Philosophy of Engineering and Technology

Steen Hyldgaard Christensen · Anders Buch · Eddie Conlon · Christelle Didier · Carl Mitcham · Mike Murphy *Editors*

Engineering, Social Sciences, and the Humanities

Have Their Conversations Come of Age?

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Philosophy of Engineering and Technology

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Editors

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Editors
Steen Hyldgaard Christensen
Department of Development and Planning
Aalborg University
Aalborg, Denmark

Eddie Conlon
School of Multidisciplinary Technologies
Technological University Dublin
Dublin, Ireland

Carl Mitcham
Colorado School of Mines
Golden, CO, USA

Editor-in-Chief
Pieter E. Vermaas

Anders Buch
VIA University College
Aarhus, Denmark

Christelle Didier
Lille University
Lille, France

Mike Murphy
Technological University Dublin
Dublin, Ireland

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Preface

The idea for this book originates from reflections by the editors on the nature and dynamics of emerging research agendas on engineering. The book is based on our understanding of both engineering practice and engineering education as a heterogeneous socio-technical enterprise transcending the technical core–social periphery dichotomy. With backgrounds in engineering, social sciences, and the humanities, we have been developing and/or teaching courses for engineering students across the liberal arts–engineering divide for decades. During participation in research projects aimed at understanding and reforming engineering education, we have published a series of books on engineering with contributions from a broad network of scholars from across the globe. This present book aspires to pull together the various strands of this trajectory of collaboration and to extend it in part by reflecting on the conversations between engineers and non-engineers. Following the Delphic injunction to *know thyself,* we want to reflect upon what we have been doing while projecting forward. Previous publications leading up to the present book include:

- Steen Hyldgaard Christensen, Bernard Delahousse, Martin Meganck (Eds.) (2007), *Philosophy in Engineering*, Academica, Aarhus
- Steen Hyldgaard Christensen, Bernard Delahousse, Martin Meganck (Eds.) (2009), *Engineering in Context*, Academica, Aarhus
- Steen Hyldgaard Christensen, Carl Mitcham, Li Bocong, Yanming An (Eds.) (2012), *Engineering, Development and Philosophy: American, Chinese, and European Perspectives*, Springer Science+Business Media BV
- Steen Hyldgaard Christensen, Christelle Didier, Andrew Jamison, Martin Meganck, Carl Mitcham, Byron Newberry (Eds.) (2015), *International Perspectives on Engineering Education: Engineering Education and Practice in Context, Volume I*, Springer Science+Business Media BV
- Steen Hyldgaard Christensen, Christelle Didier, Andrew Jamison, Martin Meganck, Carl Mitcham, Byron Newberry (Eds.) (2015), *Engineering Identities, Epistemologies and Values*: *Engineering Education and Practice in Context, Volume II,* Springer Science+Business Media BV

- Steen Hyldgaard Christensen, Bernard Delahousse, Christelle Didier, Martin Meganck, Mike Murphy (Eds.) (2019), *The Engineering-Business Nexus: Symbiosis, Tension and Co-Evolution*, Springer Nature

It has been a priority for us that the team of scholars and researchers contributing to the book should be composed of close to equal representation of female and male researchers and balanced generationally. The book is addressed to both teachers and students in engineering and non-engineering disciplines as well as practitioners and educational policy makers at political and institutional levels. It is the result of a long writing and editorial process. Hopefully readers will find it worthwhile, particularly as it aims to inspire us all to do more thinking and reflection about the conversations between engineering, social sciences, and the humanities and to launch further research within this important field.

At this place, we would like to acknowledge the very good collaboration we had with Springer Nature's project coordinator Mr. Arun Siva Shanmugam and his meticulous attention to our manuscript.

Aalborg, Denmark — Steen Hyldgaard Christensen
Aarhus, Denmark — Anders Buch
Dublin, Ireland — Eddie Conlon
Lille, France — Christelle Didier
Golden, Colorado, USA — Carl Mitcham
Dublin, Ireland — Mike Murphy
November 22, 2021

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Notes on Contributors

Lars Bækgaard is an associate professor in the Department of Business Development and Technology at Aarhus University, Denmark. He holds a PhD in computer science. His research interests include research methodology, design science research, service design, information systems, conceptual modeling, digital technology, digital innovation, digital transformation, enterprise architecture, and engineering design. He teaches digital technologies and digital transformation with a particular emphasis on relations between technical systems and social systems.

John Barry holds a BA (Hons) in politics and economics and MA in moral and political philosophy from University College Dublin and a PhD from the University of Glasgow. He is Professor of Green Political Economy at the School of History, Anthropology, Philosophy and Politics, Queen's University, Belfast. His areas of research include post-growth economics, sustainability, resilience, and low carbon energy transitions, as well as green political economy and green economics; governance for sustainable development; the greening of citizenship and civic republicanism; and green politics in Ireland, North and South. He is author of several books including *The Politics of Actually Existing Unsustainability: Human Flourishing in a Climate-Changed, Carbon-Constrained World* (Oxford University Press, 2012). He is a former co-leader of the Green Party in Northern Ireland and a former Green Party councilor on Ards and North Down Council.

Kacey Beddoes is a project director at San Jose State University College of Engineering Dean's Office and Research Foundation. She is managing editor of *Engineering Studies;* deputy editor of *Australasian Journal of Engineering Education*; and past chair of the SEFI Working Group on Gender and Diversity. She holds a PhD in science and technology studies from Virginia Tech. Her current research focuses on gender, mental wellness, and interdisciplinarity in engineering and engineering education. Further information about her work can be found at www.sociologyofengineering.org

Tom Børsen is Associate Professor of Techno-Anthropology in the Department of Planning, Aalborg University. He holds a master's degree in chemistry and philosophy from the University of Copenhagen and a PhD in university science education from the Danish University for Pharmaceutical Sciences. Research wise, he is interested in Responsible Research and Technological Innovation (RRI) and has published on how RRI is and can be integrated into technical study programs. From 2015 to 2021, he was head of the Study Board for Techno-Anthropology and Sustainable Design.

Evan Boyle holds a BA in sociology and English from University College Cork, and an MA in sociology of development and globalization from University College Cork. Currently, he is undertaking a PhD in the Energy Policy and Modelling Group, MaREI/ ERI, and the Sociology Department, University College Cork. His current research interests include the diffusion of sustainability, participatory research methods, and collaborative governance. Evan is also involved in lecturing/tutorial roles with a current focus on sociology of religions and Civilization and sociology of the community. Recent publications include *Transitory Saviour Visions and the Six Steps to Trickster Logic: Between Limits and the Limitless* (International Political Anthropology, 2020) and *Regime-Based Transition Intermediaries at the Grassroots for Community Energy Initiatives: Exploring Tidy Towns in Ireland* (Energy Research & Social Science, 2021).

Louis L. Bucciarelli is a professor emeritus at MIT. He received a PhD in aeronautics and astronautics from MIT and has held a joint appointment in MIT's School of Engineering and its School of Humanities, Arts, and Social Sciences (STS). He is the author of *Designing Engineers*. Now retired from teaching and research, he is devoting his time to the production of a Cabinet of Curiosities (Wunderkammer) to be housed online – a collection gleaned from his scholarly (and not so scholarly) travels over the past 50 years.

Anders Buch is docent and head of research program in the Centre for Quality of Education, Profession Policy & Practice at VIA University College, Denmark. His empirical research area is focused on professions, professionalism, and technological expert cultures, and his theoretical approach is primarily inspired by science and technology studies, practice theory, and classical American pragmatism. He has published articles and books on knowledge, learning, education, professionalism, and the professional development of engineers. Since 2016, he has served as chief editor of the *Nordic Journal for Working Life Studies* and he has been affiliated with Jönköping University as guest researcher since 2021.

Edmond Byrne holds a BE in chemical engineering and MSc (Agr.) in food science from University College Dublin, PhD in process and chemical engineering, and MA in teaching and learning in higher education from University College Cork. Chair Professor of Process & Chemical Engineering at University College Cork, and he is principal investigator at UCC's Environmental Research Institute (ERI).

His research interests include transdisciplinary approaches around sustainability and (engineering) education for sustainability. Chair of the 10th Engineering Education for Sustainable Development conference (EESD2021) in Cork, he co-edited *Transdisciplinary Perspectives on Transitions to Sustainability* (Routledge, 2017) and *Metaphor, Sustainability, Transformation: Transdisciplinary Perspectives* (Routledge, 2021).

Jennifer M. Case is a professor and head of the Department of Engineering Education in the College of Engineering at Virginia Tech, USA. Prior to this appointment, in 2017, she was a professor in the Department of Chemical Engineering at the University of Cape Town in South Africa, where she retains an honorary appointment. She holds a PhD from Monash University, an MEd from the University of Leeds, and an MSc from the University of Cape Town. With more than two decades of undergraduate teaching and curriculum reform work, she is a well-regarded researcher in engineering education and higher education. Her work especially on the student experience of learning as well as on topics around teaching and curriculum has been widely published.

Alan Cheville is Professor of Electrical and Computer Engineering at Bucknell University, USA. He studied optoelectronics and ultrafast optics at Rice University, and then transitioned to faculty member at Oklahoma State University, working on terahertz frequencies and engineering education. He left OSE to serve for 2.5 years as a program director in engineering education at the National Science Foundation, later taking a chair position in the Electrical & Computer Engineering Department at Bucknell University. He serves on several national-level advisory boards. Recently, he helped found Maker-E, an electronic makerspace for students, and is currently leading a department-wide effort to integrate more understanding of social sciences into the engineering curriculum.

Steen Hyldgaard Christensen holds an MA in Danish language and literature and the history of ideas from Aarhus University. He holds a PhD in research on engineering education from Aalborg University. He was a senior lecturer at Aarhus University till 2014. Since 2014, Steen is adjunct associate professor at Aalborg University. He is initiator, coordinator, lead editor, and co-author of several edited volumes on engineering education and epistemology. He has published articles on engineering epistemology, culture, and higher education. His current research interests are dynamics in higher education restructuring and research initiatives to broaden engineering education.

Cynthia Colmellere is Associate Professor of Sociology at Ecole Centrale Supélec, researcher at IDHES-UMR 8533, ENS Paris-Saclay. As sociologist of work and science, her research focused at first on work in industry. She has published articles on work, automation, control, and maintenance issues in high-risk industry. She is co-author of *Les processus de normalisation. Enjeux et pratiques professionnelles dans les organisations*, Rennes, PUR. Cynthia is interested in the

socialization of engineers, she published on this issue too. Her current research interests are sociology of scientific work, scientific work to study archeological and art objects (authentication and conservation), ethnography of labs, and Fablabs. She is currently working on several publications on these topics.

Eddie Conlon is a sociologist and works at the Technological University of Dublin. He has been working with engineering students for almost 20 years to help them explore the relationship between technology, engineering, and society. His interests are in the sociology of work, but he has recently published as well as supervised graduate students in areas such as engineering ethics, the social position of engineers, the integration of sustainability into engineering education, and the use of case studies in teaching ethics. He has published in fields of science and engineering ethics and in the *European Journal of Engineering Education*.

Christelle Didier is Associate Professor of Sociology and Philosophy of Education in the Education Department, Lille University, and member of laboratory CIREL. She holds a BSc in engineering, an MA in education, and a PhD in sociology. Her research areas are engineering ethics and engineering education, including historical, cultural, and gender perspective. She is co-author of *Ethique Industrielle. Textes pour un débat*, De Boeck, 1998; author of *Penser l'éthique des ingénieurs*, Presses Universitaires de France, 2008; *Les ingénieurs et l'éthique. Pour un regard sociologique*, Hermes, 2008; and co-author of *International Perspective on Engineering Education,* Springer, 2015, *Engineering identities, Epistemology and Values*, Springer, 2015, and *The Engineering-Busines Nexus,* Springer, 2019. Her current research interests are: engineering ethics and ethics education, and socialization from school to doctoral studies and adult education.

David E. Drew holds the Joseph B. Platt Chair in the management of technology at the Claremont (CA) Graduate University. He earned his bachelor's degree from Syracuse University and his master's and PhD from Harvard University. He is a recovering administrator, having served for 10 years as dean of the CGU School of Educational Studies. His research interests include statistics and analytical models; STEM education, especially increasing the access and achievement of underrepresented students in STEM; and exploring ways to incorporate technology for the benefit of society. He currently is writing two books: *The Bionic Society: Rethinking What It Means to Be Human in an Age of Bits, Bytes, and Bots* and a mystery novel, *Our Days Are Numbered*, a reflection on the nature and meaning of time.

Niall Dunphy holds a BSc in environmental science from the University of Limerick, and an MSc in government and PhD in engineering from University College Cork. He is the director of Cleaner Production Promotion Unit, a fellow of the School of Engineering and Architecture, and principal investigator at the Environmental Research Institute at University College Cork, Ireland. Niall's research focus lies at the intersection of the social sciences with science and

engineering, and his group conducts engaged research focused on the theme of society, sustainability, and energy. His current portfolio of research includes multiple EU- and nationally funded projects focused on such topics as energy citizenship, energy poverty, energy prosumption, energy communities, social acceptability, and public engagement. Niall coordinated the innovative ENTRUST project (H2020, 2015–18) which explored the human dimensions of the energy system, and is presently coordinator of energy measures (H2020, 2020–23) which is focused on energy poverty alleviation.

William Grimson graduated from Trinity College Dublin (BA, BAI) and the University of Toronto (MASc) as an electrical engineer. He is a chartered engineer and a past president of Engineers Ireland. He first worked as an R&D engineer with Ferranti Ltd before joining the Department of Electrical Engineering in what became the Technological University of Dublin. In the latter part of his academic career, he made contributions to conferences and books on the relevance of philosophy to engineering. Now retired, he is a fellow and honorary secretary of the Irish Academy of Engineering.

Francois-Xavier Guchet is Professor of Philosophy of Technology at the University of Technology of Compiègne, France. He is director of the SHS Laboratory of the university, Connaissance, Organisation et Systèmes Techniques (COSTECH, Research Unity 2223). His research is on the epistemological and ethical issues raised by emerging technologies, in particular in medicine (nanotechnologies, molecular personalized medicine, biobanks, and tissue and organ engineering). He is also a specialist of Gilbert Simondon's philosophy. His recent books include *French Philosophy of Technology: Classical Readings and Contemporary Approaches*, Springer (with B. Bensaude-Vincent and S. Loeve, 2018) and *Care in Technology. A Philosophical Perspective* (Wiley, 2021).

Clodagh Harris (PhD) is a senior lecturer in the Department of Government and Politics, University College Cork, and an affiliate of the Environmental Research Institute. She specializes in deliberative and participatory democracy, democratic innovations, and democratic governance and climate change. She has served on, or advised on, Ireland's first Citizens' Assembly "We the Citizens" (2011), the G1000 Belgian Citizens' Summit (2011), Ireland's Constitutional Convention (2012–2014), the Citizens' Assembly on Brexit (2017), Extinction Rebellion UK's working group on citizens' assemblies (2019), and the Research Advisory Group to the Scottish Citizens' Assembly (2019–2021). She is co-PI on the I2050 and DIIS projects.

Ian Hughes holds a PhD in physics from Queens University Belfast, and a postgraduate diploma in psychoanalytic psychotherapy from the Irish Institute for Psychoanalytic Psychotherapy, Dublin. He has joint appointments as senior policy advisor in science, technology, and innovation in the Department of Further and Higher Education, Research, Innovation and Science, and as senior research fellow at the SFI MaREI Centre for Energy, Climate and Marine at University College

Cork, Ireland. He is lead researcher in the Deep Institutional Innovation for Sustainability and Human Development (DIIS) project at MaREI. His publications include, as author, *Disordered Minds: How Dangerous Personalities are Destroying Democracy* (Zero Books, 2018) and, as co-editor, *Metaphor, Sustainability, Transformation: Transdisciplinary Perspectives* (Routledge, 2021).

Brent K. Jesiek holds a BS in electrical engineering from Michigan Tech, and MS and PhD in science and technology studies from Virginia Tech. He is a professor in the Schools of Engineering Education and Electrical and Computer Engineering at Purdue University. Much of his current research uses social science research methods to investigate various aspects of professional formation among engineering students and practitioners. He has also written extensively on geographic, disciplinary, and historical variations in engineering education and practice.

Kieran Keohane holds a PhD in sociology/social and Political thought from York University, Toronto, Canada, 1993, and an MSocSc from the University College Cork 1987. He is a professor in the Department of Sociology & Criminology, University College Cork. His research, teaching, and publications include social theory, anthropology, and cultural-psychoanalysis, and his research topics are moral foundations of economy and society, deep institutional innovation for sustainability and human development, and social pathologies of contemporary civilization.

Mike Klassen is a PhD candidate in higher education at the Ontario Institute for Studies in Education, University of Toronto. He is a board member of the Research in Engineering Education Network (REEN) and an editorial board member of the *European Journal of Engineering Education*. He holds an MA in higher education and a BSc in engineering science from the University of Toronto. His research applies theories from the sociologies of education, professions, and organizations to engineering education through a comparative lens. His PhD thesis investigates the interpretation of accreditation reforms associated with the Washington Accord at different levels of the educational system in the United Kingdom, Singapore, Australia, and South Africa.

Charles Larkin (Discip. Schol.) BA, PhD [TCD], is director of research at the Institute for Policy Research at the University of Bath. He was previously special advisor to the chairman of the Oireachtas Committee on Health, Dr. Michael Harty, TD (Ind.), and to Senator Sean Barrett (Ind.) of the Irish Senate. Dr. Larkin is also an adjunct assistant professor at Trinity College Dublin, Johns Hopkins University, and the Institute of Public Administration (Dublin). Dr. Larkin also holds non-executive director positions as member of the governing authority of Technological University Dublin and the board of Accounting Technicians Ireland. Dr. Larkin has authored several items of Irish legislation and over 60 scholarly articles, most especially in the areas of finance, cryptocurrencies, and public policy economics.

Luc Lefort holds an MSc in engineering at ISAE-Supaero (Toulouse, Fr.) and an MSc in social sciences from Université Paris Sciences et Lettres (Paris, Fr.).

Christian T. Lystbæk is an associate professor in the Department of Business Development and Technology at Aarhus University, Denmark. He holds an MA in philosophy and political science from Aarhus University. His research interests include research methodology, action research, knowledge management, philosophy of science, philosophy of technology, service design, and user experience.

Marie Magnell is a lecturer in the Department of Learning in Engineering Sciences, KTH Royal Institute of Technology, Sweden. She holds a PhD in technology and learning from KTH. Her research interests include links to professional practice in the engineering curriculum, the teaching-research nexus, and differences in cultures across engineering programs. She teaches in faculty development courses.

Marie-Pierre Bès (1965–2021) was Full Professor of Sociology at University Toulouse Jean-Jaurès, and a researcher at LISST. She began her carrier as an economist. She studied innovation in the spatial sector. From the end of the 1990s, she chose a more sociological perspective to study connections between research in academic laboratories and companies from a network perspective. For 20 years, she developed a program focused on relations between science and industry. Her research mixed qualitative and quantitative methods to precisely analyze the nature and the idiosyncrasies of these relations, from the individual to the institutional level. She published many articles on those topics. Her last book, published in 2022, *La mécanique de l'excellence dans une Grande école. Récit de l'intérieur à l'Institut supérieur de l'aéronautique et de l'espace*, is based on her personal experience as a professor in a school of engineers for 20 years. Through daily situations, she captured the merging between her institution and another, showing the human and organizational costs of the actual transformations of higher education and research.

Diana Adela Martin is a postdoctoral researcher at TU Eindhoven, the Netherlands. Her PhD research study was conducted at TU Dublin, Ireland, in cooperation with Engineers Ireland, and focused on ethics in the context of accreditation. Prior to that, Diana co-founded in 2008 in Romania the educational NGO Link Education and Practice, and between 2012–2015, she collaborated with DG Research & Innovation on issues regarding researchers' rights in the European Research Area, as member of the founding group Euraxess-Voice of Researchers. Her multi-stakeholder projects aimed at improving the employability prospects of youth from underprivileged backgrounds have received the recognition of Délégation générale Wallonie Bruxelles à Bucarest (2009), the Policy Center for Roma and Minorities (2011), and in 2015, Diana was named by the European Forum Alpbach as one of Europe's innovators in tackling inequality in higher education.

Natasha McCarthy leads the Royal Society's Data theme, within the Science Policy Section. The Society's Data Theme carries out a range of policy activities to promote the development and use of data and digital technologies for the benefit of humanity. The team has delivered work on machine learning and AI, data governance, digital skills, and privacy technologies. Natasha previously led the policy teams at the British Academy for Humanities and Social Sciences and the Royal Academy of Engineering; was part of the founding team at UCL's Department for Science, Technology, Engineering and Public Policy; and held an academic post in philosophy at the University of St Andrews. She is author of a number of papers and editor of collected volumes on philosophy of engineering, engineering in policy-making, and the role of technology in governance, and is author of *Engineering: A Beginner's Guide,* an introduction to the social and historical impacts of engineering.

Connor McGookin holds a BE and PhD in energy engineering from University College Cork, Ireland. Currently, he is a postdoctoral researcher in the Energy Policy & Modelling Group based out of MaREI/Environmental Research Institute, University College Cork, working on Ireland's Five Year Assessment Report Volume 2: Achieving Climate Neutrality by 2050. His primary research interests include participatory approaches to energy system modelling and planning, local energy planning, and community responses to sustainability challenges (in particular climate change).

Diane Michelfelder is Professor of Philosophy at Macalester College, St. Paul, Minnesota, USA. A past president of the Society for Philosophy and Technology, her primary research interests include the philosophy of technology, the philosophy of engineering, and digital ethics. Her most recent book volume is the *Routledge Handbook of the Philosophy of Engineering* (2021), co-edited with Neelke Doorn.

Glen Miller is Instructional Associate Professor of Philosophy at Texas A&M University. He holds a bachelor's degree in chemical engineering from Missouri University of Science and Technology and master's and doctoral degrees in philosophy from the University of North Texas. He is associate editor of the journal *Science and Engineering Ethics.* His current research focuses on philosophy and engineering, environmental philosophy, philosophy of technology, and cyberethics. With Ashley Shew, he co-edited *Reimagining Philosophy and Technology, Reinventing Ihde* (2020).

Carl Mitcham is Visiting Professor of Philosophy of Technology at Renmin University of China and Emeritus Professor of Humanities, Arts, and Social Sciences at Colorado School of Mines. His work focuses on philosophy and policy issues related to engineering, technology, and science. His most recent books are a co-edited volume titled *Philosophy of Engineering, East and West* (2018, with Li Bocong, Byron Newberry, and Zhang Baichun) and *Steps toward a Philosophy of Engineering* (2020).

Gerard Mullally holds a BA in sociology and history, an MA in sociology of development, and a PhD in sociology all from University College Cork (UCC). He is a lecturer and deputy head of the Department of Sociology and Criminology, School of Society, Politics and Ethics, UCC. He is currently the lead researcher in the transdisciplinary research project Imagining 2050 (2018–2021); a research associate with the Environmental Research Institute, the Cleaner Production Promotion Unit, and the Institute for Social Sciences in the 21st Century; and a funded investigator at the SFI MaREI Centre for Energy, Climate and Marine, all at UCC. He is the co-editor of *Transdisciplinary Perspectives on Transitions to Sustainability* (Routledge, 2017) and the forthcoming *Metaphor, Sustainability, Transformation: Transdisciplinary Perspectives* (Routledge, 2021).

Mike Murphy holds a BSc (Eng.) in electrical engineering, Trinity College Dublin (1980), MEng (1982), and PhD (1987) in electrical engineering, Stevens Institute of Technology (USA). He is Professor of Engineering at Technological University Dublin (IE). He commenced his industry career with AT&T Bell Laboratories in New Jersey, and later with Bell Communications Research. Previously, he was director and dean of the College of Engineering & Built Environment at Dublin Institute of Technology and academic registrar of Technological University Dublin – City Campus. He has served as president (2017–19) of the European Society for Engineering Education (SEFI), and is a founding member of the European Engineering Deans Council. He is a Fellow of Engineers Ireland, and a member of the IEEE.

Brian Ó Gallachóir holds a BSc (Applied Sciences) from Trinity College Dublin and PhD in mathematical physics from University College Cork. He is Chair Professor of Energy Engineering at University College Cork and director of MaREI, SFI Research Centre for Energy Climate and Marine. His research interests include developing energy systems modelling tools and using them to inform energy and climate mitigation policy. He is elected chair of the International Energy Agency Technology Collaboration Programme on energy systems modelling (IEA-ETSAP) and elected fellow of Irish Academy of Engineering. His publications include *In-forming Energy and Climate Policies Using Energy Systems Models* (Springer, 2015) and *Limiting Global Warming to Well Below 2 °C: Energy System Modelling and Policy Development* (Springer, 2018).

Claire O'Neill holds a BSc in food business from University College Cork, an MSc in strategic management from Technology University Dublin (formerly Dublin Institute of Technology), and a PhD in Commerce from University College Cork. Claire is a marketing lecturer in the Department of Management and Marketing at Cork University Business School, UCC. Her research interests include food sustainability, intergenerational sustainable behaviors, environmental education, and social marketing for sustainability. She is co-PI in H2020 ERA-NET SUSFOOD2 project PLATEFORMS (2018–2021) – Sustainable Food Platforms: Enabling Food Practices through Socio-technical Innovation, which addresses how sustainable

household food consumption can be enabled through socio-technical innovations in food provisioning systems. She has researched sustainable behaviors resulting from both the Green-Schools Ireland program (a Foundation of Environmental Education (FEE) program, known internationally as EcoSchools) and Green Campus in UCC.

Gabrielle Orbaek White holds a BA in cognitive science from Rice University and MPH with concentrations in health services organization and global health from the University of Texas Health Science Center in Houston, Texas. After 10 years in the field of public health practice, Gabrielle has recently returned to academia as a PhD student at Swansea University in the UK. As a social scientist based in the Faculty of Science and Engineering, she is exploring opportunities to bring critical scholarship into engineering education. Prior to her return to academia, Gabrielle's work took her to Ethiopia, multiple states across the USA, and most recently, Wales, where she worked to catalyze policy and systems-level change to improve health and well-being across communities. She prioritizes a social justice lens and systems approach in all her work.

Madeline Polmear is a Marie Skłodowska-Curie, EUTOPIA Science and Innovation COFUND Fellow at the Vrije Universiteit Brussel, Belgium. She received her bachelor's in environment engineering, master's in civil engineering, and PhD in civil engineering from the University of Colorado Boulder. She previously worked as a postdoctoral research associate in the Department of Civil and Coastal Engineering at the University of Florida. Her research focuses on engineering ethics education and the development of societal responsibility and professional competence inside and outside the classroom.

Michael Portal is a doctoral student in the Department of Philosophy at Texas A&M University (USA). He studies contemporary hermeneutics, phenomenology, and existentialism. He is the book review editor for A*rendt Studies: A Journal for Research on the Life, Work, and Legacy of Hannah Arendt*.

Alexandra Revez holds a BA in political science, and sociology and geography, MA in community development, and PhD in human geography from the National University of Ireland, Galway. Her work has concentrated on key public participation issues linked to environmental, disaster management, and social care policy. Previous research has included: *ENTRUST (2015–2018)* focused on exploring the social dimensions of the energy system across different European communities; the *3-Cities* (2013–2015) focused on collaborative evaluation and development of community services in urban neighborhoods, for people with disabilities, older people, and children; and ANDROID (2012–2015) concerned with promoting interdisciplinarity in disaster research in a European context. Alexandra has published on topics related to interdisciplinarity and community engagement. She was senior postdoctoral researcher with Imagining2050 (2018–2021) in University College Cork.

Colin Sage holds a PhD in geography from the University of Durham. Colin has worked on the interconnections of food systems, agriculture, environment, and well-being throughout an academic career in Cork, London, and Leeds, supported by field research in Bolivia, Mexico, and Indonesia. More recently, he has focused on urban community food initiatives and was the founding chair of the Cork Food Policy Council. He is the author of *Environment and Food (2012)* and co-editor of five books including *Food System Transformations* (2021) and *Transdisciplinary Perspectives on Transitions to Sustainability* (2017). He is a visiting professor at the American University of Rome and at the University of Gastronomic Sciences, Italy.

James P. Trevelyan is an emeritus professor, engineer, educator, and researcher with 45 years of experience and became a start-up entrepreneur in 2015. He leads Close Comfort, inventing and commercializing energy saving, climate friendly Coolzy personal cooling technology. He taught design, mechatronics, project management, and sustainability at The University of Western Australia. He is best known internationally for pioneering research that resulted in sheep shearing robots and for the first industrial robot that could be remotely operated via the Internet in 1994. He has received international awards for robotics research and engineering education. He also researched landmine clearance methods. In 2002, he was elected a fellow of Engineers Australia and started researching engineering practice, what engineers really do in their work. He built on this research the design of the current Australian stage 2 professional engineering competencies for engineers, technologists, and associates. His 2014 book *The Making of an Expert Engineer* provides, for the first time, a comprehensive research-based understanding of engineering practice in several countries. It explains why engineered products and services are usually far more expensive in developing countries than the industrialized world, which in turn explains why so many people continue to live in stubbornly persistent poverty.

Natalie Wint holds a BSc in physics with medical physics and an engineering doctorate in materials engineering. She is a senior lecturer in the Faculty of Science and Engineering at Swansea University. Natalie has technical expertise in the field of corrosion and coatings, and her research career to date has primarily been focused on industrial issues. In recent years, she has become interested in professional engineering skills and the role of engineers within society. She currently supervises two postgraduate research projects that aim to understand the experience of marginalized engineering students.

Patricia Xavier holds a MEng and a PhD in civil engineering. She is Associate Professor of Program Development and Enhancement in the Faculty of Science and Engineering at Swansea University. Patricia spent time working in the water and wastewater industry as a design engineer and was previously involved with Engineers without Borders UK and Engineers for Overseas Development. She teaches conceptual design and a servicelearning course where engineering and social science students are partnered with local and international community

partners. She is the lead of an interdisciplinary pedagogy research group interested in critical scholarship and the intersection of personal and professional value systems in engineering education. Having transitioned away from technical research and been strongly informed by both positive and negative experiences in service learning, Patricia is particularly interested in the conceptual and skill barriers encountered by engineering educators who seek to use contextualized project-based learning with external community stakeholders.

Xu Xin is a doctoral student in the Philosophy of Science and Technology Research Center at Northeastern University (China). She holds a Master of philosophy from Northeastern University (China). She is generally interested in philosophy of technology and ethics of technology.

Lina Zheng is a PhD candidate at the Institute of Education, Tsinghua University, with interests in the international engineering education and educational policy analysis. Her current research portfolio includes studies focused on the "New Engineering" initiative in China, as well as approaches and innovative efforts in multidisciplinary engineering education internationally. She primarily identifies with the mixed methods approaches, with emphasis on quantitative research methods.

Chapter 1
General Introduction: The Rationale for Engaging in Conversations Between Engineering, Social Sciences, and the Humanities

Steen Hyldgaard Christensen, Anders Buch, Eddie Conlon, Christelle Didier, Carl Mitcham, and Mike Murphy

Abstract The title of the book suggests that conversations between engineering, social sciences, and the humanities are important because ultimately the outcome of these conversations would have real world consequences in engineering education and practice. We feel assured that the contributions to this book will, in different ways, assist those who may be thinking about what needs to change or may be trying to implement projects for change in engineering education and practice. In this short introduction we cannot do full justice to the breadth of the contributions in this book. Rather we use it to address some key questions that arise from the contributions. These might provide a frame to help us deepen the conversations or at least begin to ask better questions and develop better approaches about how these conversations can be developed further.

S. H. Christensen (✉)
Department of Development and Planning, Aalborg University, Aalborg, Denmark
e-mail: steenhc@plan.aau.dk

A. Buch
VIA University College, Aarhus, Denmark

Jönköping University, Jönköping, Sweden

E. Conlon
School of Multidisciplinary Technologies, Technological University Dublin, Dublin, Ireland

M. Murphy
Technological University Dublin, Dublin, Ireland

C. Didier
Lille University, Lille, France

C. Mitcham
Renmin University of China, Beijing, China

Colorado School of Mines, Golden, CO, USA

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The title of the book suggests that conversations between engineering, social sciences, and the humanities are important because ultimately the outcome of these conversations would have real world consequences in engineering education and practice. We feel assured that the contributions to this book will, in different ways, assist those who may be thinking about what needs to change or may be trying to implement projects for change in engineering education and practice. In this short introduction we cannot do full justice to the breadth of the contributions in this book. Rather we use it to address some key questions that arise from the contributions. These might provide a frame to help us deepen the conversations or at least begin to ask better questions and develop better approaches about how these conversations can be developed further. These questions are

- Why are the conversations important for engineering, for social sciences, and for the humanities?
- Are there key places in practice, the curriculum, and institutions where the conversations can best develop?
- What are the barriers to successful conversations?
- What proposals can be made for deepening future conversations?
- How would we know that the conversations have come of age, and who gets to decide?

In commencing this book project, we were collectively committed to the idea that work in developing and deepening conversations between the social sciences, humanities (SSH) and engineering was important for engineering practice and education, and that they could both be improved through these conversations. So, throughout there is a concern with broadening the goals of engineering education and practice and identifying the barriers and enablers to achieving the goals. We were also keen to take a wide view of the domain of engineering to embrace the relationships between engineering as a profession, engineering as a field of work, engineering and society, engineering as an academic field and its research practices, engineering education, and finally research about engineering education.

1.1 Why Are These Conversations Important?

In case there is any doubt that the conversations are important, the reader will find affirmations as to their importance across all the chapter contributions and their relationship to the sub-domains listed above. Thus, we learn that that these conversations are important for a variety of reasons:

1. They can help us to better educate engineers to deal with contemporary (un)sustainability challenges and understand why technical change alone is not sufficient to address key societal problems (Chaps. 4, 5, 10, 11, 18, and 19).

2. They can help us to better address challenges in engineering education, sometimes arising from accreditation processes, such as the teaching of ethics (Chaps. 5, 7, 8, 10, and 11).
3. They can allow us to better understand how the work of engineers is changing (Chaps. 6 and 13).
4. They can help us to better understand processes of change in engineering education and why change can be difficult (Chaps. 3, 4, 5, 7, 8, 10, and 15).
5. They can help us to better understand how the institutional contexts where engineering education and practice take place are changing (Chaps. 5, 13, 14, and 19).
6. They can help us to better understand what paradigms, models, and often unstated assumptions inform engineering education and practice (Chaps. 5, 7, 15, and 19).
7. They can help us to better research points 1 to 6 above (Chaps. 3, 11, 13, and 15).
8. They can provide us with a range of theoretical tools to understand and inform all the above (Chaps. 8, 9, 11, and 18).

From this it might be concluded that it is only engineering that gets to benefit from the conversations. It might also be concluded that there is something fatally wrong with engineering and engineers which can be fixed by the conversations. Martin and Polmear in Chap. 7 quote Herkert's characterization of engineers to the effect that

> Engineers are no-nonsense problem solvers, guided by scientific rationality and an eye for invention. Efficiency and practicality are the buzzwords. Emotional bias and ungrounded action are anathemas. Give them a problem to solve, specify the boundary conditions, and let them go at it free of external influence (and responsibility). If problems should arise beyond the work bench or factory floor, these are better left to management or politicians (Herkert, 2001).

It might appear then, that the humanities and social sciences are to play a role in providing a "social fix" for engineers. But this overlooks the benefits of the conversations for those working within SSH fields. Perhaps this is stated most directly by Byrne and others in Chap. 19, when they say that, left to its own devices, sociology can often remain within 'problem defining' or 'problem analysis' domains, thus constraining its real, practical and transformative potential. Moreover, exposure of the social scientist to the disciplinary language of engineering, while filling one with different terminologies and acronyms, may also lead to greater awareness and reflection on the density of one's own disciplinary language.

So, what engineers can contribute to these conversations is a focus on problem-solving and, perhaps, an impatience with an arid academicism where, as Anders Buch points out in Chap. 18, academic practices have become overly specialized and esoteric obstructing the transdisciplinary conversations argued for throughout this book.

Buch goes further to argue that the focus on problem solving in engineering gives engineering the potential "to mediate, revitalize, and transform the conversation between the sciences and SSH". But only if it is reconstructed as a problem-solving discipline that seeks to ameliorate living conditions rather than as a discipline of applied science. Such reconstruction concerns the very telos of engineering. As argued at many points in this book such as in Chaps. 5, 8, 18, and 19 a reconstructed engineering discipline would acknowledge that the key societal problems do not

belong to any one domain. A recovered engineering, as Buch puts it, would "not only draw from the sciences and SSH but also contribute to the sciences and SSH by putting these domains in dialogue in relation to solving-problems." Thus, there is much for SSH to gain. But if there is to be progress or even a start in conversations there are some hard issues which need to be addressed.

Firstly, an important theme in the book concerns integration of the social dimension in engineering education and practice. There is both a desire to broaden the education and horizons of engineers. However, as dealt with extensively in Chap. 4, by Patricia Xavier and her colleagues, there seems to be little consensus about what it means to integrate the social into engineering education but there is agreement that, whatever it is, it is poorly integrated. They say that "in some instances, there was a perceived gap between aspiration and pragmatism, which was believed to be driven by surface-level conceptualizations and a lack of deeper understanding". This begs the question as to whether the recovery of engineering proposed by Buch can be achieved from a starting point, which seeks to add the social to the technical in engineering education rather than reconceptualizing engineering education in a manner proposed by Buch and by others such as Jamison et al. (2014). In the latter's integrated approach the curriculum is focused on the development of a hybrid identity and the exercise of social responsibility and includes the "scientific, the technical, the social, and the environmental dimensions of engineering in one comprehensive form of education" (p. 264). This requires in the first instance that we clarify our aims for change in engineering education and practice. To be concise we urgently need clarification as to whether engineering is to be recovered to serve the changing demands of industry and the profession or to serve some wider social purposes. If it is the latter, how are we to achieve the civic and community engagement needed as Byrne and his colleagues put it in Chap. 19 "to make meaningful and authentic progress". This requires considerations of conversations beyond the academy.

Secondly, and arising from this is the question of what intellectual transformations are required to allow our conversations to be meaningful and sustained and lead to the kind of change needed within engineering education and practice and in society more generally. In a cautionary piece Beddoes in Chap. 9 points to the limited use of theory in engineering education research (EER). Beddoes argues that social theory has been mobilised in "narrow and limited ways" limiting the questions asked and the interpretations of findings offered. She points to a marginalisation of more radical approaches such as a range of feminist theorising within the EER community with the effect that "it limits what can be seen, known and understood" and therefore "the possibilities for change are also limited". Thus the status quo remains unchallenged. In a similar vein Conlon in Chap. 11 following Bhaskar calls for *depth struggle* in which learning about and changing the world are combined. Marie Magnell in Chap. 15 argues for deeper understanding in addressing issues of change in engineering education. Mike Klassen and his co-authors in Chap. 3 offer a comparative analysis of the institutionalization of EER in Australia, China, and the US by drawing on *neo-institutionalism*. The benefit of this framework is that it represents a new perspective on the growth of EER in looking for less obvious explanations of organizational behavior.

The issue arises as to how a shared language can be developed to allow those in engineering to engage more fully in *a depth struggle* and move beyond a superficial approach to the "social". It might be suggested that a good place to start would be, as Cheville suggests in Chap. 5, to acknowledge that a simple binary approach to understanding the different sides of the conversation as two "immiscible cultures" is not always accurate. As Magnell in Chap. 15 and Børsen in Chap. 8 show there are a range of sub-cultures within engineering and the SSH. Further, there is an emergent set of issues such as social justice, sustainability, and ethics (Chaps. 5, 7, 8, 10, 11, 18, and 19) which can serve to create connections between engineering and SSH. In this context a focus on what Børsen in Chap. 8 calls *boundary objects* and the way in which "different epistemic cultures can come together to form a shared *modus operandi*" seems important.

This leads us then to some specifics.

1.2 Where Are the Best Places/Arenas for These Conversations to Develop?

Conversations between professionals and the public occur all the time, but with very different degrees of intensity, eagerness, and productive outcomes. Whether such conversations bring people closer together, result in joint action, unilateral action (perhaps based on shared understandings) or rather distance them from one another has to do with the specificities of the social spaces, physical and institutional places, and interactional structures.

Engineering and SSH comprise intellectual traditions and social practices that have evolved along different paths over centuries and gradually coalesced into academic disciplines, professions, and other institutional markers of difference. Can paths be changed, and is it possible to identify venues that have importance for a revitalization of the conversations between engineering, the social sciences, and the humanities? In the C.P. Snow narrative of the two cultures, Cheville, in Chap. 5, outlines how the process of differentiation between engineering and SSH has resulted in the binary conception of two worldviews that have very little in common. From a very early stage the educational system channels people into two separate camps constructed through an epistemological duality:

> One possibility is teaching engineering as an increasingly rational and empirical discipline that dives deeper and deeper into technology, focusing on objective truths to drive economic development. The other possibility is for engineering education to recognize that we increasingly live in a built social world in which technology has become an integral part of all our inter-subjective and inter-objective reality.

Cheville points to engineering education, but there are also other arenas that are central for framing the conversations. The institutional organization of educational and research institutions is one of them. Other arenas comprise engineering work practices and professional aspirations outside academia – in industry and more

broadly the way engineering is envisioned to contribute to society. All these arenas seem to be interlinked in what Abbott (2005) has called ecologies – each arena acts as a flexible surround for the other. This means that conversations in one arena have potential for affecting conversations in other arenas. But it also means that the development of conversations in one arena are not automatically adopted in other arenas (Buch, 2016). New conversations in one arena can in fact be 'suffocated' or ignored in other arenas. Many authors of this book point to examples where conversations between engineering and SSH have started to develop in promising ways.

As mentioned, Børsen's Chap. 8 explores how different sub-cultures within engineering and SSH engage in conversations. Børsen outlines how such conversations have been stimulated by the development of an educational program in techno-anthropology in Denmark. This is a case of how scholars and educators from SSH have found their way into engineering departments and influenced the engineering curriculum to include perspectives from History and Philosophy of Science (HPS) as well as from Science and Technology Studies (STS). Here the socio-technical perspective of the techno-anthropology program has been developed through comprehensive negotiations between representatives from research groups coming from engineering and the humanities.

Likewise, Bucciarelli and Drew in Chap. 12 are preoccupied with the educational arena as they discuss and critique how a recent report from The National Academies of Science, Engineering, and Medicine – the NASEM report – construes interdisciplinary program development in higher education. Their point is that the challenges of interdisciplinary program development often are glossed over and trivialized by sweeping metaphors suggesting that an integration can be achieved without dissonance. Instead, they argue, it is important to attend to the dissonances to enable students to critically access the different ways of thinking inherited in the traditions of engineering and SSH. They thus point to the fact that the educational arena is closely linked to prevalent research traditions in the university and work practices in industry.

In Chap. 11 Conlon zooms in on one of the key points that have brought SSH in dialogue with engineering, namely engineering ethics. However, he argues, the dialogue over ethics in engineering education tends to be simplistic and based on dubious presumptions about individuals' capacities for moral agency that do not reflect the potentials of social theory developed by some approaches within SSH. Conlon thus points out that ethics education in engineering programs remains insufficient if it does not consider how ethical responsibility is restrained and enabled by the social structures that frame the context.

Other authors turn to the arena of engineering work practices to explore conversations. Cynthia Colmellere's Chap. 6 explores how the field of engineering studies have brought philosophy, history, STS, the sociology of professions, and the sociology of education in dialogue with the engineering field. James Trevelyan in Chap. 13 further discusses how engineering practices have been uncovered as workplace performances by SSH scholars, but that prospects of engineering advances in raising productivity of enterprises and economic development needs more attention and bear the potential for new SSH research.

In Chap. 19, Byrne and his co-authors address the wider arenas that appear as both engineers and SSH scholars partner up with one another to engage with actors outside academia. Pressing agendas of (un)sustainability and climate crises, they argue, are challenges that call for 'disciplinary humility' and addressing these challenges stimulates interdisciplinary conversations.

Many arenas thus bear the potential for fruitful conversations to develop, but it must be recognized that these arenas also are fraught with barriers that can easily obstruct successful conversations.

1.3 What Are the Barriers to Successful Conversations?

Being collectively committed to proposing a new vision and re-build strategy of what engineering education could/should be through ESSH conversations, the editors are acutely aware that there are many obstacles and barriers to overcome. Our vision following Ronald Barnett's terminology is termed the ecological university (Chap. 4; Jamison et al., 2014; Barnett, 2011; Martin et al., 2021) branching out also into other areas of engineering concerned with sustainability and ecology. Obstacles and barriers to change are located at individual, institutional, policy, and cultural levels.

At the individual level the editors have experienced barriers partly through their own work as instructors and partly through their research within the fields of engineering education and engineering ethics. At this level the editors are also aware of and have personally experienced how the prevalent neoliberal economic paradigm puts pressure on higher education generally and intensely on engineering education to promote STEM fields using a pipeline metaphor as opposed to engineering education as a complex ecosystem. As Cheville puts it in Chap. 5 "pipelines need to be managed and fixed while ecosystems need to be protected and nurtured". Hence, metaphors play a crucial role in change processes both to promote or prevent. Many instructors in engineering ethics have backgrounds in the humanities and the social sciences and an academic track record of research within the field. They consider engineering ethics as a seamless part of engineering epistemology and therefore also of engineering degree programs. However, issues arising from the discursive enactment of engineering ethics and related initiatives such as inclusion of social justice are reported in Chaps. 4, 7, 10, 11, 13, and 15.

These chapters show that conversations between engineers, social scientists, and scholars from the humanities are deficient in many ways. Historically, it was during the 1970s that the social dimension of engineering came to be represented by engineering ethics. Prior to this, engineering science disciplines were regarded as morally neutral or even as morally good (Martin et al., 2021, p. 60). In Chap. 4 Patricia Xavier and her co-authors discuss various strategies to implement engineering ethics. They emphasize that the prevalent strategy in the UK is an add-on strategy of engineering ethics whereby a component or module is added without changing the remaining curricular structure. Xavier and her colleagues have found that a major

challenge to change in engineering education is that there is evidence that engineering ethics is undervalued, and that instructors did not always find their work appreciated and often felt resistance from their engineering colleagues. This is echoed in Chap. 7 by Martin and Polmear who present similar findings from two studies conducted separately within the Irish and American system of engineering education.

Trevelyan's Chap. 13 identifies four significant engineering performance issues that impede global and economic development. These factors are associated with weaknesses in engineering education and practice. He notes that "insights from social science and humanities research might inform education and practice improvements to alleviate these issues and, in doing so, have a large and positive influence on social and economic development and sustainability, globally".

Discursive enactments of the "social" also become visible in Chap. 10. In this chapter Murphy, Christensen, and Conlon have examined whether social justice issues would be relevant at an Irish technological university. In interviews with four engineering program chairs the "social" was discursively enacted as a "soft" discipline as opposed to engineering which was enacted as a "hard". Their study identified four barriers to change in engineering education, which was believed to be of a general nature and thus also valid in other institutions. These are:

1. Defining and defending engineering identities as rooted in engineering science.
2. Defining and defending the hard/soft engineering disciplinary dualism.
3. The valuing of some forms of non-technical knowledge while also seeing these as of lesser value than technical knowledge. The value of some forms of non-technical knowledge is questioned.
4. The prevalence of a narrow conception of engineering ethics limited to a code of conduct.

However, what should have been, but is not necessarily achieved at an institutional level through the above conversations is succinctly put in Chap. 5 by Cheville saying "engineering needs the perspectives of the social sciences and the humanities, not as something for our use and convenience, but rather to help us define our values". He further observes in a section titled *Institutions – Design and Making as a Home for non-STEM* that "Engineers need to take responsibility not only for navigating to other disciplines, but also to create spaces within engineering where other disciplines are welcome". The editors agree but have doubts as to what extent it is happening. However, his observation aligns well with Buch's call for a recovery of engineering in Chap. 18. In contrast to this call for recovery, Martin and Polmear in Chap. 7 present the prevalent historical model of engineering education in need of change. This model functions as a barrier for change in being characterized by a tight packed curriculum focused on math and engineering science fields leaving little room for inclusion of the social dimension of engineering.

At the policy level accreditation has served as a lever for including ethics in engineering curricula, but there are doubts that the pressure from accreditation criteria can inform deeper curricular change (Martin et al., 2021, pp. 59–60).