



FALL 2021

## Overview - Special Issue on Worldwide Leading Innovative Engineering Education Programs

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### INTRODUCTION

The world is changing, and the rise of interdisciplinary and collaborative approaches in solving global challenges is attracting a broader and more diverse set of students who see engineering as a powerful force in these efforts. As a community, engineering educators recognize that transforming educational experiences is crucial both to meet global needs and to increase access for all capable future engineers. As guest editors of this special issue of *Advances in Engineering Education*, we have been energized by the consistent and strong focus on innovation and student-focused learning throughout all the papers, and struck by the creative and distinct approaches different programs and institutions have developed to achieve this in their own contexts.

Contributors to this special issue include authors from a set of institutions recently recognized as global leaders in undergraduate engineering education. Collectively, this is a group of sixteen institutions who have found, identified, or built pathways to sustainable innovation in engineering education. Some of these institutions found pathways within existing structures or cultures and others built these pathways within new systems and cultures. The institutions represented in this special issue provide some compelling examples but represent in no way a complete list of the programs and institutions who are driving student-centered innovation in engineering education. The articles are snapshots of the innovation the institutions represent, sometimes motivated by the burning questions of the authors, and sometimes motivated by the opportunity to get a program or institution's "big picture" on paper. We invite you to consider these stories of change and transformation as you walk your own path of innovation in engineering education.



### WHY THESE INSTITUTIONS?

In the summer of 2016, the Dean of Engineering at the Massachusetts Institute of Technology (MIT) chartered the New Engineering Education Transformation (NEET) program with the goal of building on MIT's strong foundation to focus on new machines and systems – defined as machines and systems that are complex, highly networked and part of larger systems of systems, have higher levels of autonomy, and are supportive of a sustainable environment (e.g., internet of things, bio-devices, infrastructure, and the environment). NEET was formally launched in fall 2016, with the first phase focused on gathering evidence and input from stakeholders. In January 2017, as part of this phase, NEET commissioned Ruth Graham for a benchmarking study on [“The Global State of the Art in Engineering Education”](#) as described in her framing article for this issue.

The study identified a total of sixteen institutions as emerging and current leaders in undergraduate engineering education, including, in alphabetical order: Aalborg University (Denmark), Arizona State University (United States), Cambridge University (UK), Chalmers University (Sweden), Charles Sturt University (Australia), Iron Range Engineering of Minnesota State University, Mankato (United States), Massachusetts Institute of Technology (United States), National University of Singapore (Singapore), Olin College of Engineering (United States), Pontifical University of Chile (Chile), Purdue University (United States), Singapore University of Technology and Design (Singapore), Stanford University (United States), Delft University of Technology (Netherlands), Tsinghua University (China) and University College London (UK).

The release of this benchmarking report in March 2018 triggered conversation across the globe. The sixteen institutions identified were interested in exploring how this interest could be converted to sustainable engagement among these institutions and beyond. There had already been many informal and formal collaborations and communications between these institutions and a sense that there were common paths to be tread going forward. This led to the organization of an event that could serve as the first step in a deliberate series of future activities that not only impact and transform engineering education in each institution but also influence the global state of engineering education.

MIT and Olin College jointly convened a first-of-its kind Colloquium on the Global State of the Art in Engineering Education on April 29–30, 2019, with participants drawn from the sixteen institutions to explore and concretize the opportunity. The goals of this colloquium were to form a community framework through which these institutions could engage with each other in a sustainable way going forward, and to begin to imagine a larger community beyond these institutions with a goal of positively affecting the global state of engineering education. The colloquium was designed to foster connection, collaboration, and joint exploration of challenges, engage change agents at all



levels (including students), and to support deep personal exchange among the participants. There were over 96 participants from the sixteen schools at the first colloquium, held at the MIT campus in Cambridge, MA and at the Olin College campus in Needham, MA. They included presidents, provosts, department heads, faculty, academic staff, and students. Several clear themes emerged among the participants and were used to drive collaboration and conversation, and included:

- Sustainable development goals, social responsibility, and the grand challenges
- Student-centeredness, motivation, empowering students
- Personal learning tracks and continuing education
- Broad competencies, interdisciplinarity, complexity
- Faculty development, and faculty engagement in educational change

In response to the strong interest in engagement and collaboration, three of the institutions (University College London, Aalborg University and TU Delft), held a second virtual colloquium November 30 - December 4, 2020. Using the emergent themes from the first colloquium, participants shared related institutional initiatives, and, in particular, laid out some of the change models and strategies that helped lead to sustainable change in their programs. Across four sessions, shifting in time to accommodate the diverse range of time-zones represented, over 90 attendees took part in presentations and themed breakout sessions. The participants included students, faculty, academic staff, program leads and senior university leaders.

Colloquium participants were invited to participate in this special issue of *Advances in Engineering Education*. The purpose of the special issue is to develop and publish a set of short peer-reviewed papers that highlight achievements of these sixteen institutions as well as some of their learnings, and articulate future directions, with a planned future issue disseminating the deliberations and collaborations of the colloquia in order to broaden the reach of the ideas. An invitation to authors was sent out by *AEE* leadership in March 2019, just prior to the first colloquium and papers were updated and revised during the last 18 months. As the invited institutions were affected by the pandemic, we and our colleagues around the world became overwhelmed by the emergency pivot to online or distance learning which pushed our publication date later than planned. We are grateful to all our contributors who made time and space in an unusual year to share these innovations with the engineering education community.

### **WHY THESE ARTICLES?**

Change and innovation occur in many forms and at many levels. All these institutions are self-identified as student-centered, but the way in which this manifests itself looks different in different



contexts. These articles present a range of perspectives and distinct approaches that center the design of engineering education programs around student needs.

Some look at large-scale institutional endeavors and the challenge of institutional change, e.g., Arizona State University (McKenna and colleagues). Some look at components of their programs and how they address a particular concept, e.g., entrepreneurship at the National University of Singapore (Loh and colleagues) and Pontifical University of Chile (Hiliger and colleagues), or ethics at TU Delft (Van Grunsven and colleagues) or across multiple institutions with the same framework (Collofello and colleagues). One looks at faculty development and assessment at Olin College (Martello and colleagues), a particular issue that has been a challenge over time in how innovative pedagogies are implemented and sustained at many institutions. Chalmers University of Technology (Karlsson-Bengtsson and colleagues) has institutionalized the inclusion of the student voice through the creation of a powerful student union, mandatory for all students to join. The student union is the formal link between the administration and the student body and allows for strong advocacy for student needs and “ensures that students can safeguard their personal and collective rights.” This approach brings students to the table in a formal way.

Another approach that several institutions describe is creating student agency by allowing self-design of a degree program or educational path. A compelling example is described in the Purdue University submission (Adams and colleagues) where for the last 50 years, students in the Interdisciplinary Engineering program (now the Multidisciplinary Engineering program, or MDE) can self-design an engineering program or choose from programs that students before them have developed. In some cases, these paths are formalized into new programs available for incoming students. This program and approach have allowed for new disciplines to emerge as an ultimate result of the increased student autonomy to self-design paths and led to institutional commitment and resources for these new disciplines. Singapore University of Technology and Design is a younger example of a program moving away from traditional disciplines and focusing on “pillars” of engineering as needed in industry, i.e., product, systems, and services.

Even within an established degree program, providing students an optional program to broaden and deepen their engineering education allows for increased student choice and the autonomy to shape their education. This approach is described well by the MIT NEET program (Lavi and colleagues) which has seen increasing enrollment over the last four years in a voluntary certificate program that students pursue in parallel with their majors, a program that is designed to educate young engineers to build the new machines and systems that will address the societal needs of the 21st century. The NEET program has attracted more women and underrepresented minorities when compared with average representation across MIT.

There are multiple other approaches to building a student-centered engineering education highlighted in these papers, several of which create time and space for students to develop and attain their



own learning goals within a class or module. The ongoing and robust application of project-based learning requires ceding some control to the student, and the papers from the University College London (Hailes and colleagues) and Aalborg University (Bertel and colleagues) both emphasize the benefits of PBL (problem based) and PjBL (project based) approaches to student learning. Charles Sturt University (Morgan and colleagues) designed the engineering program around a self-directed, just-in-time philosophy where students access and engage with online learning modules covering the underlying technical curriculum as and when they need them, in support of the project-based portion of the curriculum.

Stanford University (Sheppard and colleagues) describe an approach that focused on the shape of the student experience first. They acknowledge the ways in which degree programs must adapt to better serve students (and articulate some of the challenges and trade-offs associated with that approach). Iron Range Engineering (Ulseth and colleagues) consider ways to support student engineers who may not be easily served by traditional programs, providing project-based and industry co-op experiences as a means to increase access for more students.

It is clear from our experiences that no one recipe for change works in all settings. It is also clear that there are many challenges to be grappled with as institutions and programs work to align their vision of a student-centered education with the realities of academia. These examples, curated from the papers in this special issue, are not an exhaustive review, but rather provide glimpses of the myriad of ways that a set of institutions can participate in educational innovation.

### **AN INVITATION**

Participating in a community of innovators does not require recognition in a report or study, although that has allowed some emerging institutions to be a part of these formal conversations. The scope of our challenges, whether it is addressing sustainability and other global challenges or whether it is inclusively training student engineers to be able to address all aspects of their future roles, requires that the collaborations and conversations continue beyond the colloquia described here and include institutions beyond those included here. The stories highlighted in these articles are meant to be a starting point, illustrations of innovation in particular contexts that incorporated evidence of what works and then adapted or developed the innovation for those contexts. We invite you to learn from this (incomplete) set of examples, to share your stories, to be a part of the conversation, and to reach out to other innovative educators for motivation, inspiration, intellectual sustenance, and practical support. The pandemic experience has shown us that we can come together even when resources are tight. While we hope there will be a third colloquium, there will



also be branches of these conversations continuing at a variety of conferences (SEFI, FIE, ASEE and others). We hope you will take part or start your own conversation.

### **ACKNOWLEDGEMENTS**

We want to thank the ASEE and *Advances in Engineering Education* for publishing this special issue highlighting the work of these institutions, and also want to give special thanks and deep appreciation to Larry Shuman, Founding Editor of *Advances in Engineering Education*, for expertly shepherding the special issue, and for creating and fostering a space for sharing stories of innovation in engineering education.

We want to acknowledge the many people who have participated in the colloquia, beyond the authors of these papers. While the authors were frequently members of faculty, program directors, and deans, the colloquia conversations included many more perspectives. We thank the following colloquia participants: Robin Adams, Nathaniel Agharese, Maggie Anderson, Lourdes Andrade, Ricky Ang, Inger Askehave, Gabriel Aspegrén, Jorge Baier, Birgitte Bak-Jensen, Terkil Bak-Jensen, Rebecca Bates, Mark Bathe, Lykke Bertel, Mary Besterfield-Sacre, Mattias Bingerud, Jörgen Blennow, Malin Blomqvist, Sharon Breitbart, Andrew Brightman, Lykke Brogaard Bertel, Henrik Brohus, Aaron Budge, Markus Buehler, Tom Byers, Annoesjka Cabo, Shara Cameron, Roberto Cavallo, Allan Chan, Patricia Chane, Tow-Chong Chong, Shreya Chowdhary, Rebecca Christianson, Tom Cock, James Collofello, Ed Crawley, Jennifer DeBoer, Neelke Doorn, Allen Downey, Mikael Enelund, Olav Geil, Chris Gerdes, Beverley Gibbs, Allison Godwin, Jeff Goldenson, Carl Gombrich, Siddhantan Govindasamy, Erhardt Graeff, Ruth Graham, Roger Hadgraft, Steve Hailes, Daniel Hastings, Hans Hellendoorn, Kristina Henricson Briggs, Anette (Peko) Hosoi, Patrik Höstmad, Geert-Jan Houben, Arynn Isaacson, Leah Jamieson, Bart Johnson, Liz Jones, Shawn Jordan, Alexandre Kabla, Aldert Kamp, Christine Kennedy, Maria Knutson Wedel, Gabrielle Koepke, Edwin Koh, Anette Kolmos, Sacha Kroonenberg, Wei Lek Kwan, Tove Larsson, Rea Lavi, Elliot Law, Christina Lim, She-Chun Lim, Jian Lin, Euan Lindsay, John Liu, Timothy Liu, Ai Poh Loh, David Lowe, Ulrika Lundqvist, Reza Mahinroosta, William Maki, Robert Martello, Brian Martensen, Brooke Martin, Lindy Mayled, Ann McKenna, Joris Melkert, Martina Micheletti, Richard Miller, John Mitchell, Amitava (Babi) Mitra, Jim Morgan, Robert Mudde, Chika Nweke, Abel Nyamapfene, Luke Nyberg, William Oakes, Nis Ovesen, Aart Oxenaar, Elizabeth Pearson, Mar Pérez-Sanagustín, Kin Leong Pey, Weifeng Qiao, Judy Raper, Donna Riley, Kate Roach, Paige Rudin, Thomas Ryberg, Mehran Sahami, Sheri Sheppard, Marcus Specht, Sarah Spence Adams, Kyle Squires, Lynn Andrea Stein, Jakob Stoustrup, Peng Su, Mike Sutcliffe, Emanuela Tilley, Jessica Townsend, Fiona Truscott,



Ron Ulseth, Linda Vanasupa, David Webb, Kevin Win, Alison Wood, Lihui Xu, Larry Yung, and Yevgeniya (Zhenya) Zastavker.

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**Amitava 'Babi' Mitra** is the founding Executive Director, New Engineering Education Transformation (NEET) at the Massachusetts Institute of Technology, an initiative that was launched in 2017 to reimagine and transform MIT's undergraduate engineering education. What he enjoys doing most is visioning, designing, setting up and operationalizing innovative 'start-up' educational initiatives. Dr. Mitra has over twenty-five years' experience in institution building, higher education, corporate e-learning, and distance education. As Senior Vice-President, Knowledge Solutions Business, NIIT, Inc., Atlanta, he led the development

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**Jessica Townsend** is a Professor of Engineering at Olin College, where she served as Interim Academic Vice President for External Engagement, Associate Provost, Associate Dean for Curriculum and Academic Programs, and Associate Dean for External Engagement. Since joining the Olin College faculty in 2004, Dr. Townsend has worked as a facilitator and consultant with universities and professional organizations looking to improve engineering student engagement. In her roles at Olin, she had oversight of institutional-level strategy for Olin's external educational change mission and contributed to the development of innovative pedagogies, courses, and curricula at Olin College. Her technical area of interest is experimental thermal-fluids and she worked for many years on the development and characterization of nanofluids (colloidal suspensions of nanoparticles). Dr. Townsend has industry experience in both air-breathing propulsion, as a gas turbine performance engineer at Hamilton Sundstrand Power Systems, and in rocket propulsion, as a visiting engineer at Blue Origin, a commercial spaceflight company based in Seattle, WA.