineering education and practice is an object of heated debate. On the one hand, claims are made that context is an artificial construct, reifying a distinction between context and content and producing the sense of an inside and an outside. On the other hand, claims are made that the distinction between technical context and social context (a) reflects real tensions in engineering education and practice, (b) is constantly being re-negotiated, and, most importantly, (c) the outcome of such negotiations has real world consequences. Positions that adopt the context approach often focus on social justice, and more broadly empirical studies of engineering students' engagement with context, have been reflected in a number of path breaking works. Among these are: Cindy Atman and colleagues (1996, 2008), Caroline Baillie (2006), Donna Riley (2008), Baillie and colleagues (2011, 2012), and Juan Lucena (2013). Baillie et al. (2012), Most recently Bill Williams, José Figueiredo, and James Trevelyan in a collection on *Engineering Practice in a Global Context* (2014) have made another significant contribution.

The position taken here is that context matters and has practical consequences. The relevance of context is related to at least three different meanings of context and to inherent tensions that result:

- The embedding of institutions of engineering education into higher education systems,
- The breadth of problem scoping in engineering problem solving
- Contextual knowledge

Context, however, is an inherently dialectical concept, since contextualizing is itself dependent on definitions of what are perceived to be the relevant boundaries regarding both the education and the practice of engineers. Contextualizing unfolds its inherent dialectics in the terrain between "is" and "ought," fact and value. In this way, the quest for a recontextualizing of engineering education and practice inevitably is a value-laden enterprise and thus not without a certain degree of controversy. It is concerned with both what engineering "is" and what it "ought" to be. Ultimately a greater awareness and understanding of context should result in better preparation of engineers to render those contexts visible in their work, and consequently enable them to contribute to more socially robust and responsible endeavors.

When thinking about how far context can influence engineering and engineering education, one rapidly discovers challenges or even crises that can be roughly categorized into a number of ideal typical arguments:

- The captivity argument
- The cultural change argument
- The identity crisis argument
- The weak profession argument
- The convergence argument

This list of arguments, most of which have been developed in one form or another over recent years, should be understood as neither complete nor definitive, although it provides a useful point of departure for anyone interested in understanding and innovating with respect to engineering and engineering education. Despite overlaps between these arguments, the merit of distinguishing them is that each emphasizes a specific aspect of engineering and/or engineering education that poses challenges – and opportunities – for the engineering profession.

In many chapters of these two volumes, the ideas and analyses aim to further identify, characterize, and explicate one or more of these challenges. Other chapters, drawing on such analyses, propose responses in hopes of transforming engineering and engineering education in ways that will sustain the profession as a vital, constructive, and responsive social institution. A brief summary of relevant arguments follows.

The *captivity argument* is that the engineering profession, in regard to both education and practice, has been locked in a number of social and intellectual captivities that may be interpreted as a "fundamental usurpation of the intellectual and social dimensions of engineering as an autonomous discipline" (Goldman 1991,

p. 121). An "intellectual captivity" consists of engineering being considered subordinated to science. Engineering education requires students to master large doses of mathematics and physical sciences. Engineers in turn tend to believe that science and engineering are objective and able to exclude human values from influencing the esoteric work taking place in engineering disciplines. Engineers become overly concerned with order and certainty and adverse to ambiguity. Issues of meaning and social impact are marginalized because scientific methodology, the structure of hypothesis, proof, validation, publication, and critique are embedded in a scientific culture to which engineers find themselves attached. A "social captivity" lies with engineering practice being subordinated to a managerial agenda driven by economics and the market. Engineers exercise their power only within that mandate, which raises questions about the idea of engineers as the primary agents of technological change. According to Johnston et al. (1996), the result has been a serious limitation in engineers' capacity to examine the social meanings and effects of their work and to self-consciously reflect on their practices and professional identities.

Captivity arguments surface throughout these volumes. For example, in Volume I, Chap. 1, Atsushi Akera and Bruce Seely provide a historical account of the American system of engineering education. In it they highlight the rise to dominance of the *engineering science* paradigm, as well as the influences of "neoliberal economic doctrine." Similarly, in Volume II, Chap. 10, Stig Andur Pedersen delves into the intellectual tensions between science and engineering. Other chapters present ideas for moving beyond such intellectual and social captivities. For example, Tony Marjoram argues in Volume I, Chap. 16, for a problem-based, as opposed to science-based, education, with an emphasis on addressing human and social development goals. And in Volume II, Chap. 17, Carl Mitcham and Wang Nan advocate an expansion of engineering ethics into the political arena, so that "taking a global perspective on investing in a new technological innovation, for instance, would involve going beyond economics to include assessments of multiple risks and benefits at the social and environmental levels."

The *cultural change argument* concerns an alleged lack of diversity in engineering. In one version of this argument, feminist research criticizes the social norms of engineering culture as overly masculine. How could female students feel attracted to engineering faculties that are not only demographically dominated by men but also culturally emphasizing of male interests? Research has shown that male students go for engineering because they like to tinker; the choice of female students seems more inspired by a general interest in mathematics and physics. Even without giving in to the caricature of the pragmatic and performance-oriented male vs. the more caring and relation-oriented woman, bridging these "two cultures" is far from evident. But this is only one aspect of the cultural change argument. In Volume I, Chap. 8, Amy Slaton describes the "less-than–democratic character" of engineering and other science, technology, engineering, and mathematics (STEM) occupations and the weak influence of many inclusive efforts made in the United States to address diversity issues (gender issues, but also social diversity). Wendy Faulkner in Volume II, Chap. 2, highlights how gender operates alongside professional and organizational to produce engineering culture and proposes to disseminate "heterogeneous" images of engineering in order to create space for a more diverse range of people.

In a context where the global engineering competency becomes "a problem of engaging people from different cultures" (Downey et al. 2006), another aspect of cultural change has to do with cross cultural and globalization issues. In Volume I, Chap. 7, Qin Zhu and Brent Jesiek highlight the need to develop a better understanding of the history and cultural context of engineering education and profession in other countries and regions. They propose three key intellectual concepts enabling understanding Chinese culture: Confucianism, Marxism, and pragmatism.

A further aspect of cultural change involves preparing engineers to deal with environmental issues. In Volume II, Chap. 13, Christelle Didier and Kristoff Talin highlight French engineers' attitudes toward the environment and how they differ from those of their fellow citizens; "ecoskepticism" is the norm even among the younger generation of engineers. In Volume II, Chap. 15, Jen Schneider, Abraham Tidwell, and Savannah Fitzwater describe the tremendous difficulty of reforming nuclear science and engineering education in the United States to better integrate environmental issues. Encouraged by physics and engineering educators, student skepticism toward climate change research constitutes a cultural value and contributes to constructing an "insular culture." Rather than simply objecting to their opinions, the authors invite nuclear engineers to make their voices better heard at the "table of discussion."

The *identity crisis argument* has several manifestations, ranging from how engineering is understood – or misunderstood – by the public, to uncertainties in the roles engineers play, or will continue to play in the future, in technology development. The latter issue, for example, was developed forcefully by Rosalind Williams (2002). In a reflection that grew out of her service as Dean for Undergraduate Education and Student Affairs at MIT, she analyzes how a division of labor has eroded the identity of the engineering profession.

> What engineers are being asked to learn keeps expanding along with the scope and complexity of the hybrid world. Engineering has evolved into an open-ended Profession of Everything in a world where technology shades into society, into art, and into management, with no strong institutions to define an overarching mission. All the forces that are pulling engineering in different directions – toward science, toward the market, toward design, toward systems, towards socialization – add logs to the curricular jam. (Williams 2002, p. 70)

The challenge for engineering education is complex: it can lead to cramming more and more into the curriculum. It can lead to hyper-specialization, with a set of narrowly defined skills and competencies for preestablished jobs. But this contrasts with future demands for "educating active, rigorous and flexible individuals, rather than skilled workers for pre-established jobs." For Williams, the curricular response should be a convergence between the technological and liberal arts, educating the engineering student both for life and flexible employment.

> Only a hybrid educational environment will … prepare students for handling … life in a hybrid world. Students need to be prepared for life in a world where technological, scientific, humanistic, and the social issues are all mixed together. Such mixing will not take place if students have to decide from the outset that they are attending an "engineering school" as opposed to a "non-engineering school." (Williams 2003, p. 4)