

Expanding Engineering Limits—A Concept for Socially Responsible Education of Engineers*

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Given changing demographics among engineers and engineering students, increasing international teamwork, and growing awareness of the ways in which cultural and cognitive biases may impinge on engineering problem-solving to reach optimal solutions, *can a course providing an opportunity to learn about culture and diversity benefit engineers' training?* In 2015, the inaugural Expanding Engineering Limits course was offered to undergraduate and graduate students as a transnational course between Stanford University in the United States and RWTH Aachen University in Germany. The course was designed to introduce students to a variety of terms, concepts, and paradigms that could deepen their understanding of culture and diversity in engineering education and practice. In addition to classroom lectures, students from both RWTH Aachen University and Stanford University participated in a Design Thinking course developed by the two teams and realized at Stanford's Hasso Plattner Institute of Design and worked on group projects throughout the academic term, examining organizational and cultural change in transnational teams. Instructors employed several qualitative and quantitative course evaluation methods, including pre- and post-surveys to measure student change in key attitudinal domains, short in-class reflections and questionnaires to solicit student feedback, institution-level course evaluation forms, and data from students' final projects. Overall, results from these evaluation techniques indicated that the course informed students' thinking and knowledge about the importance of diversity and culture in engineering. Students saw the experiences of working together in a transnational project team as very beneficial for the understanding of cultures and diversity in a professional context. Evaluation findings suggest that the course's intended goals were met to a substantial degree. We propose that a course-based experience such as this one *can* benefit an engineer's training, and share recommendations and "lessons learned" for engineering educators and leaders.

Keywords: engineering education; design thinking; diversity; gender; social responsibility; interculturality; international cooperation; intersectionality

1. Introduction

Engineers design solutions with and for people—people who come from a wide variety of cultural backgrounds, with many different and intersectional identities based on gender, ethnicity, race, religion, sexual orientation, socioeconomic background, and more. And they increasingly work within interdisciplinary teams and across cultures to develop, adapt, and deploy technologies that consider today's societal challenges [1–4]. If they have not had learning experiences that focus on

dimensions of human diversity, however, engineers are more likely to fall back on stereotypes and personal frames of reference that can limit the scope and quality of their work [5].

Unfortunately engineering students around the world have few opportunities to learn about diversity in the context of engineering. Required engineering curricula focus primarily on mastering knowledge and skills in areas of mathematics and sciences, and a set of technical methods and skills to enable students to solve many types of technical problems [1, 6, 7]. Those skills have been in high

demand worldwide for decades, with attendant policy interests in “workforce development” [8]. Increasingly, government agencies, companies and organizations are proactively making training and procedures related to cultural aspects of engineering practice and research part of their portfolios; emerging pedagogical and curricular strategies and recommendations also reflect this trend (e.g., Design Thinking, User-centered Design, Ethical Principles of Engineering Profession defined by the Association of German Engineers (VDI)). Such interests are often mirrored by individual engineering students who frequently are perplexed that their classes are not more diverse, who are eager to abandon vestiges of past history of exclusion of certain groups from engineering, and who often wrestle with interpreting their own experiences, or those of their classmates, in the context of an engineering culture that changes more slowly than its constituent groups [9].

In response, technical universities and schools/colleges of engineering are starting to develop various approaches to engage engineering students in learning about culture and diversity within technical contexts. This paper describes one such approach: the pilot year of an elective course titled “Expanding Engineering Limits: Culture, Diversity, and Gender”, developed jointly between RWTH Aachen University in Germany and Stanford University in the United States, and offered simultaneously in fall 2015 through classrooms joined by technology. The course was designed to bring social science research on culture, diversity, and gender to the engineering curriculum in a focused, intentional manner, and presents a model that could be adapted in engineering programs around the world, with prospective benefits to students, institutions, and the engineering profession.

In this paper, we share the conceptual foundations of the course, its various pedagogical components, its implementation in its first trial run, and what instructors and students learned as a result of developing and offering the course. We consider whether the course met its ambitions for students’ learning, “lessons learned” as teachers of the course, and recommendations for others who might seek to develop such courses in the future.

2. Conceptual foundation

The driving rationale for this course stands on two key assertions: (Assertion 1) considerations of “societal context to technical work” and “diversity of people” are not systematically included in engineering education worldwide; and (Assertion 2) in order for engineering education to address today’s challenges most effectively, “context” and

“diversity” need to be more strongly incorporated into the engineering curriculum. Before we elaborate on each assertion, however, we share our organizing terminology. These terms and definitions are core ideas embedded in our course architecture (as outlined in Section 3). Rather than only providing students with such terms and definitions explicitly, our course invites students to develop insights into these ideas, and form their own understandings.

2.1 Terminology

For the purpose of our course, we define “context” as the cultural, social, economic, and political dimensions of technical design and problem solving. We define “diversity” as (at least) a two-part concept: (Concept A) Broad heterogeneity in social identities and statuses represented among individuals in a shared engineering experience, with particular attention to heterogeneity of identity and status on the basis of gender, ethnicity, race, religion, sexual orientation, socioeconomic resources, and related dimensions that afford more or less power and perceived competence/legitimacy in engineering interactions and organizations; and (Concept B) Environments that *actively, equitably, and transformatively* engage individuals who have different degrees of access to status, power, and resources on the basis of their group memberships and widely shared cultural beliefs about those groups [see 10–13]. Our approach to “diversity” has a practical element, recognizing organizational management literature that investigates team diversity as a (potentially highly productive) function of myriad human dimensions (e.g., [14]). It also has a distinct critical sociological and social-psychological element, seeing diversity as transformative interactions within and against existing inequalities and negative group stereotypes (see [15] for deeper discussion of factors that mediate interaction and knowledge shared in diverse groups). Gender is a focal point of diversity in our course, as it is a long-standing marker of homogeneity in engineering communities, and a major source of stratification and inequality across most societies over time [11]. But gender as a monolith is simplistic. We urge greater emphasis on gender *alongside* race/ethnicity and socioeconomic class as major *intersecting* frames through which to see power and privilege in engineering, keeping intersectionality at the forefront of our thinking about how the course content was delivered in our pilot year and should evolve in the future (guided by such cornerstone texts and applications as [16–19]).

In our course framework, diversity in engineering depends on the cultural context of engineering, just

as engineering cultures emerge from diverse (or non-diverse) environments, historical backgrounds, and habits of behavior [20]. “Culture”, or shared ways of thinking, values, and symbols, exists in the overlapping realms of ideas, interactions, institutions, and the self [21], influences expectations and behaviors (e.g., [22, 23]), and shapes individuals’ social realities “by transmitting beliefs, knowledge, and standards between people and over time” [24]. Culture and diversity are dynamic synergistic entities, both of which condition engineering knowledge and output. This very course is developed in a specific historical engineering moment and designed to address what we see as a complex engineering problem of our day: that of culturally produced limitations to who can be an engineer and what engineering can accomplish.

2.2 Assertion 1: Context and diversity are not systematically included in engineering education

Having established our terminology, the first assertion driving this course rests on a contradiction: although engineering is fundamentally a social enterprise, now more than ever involving distributed work across multiple sites and global teams [2, 7, 25–27] the dominant “engineering identity” is a technical one [27]. Social dimensions of engineering practice can be actively downplayed or minimized in order to preserve the status (quo) of the profession [28]. Engineering education can reinforce the exclusivity of technical talent and skills in several ways: productive teamwork in classrooms is often incidental and is not tied to any particular content knowledge being taught [29]; assignments do not routinely integrate ethical, political, and/or economic dimensions into the bounded “right answer vs. wrong answer” technical problems being presented [2, 30]; and the cultural context of technical problems is especially ill-defined or under-discussed [1, 31].

Engineering disciplines themselves have distinctive cultures, which, in many Western parts of the world, have been cultivated primarily by white men, and, over time, men from middle- and upper-middle class backgrounds (e.g., [32]). Local, hands-on, lived knowledge of materials, resources, tools, and people has not readily found a home in the dominant contemporary engineering canon [32]. The gradual professionalization of engineering in the West over two centuries is still influenced by its origins in military organizations that actively excluded whole groups of persons. A system that did not include women, was late in integrating people of color, and still is working through consideration of individuals with gender-nonconforming identities led to engineering cultures that were male-dominated, largely white, and slow to change, with persistent tradi-

tional institutional structures, curricular content, and pedagogies. The cultures of engineering and its manifestation in education and workforce development have been on a collision course in recent decades as demographic changes, increased labor demand, activism, and new laws supporting civil rights and equal opportunity have brought greater diversity to the general labor market [1, 17, 33–36]. However, to our knowledge, few engineering students formally engage in “culture-mapping” of their own engineering majors. Engineering education does not offer students many opportunities for reflection or discourse on the cultural parameters of engineering itself. The transformative engagement of different social identities, statuses, and groups that is constitutive of diversity (Concepts A and B, as described above) are to be explored in other parts of a student’s education, not in the realm of technical problem-solving. Whiteness and maleness in (western) engineering and engineering education research are defaults even as they are increasingly questioned by faculty, policymakers, and students themselves (e.g., [37])

2.3 Assertion 2: Challenges require more systematic inclusion of context and diversity

The second assertion acts on the first: *the “grandest” challenges facing even the most technical engineers today are ones that require transformative social interactions around often scarce or underdeveloped resources.* A few of these global challenges outlined by the National Academy of Engineering (NAE) (2016) in the United States include: provide access to clean water; improve urban infrastructure; engineer better medicines; prevent nuclear terror [38]. In 2013, the U.S. National Academy of Sciences (NAS) and acatech (Deutsche Akademie der Technikwissenschaften, established as the German Academy of Science and Engineering) organized the first conference discussing “Meeting Global Challenges: German—U.S. Innovation Policy” to build international dialogue and exchange. International Academies of Engineering (IAE) are addressing global challenges worldwide, as is CDIO (<http://www.cdio.org/>), which is a worldwide collaborative network of engineering schools focused on a shared premise that engineering graduates should be able to “Conceive—Design—Implement—Operate” complex value-added engineering systems in a modern team-based engineering environment to create systems and products. For engineers (and their non-engineering colleagues) to make significant progress on these global problems and in these global arenas, a deeper engagement with cultural dimensions of existing conditions, and cultural dimensions that could help to catalyze change, is arguably critical. Moreover, these problems simply

do not exist in isolation of differential power and status of people in the world, nor are they optimally solvable with only one set of perspectives and privileges represented at the table. An educational imperative is to provide students with meaningful examples of how diversity really works if the challenges are to be taken on in full.

In fact we see many examples of engineering work that benefits from consideration of context and diversity. For example, the international project “Gendered Innovations” [39] illuminates major engineering advances when “sex” and “gender” are factored into the earliest stages of the research process, i.e., the very questions being asked (see <http://genderedinnovations.stanford.edu/>). We see many examples of engineering work that fails from a lack of consideration of context and diversity—racist algorithms and product features are among the more blatant outcomes of such failure (see [40]).

In postsecondary education settings, there *is* a groundswell of effort to provide engineering students with formal and informal opportunities to deepen their insights into the relationships between culture, diversity, and engineering. Approaches vary in terms of the primary foci they address (such as “culture”, “leadership”, “professional development”, “gender”, etc.) and how strongly they connect with engineering curricula. For example, co-curricular experiences such as study abroad programs represent one means by which engineering students can develop insights into the cultural dimensions of engineering work and intercultural communication. However, in the United States, some 22% of engineering students are able to study abroad [41]; and 30% of all German students had a study-related stay abroad experience [42].

Other approaches target undergraduate and graduate-level curricula, ranging from (voluntary) courses in arts and humanities to a tailor-made obligatory course integrated into the engineering curriculum [1, 43–45].

Moreover, the majority of existing courses are offered from social science institutes and departments (partially open to engineering students) and are not embedded in engineering institutions themselves. Such a curricular approach, where engineering students are encouraged or even required to take a course in, for example, gender, ethnic, or disability studies, may fail to communicate to the students a deep understanding of the *interrelations* among the associated concepts, theories, and principles and engineering work [2].

2.4 The charge of expanding engineering limits

Thus, on these foundations, Expanding Engineering Limits (EEL)—a course located in the faculty of engineering at a German technical university

(RWTH Aachen) and a school of engineering at a U.S. research university (Stanford)—set out to examine culture, diversity and gender in the context of engineering in both school and work environments, and to consider the implications of how greater consideration of human diversity might benefit both engineers and the solutions, products, and services they (co-)develop with and for others. Moreover, the pilot version of the course undertook this kind of examination in an international setting, in which the course was designed *jointly* by RWTH Aachen and Stanford instructional teams (Aachen had already developed national prototypes—see [1]). In designing the course, the team considered:

- concepts of gender, diversity and culture, and how they interrelate,
- how these concepts fundamentally frame (and limit) what “engineering” is, and
- how to question and challenge that fundamental framing.

The balance of this paper is devoted to a full description of the pilot course as well as a discussion of new directions and adaptations in the future.

3. Course framework

We translated the ideas in Section 2 into three Learning Objectives [46] for the pilot course. More specifically, by the end of the course, students should be able to:

- (1) Identify and analyze the interdependencies of gender and engineering, using a variety of methods.
- (2) Analyze one particular method in engineering (e.g., Design Thinking), from gender and cultural perspectives, and make recommendations on process improvements.
- (3) Envision new engineering processes, practices, and cultures that reflect new or expanded perspectives on gender and sex, and other aspects of diversity and intersectionalities.

In order to realize these objectives, we designed a three-component course to provide meaningful cross-cultural interaction for students, learning through readings, talks, discussions and writing, and an immersive experience of putting the course ideas together with personal interests through project work. Our course design principles are based on proven educational practices of engagement, including: building a sense of belonging, building on student motivation, scaffolding of topics, reflection opportunities throughout the term, and use of experiential and active learning strategies [47–52].

3.1 Component 1—The Pop-Up class

As we planned and developed our course, and in anticipation of the Aachen team visiting the Stanford campus for one week at the start of the course, we developed a stand-alone eight-hour Pop-Up Design Thinking class called “Reshaping Engineering Culture” in collaboration with instructional staff at the Hasso Plattner Institute of Design at Stanford, otherwise known as the “d.school” (<http://dschool.stanford.edu/>). The Pop-Up was largely designed in direct support of Learning Objective (2), “Analyzing one particular method in engineering, namely Design Thinking from gender and cultural perspectives, and make recommendations on process improvements.” Our specific rationale for developing and embedding the Pop-Up in the EEL course structure was multifold. First, the Pop-Up was intended to introduce the practices of Design Thinking as a set of methods for investigating engineering cultures, developing innovative approaches to strengthen or even transform engineering practices, and developing the foci for student projects for the larger course. Second, we wanted to encourage students to examine Design Thinking itself as a culturally situated process that might be expanded and enriched through consideration of diverse perspectives and backgrounds. Third, this Pop-Up course provided an opportunity for students who had not already experienced Design Thinking to learn more about this method and the intersections between diversity and Design Thinking.

Finally, adding the Pop-Up class to regular and special class meetings for the course during this first week created an intensive opportunity for students of both universities to get to know and work with one another in person in a supportive and engaging environment before working together from a distance (which was called for in both transnational discussions and project work). The Pop-Up also allowed students to experience the positive impact of a diverse team in a transnational context, diverse teams being a feature of an ideal Design Thinking process [53, 54]. The culturally mixed teams in the Pop-up course enabled students to reflect on their own cultural socialization by learning firsthand about other perspectives and working approaches.

The Pop-Up class met during two four-hour sessions during the first week of the EEL course. Its Design Thinking methods gave students the opportunity to explore engineering culture and diversity through the lens of applications. In the initial class session, students had their first opportunity to complete the five phases of a Design Thinking process—Empathize, Define, Ideate, Pro-

totype, Test [55]. This process began with their identifying user needs; students worked in small groups to interview one of several practicing engineers visiting the class for this purpose, to learn more about their individual user needs. Each group then brainstormed and came up with a prototype of an approach designed to address the need of that engineer. To reflect on whether the individual need was identified correctly, students had a second conversation with the interview partners to reflect on their idea together and refine their approach to addressing the need. Then, the second session of the Pop-Up class was designed to allow students to focus their interests and identify project interest areas, using Design Thinking approaches to develop the project interest areas. These areas were further cemented during the last class meeting of Week 1, with students identifying and selecting one of six theme areas in which they wanted to participate for the 10-week-long projects.

3.2 Component 2—Weekly Lectures

The Weekly Lectures part of the course, consisting of 10 sessions, was focused on helping students learn to identify and analyze the interdependences of gender and engineering (Objective (1)) and to envision new engineering processes (Objective (3)). As such, it was designed for students to synthesize and discuss research-based knowledge on culture, gender and diversity in engineering, consider and critically analyze terms, definitions, and findings from relevant studies in the social sciences and humanities, and link new concepts to their own experiences and “project work” (Component 3, as discussed below). Speakers from the United States and Germany, representing different disciplines, subject areas, and specialized cultures, were invited to the course in order to highlight an international perspective on complex topics and to illuminate historical dynamics that shaped, and still shape, engineering cultures today. To prepare students for the lectures, readings for each topic and reflection questions were assigned in advance. Within each of these lecture classes, both speakers’ presentations and readings were discussed by students and instructors.^{1,2} Sessions also included opportunities for questions and answers (Q&A) with the speakers themselves, as well as written reflections [56] through One Minute Papers (OMP) [57], described in more detail in Section 3.4. Table 1 provides the thematic sequence of these lecture-based class sessions.

¹ Beginning in Week 2, class was held simultaneously at Aachen (at 17:30 local time) and at Stanford (at 8:30 am local time). Appropriate technical hardware and software enabled those in the classes to conduct transnational discussions.

² Reading list and syllabus available upon request.

Table 1. Thematic Sequence of the Weekly Lectures

Session	Content
Culture	
Session 1 – Bridging Cultural Divides in Engineering	<ul style="list-style-type: none"> • Introduction to theoretical concepts of culture, gender, and diversity [18]
Session 2 – What does Culture Mean in the Context of Engineering?	<ul style="list-style-type: none"> • Challenges at the interface between diversity and engineering in academic and workplace settings [58]
Gender and Diversity	
Session 3 – Terms and Meanings	<ul style="list-style-type: none"> • Introduction to definitions of sex and gender • Consideration of gender differences from both social and neuroscience perspectives
Session 4 – Frameworks for Understanding Disparities, Inequalities and Bias	<ul style="list-style-type: none"> • Introduction to sociological and psychological approaches to analyzing social inequality • Cognitive biases about and structural barriers to degree attainment and career mobility among diverse groups
Session 5 – Representation and Underrepresentation of Different Social Groups	<ul style="list-style-type: none"> • Introduction to research on the concepts of stereotype threat and mindset (and their influences on representation) • Deeper investigation of underrepresentation/ overrepresentation of different groups in engineering
Social Science Research Methods	
Session 6 – Social Science Methods	<ul style="list-style-type: none"> • Presentation of social science research methods in the study of culture, diversity and gender • Discussions about including strengths and limitations in research papers
Gender and Diversity in Organizational Culture	
Section 7 – Higher Education	<ul style="list-style-type: none"> • Introduction to examples of integrating gender and diversity perspectives in organizational structures as well as in scientific and engineering practice in higher education
Section 8 – Gendered Innovations	<ul style="list-style-type: none"> • Introduction to Gendered Innovations and the necessity to reflect users' needs [39]
Session 9 – Industry	<ul style="list-style-type: none"> • Introduction to industry and the organizational development of a diverse workforce [9, 59, 60]
Session 10 – Strategies and Best Practices	<ul style="list-style-type: none"> • Presentation of various engineering organization strategies to advance diversity and change culture (e.g., the National Science Foundation (NSF) on the U.S. side and Integration Team Human Resources, Gender and Diversity (IGaD) staff unit of the rectorate at RWTH Aachen University)

3.3 Component 3—The Project

The Weekly Lectures component centered on application oriented topics and studies aimed at inspiring and supporting the small-group project component of the course. The Project component especially focused on Learning Objective (3) to envision new engineering processes, practices, and cultures that reflect new or expanded perspectives on gender and sex, and other aspects of diversity and intersectionalities.

The overall goal of the project assignment was to give students the opportunity to frame a question about how engineering relates to culture, gender and diversity, and to address this question based on the course readings and methodologies. The project was intentionally scoped broadly, to enable students to identify issues that had personal meaning for them, whether these issues related to engineering

education, engineering practice, or even the image or definition of engineering. This goal, along with other project details (e.g., milestones, time commitment) and deliverables (final presentation, 1,500–2,000 word project summary) was part of a project description distributed to students at the end of the first week of the course. As described in Section 3.1, through the frame of the Pop-Up Course, students identified potential project topic areas related to culture, diversity and gender, and identified their project teams in this first week.

While Component 2 (the weekly guest lectures & reading discussions) was focused on students developing foundational knowledge, Component 3 was devoted to the projects. In the frame of these sessions, students had joint group time to develop the topic areas into problem statements or questions and then address them based on literature and/or

original data-gathering. Some sessions engaged a member of the instructional team acting as a coach for each group. As with other class sessions, these small group meetings were conducted via technology-assisted video and audio (e.g., Skype, Blue Jeans). Other project sessions convened all teams for discussions and updates, including brainstorming exercises to generate a list of indicators for good teamwork or criteria for good powerpoint presentations given by the project teams.

In Week 10 of the course, each of the teams delivered final presentations and submitted draft written project summaries for peer review. Peer reviews allowed students to understand and apply criteria of a good presentation and a well-posed scientific position paper. They also gave students the opportunity to reflect on their own individual performance and to learn from others. Students' final written summaries were submitted in Week 11, and instructor assessment of performance used a standardized rubric.

3.4 Evaluation of effectiveness of different components

In order to learn about the effectiveness of these three components and the learning experiences of students, we used multiple evaluation methods and instruments, before, during and after the 2015 course offering of EEL, as summarized below. We turn to findings from these instruments in Section 4.³

- **Pop-Up Survey.** At the end of the Pop-Up class, a short survey was distributed to students about the Pop-Up's impact. The survey included open-ended items (e.g., "*Describe two of the most memorable moments from class. What made them memorable?*") as well as two fixed-choice items (e.g., "*Would you recommend this class to someone else?*") for which responses were measured on a scale of 1 to 10.
- **One-Minute Papers (OMPs).** A technique developed to support the reflection process [61], OMPs are administered to students near the end of a lecture class session, with 1-3 questions that students are asked to address in their written responses. OMPs are meant to stimulate student reflection on a class session and give the instruc-

tors formative feedback on how well the course is going [62]. Sample OMP questions from one of our sessions on theories of gender inequality are: "(1) *Give an example of a gender stereotype you have observed in an engineering environment in a classroom, laboratory, work or other setting.* (2) *How does the gender stereotype reinforce inequality?* (3) *Let us know anything else you would like to communicate to the instructors of the course.*" In total, nine OMP assignments were deployed throughout the 10 weeks.

- **Pre-Course "Calibration Survey".** This introductory online survey was administered during Week 1 of the course, and included items on students' interests in and plans for future action/work related to gender, diversity, and culture in engineering. Of particular note were five survey items that composed a construct we labeled as *Diversity Analysis Self-Efficacy*, which considers students' confidence in their ability to do each of the following:

- Integrate considerations of sex, gender, and diversity into design, engineering, and/or research questions
- Identify methodologies that help to show how sex, gender, and diversity matter to design, engineering, or research processes and outcomes
- Integrate considerations of culture into design, engineering, and/or research questions
- Identify methodologies that help to show how culture matters to design, engineering, or research processes and outcomes
- Advocate for the consideration of sex, gender, diversity, and culture in professional settings where decisions and policies are being made

These items, all measured on a five-point response scale (from 1 = Not confident to 5 = Extremely confident) were developed expressly for the course, (indirectly) speak to Learning Objectives (1), (2), and (3), and build on the Gendered Innovations framework for "designing sex and gender analysis into research from the start" [63]. The Cronbach's alpha for this scale among all respondents to the Calibration Survey was high, at 0.89 (and remained high in the Recalibration Survey, at 0.84, see below).

- **Post-Course "Recalibration Survey".** The closing "Recalibration Survey" was administered in the last week of the course, and was completed by students up to two weeks after the course ended. This was a 15-question online instrument with three objectives: (1) to gather students' feedback about the course using measures that were standardized across both institutions (students were asked to evaluate the Pop-Up class with introductory/"ice-breaker" activities, weekly guests,

³ Because data from this course would be used for the purpose of scholarly writing and publication, our course required human subjects research oversight. At Stanford, an Institutional Review Board application was submitted and approved in September 2015. The approval of the commissioner for data protection in Aachen also was obtained in September. There is a Consent Form associated with the course. The Consent Form emphasizes to students that the evaluation data will be used in scholarly analysis and writing, and that under no circumstance will individual names or other identifying information be shared.

readings, and discussion, weekly team project work, transnational interactions, and the use of technology platforms to connect our sites), (2) to “post-test” the interest, confidence, and plans items from the Calibration Survey, and (3) to ask students for information on their college curricular and extra-curricular activities, career goals, and job interests.

- **Official Aachen and Stanford Course Evaluation Forms.** These forms were institution-level forms administered to all enrolled students across all courses in the last weeks of each institution’s respective academic terms. Aachen’s form included questions relating to the concept and structure of a course, the effectiveness of the instructor, presentation and discussion of course materials, organization and implementation of the course, and personal reflection (e.g., “What did you particularly like about the seminar? What did you dislike about the seminar?”). Stanford’s form included customizable questions asking students to evaluate progress towards meeting specific course objectives. The overlap between the two forms was modest—although both forms include open-ended questions, for example, Aachen’s form had more extensive fixed-choice questions about the effectiveness of the instructors, and Stanford’s form allowed for five different pedagogical components of the course (selected by the instructors) to be evaluated (e.g., “guest speakers”, “syllabus”, “readings”).

4. Assessing the course: what roles did the three course components play in student learning? to what extent did students change over time? were learning objectives met?

Nineteen students at Stanford and 15 students at Aachen enrolled in and completed our complete pilot course. Due to the different curricular requirements and contexts at each institution, EEL was offered at RWTH Aachen University as one unit university module and at Stanford University as a one or two unit course. Thus, the number of course participants varied by component. The Pop-Up course (Component 1) included all 15 Aachen students and 19 Stanford students, plus four additional Stanford students who enrolled just in the Pop-Up (without intentions to go on to the full course). Fifteen Aachen students and 19 Stanford students participated in the weekly lectures (Component 2), and 15 Aachen students and nine Stanford students worked together in teams across six different projects (Component 3). In participating in

the project component, students attended class sessions twice per week, with the second weekly session devoted to project team meetings.

About half of students were graduate (master’s- and doctoral-level) students, and half were undergraduate (bachelor’s level) students; most were in engineering degree programs. At Stanford, 14 identified their gender as “woman”, “cis-female”, or “female when forced to choose”; the balance identified as “male”, “cis-male”, or “neither”. Aachen participants did not self-report their gender. Both Aachen and Stanford instructors required students to complete an online application for the course given enrollment capacity constraints; from this application, we learned that student motivations to take the course fell into one or more of the following five categories:

- (1) *Improving engineering design and practice with considerations of diverse people* (i.e., wanting to learn more about culture, diversity, and gender as a way to improve engineering design processes and outcomes);
- (2) *Concerns about underrepresentation of diverse people in engineering* (i.e., questions and concerns about pathways for underrepresented groups to participate in engineering, driven by (a) intellectual curiosity around a complex problem and/or (b) goals to expand access and equity in education);
- (3) *Firsthand experience with stereotypes and bias* (i.e., personal experience with stereotypes and discrimination that students wished to contextualize and explore in conversation with others);
- (4) *Interest in advocacy for diversity* (i.e., a desire to build experience as an advocate for diversity in science, technology, and engineering settings); and
- (5) *Interest in critical exploration of “Design Thinking”* (i.e., a desire to get to know the method of Design Thinking in an applied context alongside diversity topics).

We analyzed data from the Pop-Up Survey, One Minute Papers, the Calibration and Recalibration Surveys, and the official Stanford and Aachen Course Evaluation Forms to examine the effectiveness of the course overall, how specific course components contributed to students’ learning, how well the course met its Learning Objectives, and what might be improved. Table 2 lists the respondent counts for each of these evaluation instruments.

4.1 Overall impressions of the course

Students were generally very pleased with the EEL course, and offered written testimony about the

Table 2. Participation in Course Evaluation Instruments

Instrument	Reference Label in Section 4	Respondent Count	Sample Notes
Pop-Up Survey	Pop-Up Survey	26 (10 from Aachen, 16 from Stanford)	A fraction of the Stanford students completing this survey were not part of the larger Expanding Engineering Limits course, but had just signed up for the Pop-Up
One-Minute Papers	OMP	All students attending a given class session (i.e., up to 34 students depending on class attendance)	–
Calibration and Recalibration Surveys	Calibration and Recalibration Surveys	31 Calibration Survey; 23 Recalibration Survey; and 22 in both surveys (10 from Aachen, 12 from Stanford)	On several of the pre/post comparisons, the valid sample size drops to 21 given missing data for one respondent
Official Aachen and Stanford Course Evaluation Forms	Aachen Form, Stanford Form	11 from Aachen, 14 from Stanford	–

value of the course for their overall understanding of human diversity and the uniqueness of the topics covered in the course, with comments such as:

“People are very different and I need to consider that while working cross-nationally. It was a good experience I couldn’t have had anywhere else.” (Recalibration Survey)

“Thank you for putting together this course. This really helped me in understanding gender and diversity better. It also motivated me to include these aspects in future research.” (Recalibration Survey)

“Overall, this was a life-changing course. I cannot express how much I took away from this class on personal level. . .” (Stanford Form)

“Love it! Please please keep doing this.” (Recalibration Survey)

“Overall, a great enrichment and many experiences. Seminar is highly recommended.” (Aachen Form)

Some 85% of the Stanford students said that they had learned a lot or a great deal (Stanford Form) and over 80% of the Aachen students found the course to be very interesting (Aachen Form). Most Aachen and Stanford students found the course to be well-structured and very well organized (82% of Aachen students agreed or strongly agreed that it was very well structured, and 72% of Stanford students said it was extremely or very well organized) (Aachen and Stanford Forms, respectively).

4.2 Component 1—The Pop-Up

The Pop-Up class was designed as an intensive engagement with Design Thinking. Not surprisingly, given the aims of the Pop-Up class, student responses indicated that its associated introductory exercises contributed substantially to their understanding of Design Thinking (96% “excellent” or “very good”), and slightly less to their understand-

ing of culture, diversity and gender (69% “excellent” or “very good”) (Recalibration Survey). Furthermore, comments from the OMPs (*OMP 12/03/15*), and the Recalibration Survey reinforce the benefit of bringing transnational teams together in person in the Pop-Up; students pointed out that it was important to meet each other and to have a joint project kick-off for working successfully in transnational teams. Surveys of both Aachen and Stanford students after the course gave high marks to the opportunity to interact with students and faculty from another country (with 91% rating this aspect of the course as “excellent” or “very good”).

On the Pop-Up Survey, students shared that they were very satisfied with the Pop-Up content and what they had learned (mean score of 7.8 out of 10), and that they would recommend a Pop-Up experience to their friends (mean score of 8.3 out of 10). In terms of learning, they mentioned the impact of interviewing engineers and then designing for those engineers (*“Interviewing the engineer—it was wonderful how they just totally opened up when you’re sincerely trying to empathize with them.”*), that design is fun (*“I absolutely loved throwing ideas out there and running with them with a diverse group. Getting to work with these motivated and brilliant people is incomparable.”*), *“I also loved the physical motion required. You couldn’t fall asleep in this class if you wanted to.”*), that they personally are creative (*“I am creative!! And I can be a designer!!”*) and the importance of openness (*“I need to be more open to other people’s solutions.”*, *“Listening to other people more closely is hard but important.”*) (Pop-Up Survey).

Students appreciated the explicit connection of diversity and Design Thinking in the second Pop-Up session. Sample comments include *“The final*

design process exercise in the group on Thursday night was incredible because we got to choose our topic and work around an idea that was essentially why we cared about diversity in engineering.” and “I loved seeing the different reasons why everyone took this class, and finding solutions to our ‘favorite’ problems.” (Pop-Up Survey).

In responses to questions on the OMP at the end of the first week (09/25/15), 95% of students indicated they were most excited about working on projects. This high level of excitement may reflect students’ positive experiences with the Design Thinking Pop-Up course, which established the framework and process for ideation and group formation for the project work.

4.3 Component 2—Weekly Lectures

The aim of this course component was to provide students with the opportunity to develop a deeper sense of concepts relating to culture, diversity, and gender, and more specifically, reflect on the content and function of stereotypes about different social groups (in engineering and in their own lives), and explore the mechanisms behind social inequality (with particular attention to disparities in engineering settings). One student offered “Don’t get rid of the speakers! They were amazing.” and 87% of students overall expressed that the guest speakers contributed greatly to their understanding of culture, diversity and gender (Recalibration Survey).

4.4 Component 3—The Project

Table 3 lists the six project teams and respective themes. By design, each of the six themes was related to the concepts of culture, diversity and gender in the context of engineering, and ranged from investigating influences in high school on students’ participation in engineering to examining the methodology of Design Thinking in practice. The goal of balanced Aachen-Stanford teams was not met, in large part because of the smaller number of Stanford students (9) who signed up

for the project part of the course. To meet the challenges of a cross-Atlantic teamwork, each team was paired with a coach from RWTH Aachen or Stanford University.

One defined aim for the course structure was to enable students to connect content covered through the Weekly Lectures to issues in which they were personally interested (Learning Objective (3)). The evaluation data indicate that such connections were occurring throughout the course. In response to the OMP dated 10/20/2015 that asked “How does the information from today’s speaker affect your project work?” students wrote about being challenged by the speakers to think about “different categories of diversity” (including first-generation students and students from immigrant backgrounds) and gaining better understanding of “the interdependency between culture, ethnicity and success in STEM.” They also were challenged in thinking about the data collection methods they were using with their project, expressing that “statistics are very interesting but are not always easy to read; one has to be careful” and acknowledging the limitations of statistics as “you have to show the background information and side aspects, too (through, for example, interview data).”

In addition, we wanted students, through their project work, to extend and expand their learning. Three-fourths (77%) of students reported that the weekly team project work had contributed to their learning about engineering culture(s), diversity, and gender at a “very good” or “excellent” level (Recalibration Survey). Sometimes this learning was a direct result of confronting and working through the team’s very own diversity; one student expressed: “And even though the group work had its up and downs, it was a really great experience to work in a very diverse group.” (Recalibration Survey). This outcome is particularly interesting as Aachen and Stanford students approached the project aspect with a variety of feelings. There was a high level of excitement, with many students expressing that the

Table 3. Six Project Areas and Team Composition

Project Areas	Students from RWTH Aachen	Students from Stanford	Coaching from
Expanding Engineering Limits: Development and Sustainability	2	2	Aachen
“Oh the Humanity!” Increasing diversity in engineering higher education	1	4	Aachen
K-6 Engineering Education	2	1	Stanford
Investigating Influences in High School for the Engineering Pipeline	4	1	Stanford
Improving Design Thinking	3	1	Aachen
Design Thinking in Practice	3	0	Stanford

project was the aspect about which they were most excited (*OMP 9/25/2016*). At the same time, there was some worry about the imbalanced Aachen-Stanford teams, project work in a transnational context, and being in the wrong group (*OMP 9/25/2016*).

The ultimate aim of the project component was to enable students to work towards positive change. Achievement of that aim is exemplified by this comment: *"The Thursday sessions really gave us the opportunity to work towards making positive changes towards diversity in engineering culture. This went incredibly well. I would be surprised if some of the things that started in this class do not end up influencing institutional change at Stanford and beyond. In many instances we found that people knew they could improve their behavior, but did not know *how* to improve their behavior. This course is a near ideal solution to that problem, and allows us to move forward in a very tangible way."* (Stanford Form).

4.5 How students changed (and didn't change) in their thinking

We now turn to the impact of the course on attitudinal measures that were not necessarily tied to any single component, acknowledging that any shift and growth were influenced by the components working in concert and in different ways for each individual student (along with other things happening in their lives).

Student Learning: The analysis of the OMPs shows a continuous process of change. Students reflected on the concepts of stereotyping and labeling, and connected course topics with personal experiences. Student responses illustrate types of stereotypes that they have personally experienced/observed, and range from gendered perceptions of skills (*"women have social skills, men engineering skills"*), to perceptions of women needing more help (one student writing *"A professor told me to make sure to go to office hours because 'girls usually need more help'"*). Analysis also suggests that both men and women not only observed these stereotypes but sometimes reproduced them (*"My former boss, a younger female engineer, was often immediately perceived as my junior during field trips—it was just assumed that I, the man, would be in charge. This was further reinforced by my boss' bubbly, kind character (rather than 'man's' authoritativeness)"*). In this context it should be reiterated that participating students at both universities were highly motivated to learn about concepts relating to culture, diversity, and gender coming into the course. Some students mentioned a strong interest in linking studies of diversity and culture to their professional futures, seeing opportunities to apply their newfound competencies to manage diversity in their places of

work. Other students were interested in theoretical explanations of bias and inequality in order to understand constructs that had personal relevance for them, e.g., stereotyping and discrimination.

Students also mentioned that they learned more about how to work in a distributed, international team. Considering the course topics, students felt enabled to *"work towards a better future"* as they could connect their individual field of work/interest with the range of topics given in the course. The opportunity to identify their own projects, and to experience cultural and gender diversity in transnational teamwork, was mentioned positively as well: *"I learned a lot about cultures I will likely never experience firsthand (working mothers, people of color, children of immigrants) and how those perceptions can be different in different cultures—especially in the US as compared to Germany."*

PrelPost Evaluation—Insights from Calibration and Recalibration Surveys: Data from our Calibration ("pre") and Recalibration ("post") Surveys show how students' responses changed on key measures over the 10-week course experience. Results indicate that from the beginning to the end of the course, students generally changed very little on measures of *interest* and *plans* relating to gender, culture, and diversity in engineering (individual items available upon request); moreover, mean scores on each item tended to be on the higher ends of the scales (e.g., ~4.0 on a scale from 1 to 5). This reflects the self- (and application-) selected nature of the student population, i.e., students tended to have strong interest in these topics even before stepping foot in the classroom. However, it bears noting that among the interest items, at the start and end of the course students were most interested in making change in engineering culture(s), and, by comparison, less interested in employing Design Thinking methods in their work (tests of statistical significance were employed only to test differences within paired items, not across items). We also observed marginally significant *declines* in plans to evaluate diversity-related characteristics of organizations at which students might work professionally, and in interest in analyzing gender norms in engineering cultures. However, we note that these were among the highest scoring items in the Calibration Survey.

We do see a significant upward shift in scores on the Diversity Analysis Self-Efficacy construct, where "self-efficacy" refers to the strength of conviction in one's ability to successfully effectuate certain outcomes [64]. The increase in Diversity Analysis Self-Efficacy is closely aligned with our course objectives, so we are encouraged by its increase in our students, pre-course vs. post-course.

In general, that we saw little to no change on some

measures in our survey (e.g., interests and plans) could reflect both a “ceiling” on positive change given such high incoming scores, and that the course, in showing the complexity of topics (e.g., the mechanisms of gender inequality), possibly dampened some students’ motivations and “neutralized” potential gains. We are eager to test whether these findings are replicable among new cohorts of students (and whether students in our inaugural cohort show the same pattern of results one or more years later). We also recognize that without a comparison or control group, causal inferences from these data cannot be made.

4.6 Were learning objectives met?

In the prior sub-sections we considered the effectiveness of the three major course components and how student thinking evolved during EEL. We end this section on evaluation of the EEL course by returning to the three Learning Objectives around which the evaluation was designed, to consider the evidence concerning the extent to which those three objectives were achieved.

Objectives (1) and (3) focused on students learning to identify and analyze the interdependencies of gender and engineering, using a variety of methods (1), and envisioning new engineering processes, practices, and cultures that reflect new or expanded perspectives on gender and sex, and other aspects of diversity and intersectionalities (3). Across our various evaluation mechanisms, students reported that their understanding of gender and diversity was advanced by the weekly presentations, readings and discussions, and most felt that these two Learning Objectives were extremely or very well met. We saw our students apply and extend this understanding to self-defined projects in which they not only identified “problem areas” related to culture, diversity and gender in the engineering landscape (broadly construed), but also proposed improvements. The origins of these projects were in the first week’s Pop-Up course that also established transnational collaboration as a course norm, underscoring the role of the Pop-Up in realizing these two objectives was important. Furthermore, well aligned with these two objectives is the significant pre/post increase on the Diversity Analysis Self-efficacy measure, reflecting students greater self-confidence by the end of the course in identifying and integrating considerations of culture, sex, gender and diversity into design, engineering and/or research questions. In summary, survey data and students’ work products (projects and OMP) support a conclusion that Objectives (1) and (3) were strongly achieved.

Objective (2) involved students learning to analyze one particular method in engineering (e.g., Design Thinking), from gender and cultural per-

spectives, and to make recommendations on process improvements. One way we hoped students would gain this dimension was through participation in lectures, readings and discussions, particularly those in Weeks 7–10 which presented engineering related cases about practices and how those practices could be or had been improved. In addition, the first week’s Pop-Up provided students with personal experience with the particular method of Design Thinking, first in an exercise involving interviewing engineers and identifying their needs, then in a second exercise in identifying personal interest areas and possible team mates in the space of engineering, culture, diversity and gender. Two of the six teams actually chose to focus their project on Design Thinking, undertaking an analysis of how it is practiced and then recommending how it might be improved. For these two teams the tie between an engineering method, analysis of that method from gender and cultural perspectives, then recommending improvements was “tangible”. For the other four teams whose projects were focused on new and novel ways of engaging people with and in engineering, the tie to an engineering method was less obvious. This difference may be part of the reason that fewer students (relative to Objectives 1 & 3) expressed that this objective was extremely well or highly met.

5. Discussion and implications for the future

As described in this paper, EEL was initially developed and implemented by a collaborative team focused on a shared interest in engaging students in deeper learning about ways in which an understanding of gender and other diversities within engineering culture could improve engineering practice and outcomes. We sought to create a course that would engage and challenge students to think beyond traditional engineering learning, and to engage them in explorations of the ways in which deeper knowledge of gender and other diversities within engineering cultures might improve both processes and products. With an introduction to Design Thinking as a paradigm for launching a new project, and an infusion of research-based studies drawn from psychology, sociology, gender studies, education, history, and engineering education as a foundation, students joined others with similar interests to work in teams to develop projects of particular interest to each team. The twin opportunities to experience and engage in a Design Thinking process, and to do so with peers from another country provided incentives for participating for many of the students, both those from Stanford and those from Aachen, and also

provided the foundation for pedagogical practices in active and project-based learning which have proven beneficial to learning [65]. This foundation supported the instructors' efforts to engage students in learning about complex and holistic concepts of diversity, and enabled students to choose projects of particular interest, thereby fostering learning [66] and offering considerable advantage over more traditional (non-active and non-experiential learning based) classroom teaching techniques.

Each of the three course components (Pop-Up, Weekly Lectures, and Project) offered important aspects of engaging students in the course topics and played unique and complementary roles. Overall, we were pleased with the positive response from the students to the course, even as we all recognized opportunities to improve its structure, content, and delivery. Our initial goals were met, with student feedback and behaviors both indicating various positive benefits from learning more about culture, gender, and other diversities in the context of engineering, at least for this self-selected group of students. We note that many of our evaluation methods involved indirect assessments of student learning (e.g., students' ratings of different course components as captured in self-reported survey data). We look towards future evaluation opportunities to build up more direct assessments of learning (e.g., continued analysis of student reflection papers, as well as longitudinal study of students' project milestones/deliverables leading up to their final submission).

We would be remiss if we did not mention that there were some challenges with the course. For example, the digital collaboration technologies that enabled us to connect our classrooms did not always work seamlessly and did not always allow us to create a sense of a single classroom. The 9-hour time difference forced early-morning class time at Stanford and evening class time at Aachen for the Weekly Lectures (further complicated when the two sites went off Daylight Savings in different weeks, creating some challenges in securing classrooms for a simultaneous meeting). The time difference (and use of different video conferencing technologies) also proved challenging for some of the Project teams to navigate, particularly in the early phase of the projects. On a larger scale, the schools have different academic calendars, making it challenging to have a common course that starts and ends on the same dates. Working through these challenges required open communication and developing respectful relationships built on mutual trust, interdependence, and belief in the importance and goals of the course. They also suggest areas for future improvement.

After this pilot course was offered in 2015, each campus team took action to offer the course again, though opted not to link their classrooms in the next iteration. This decision, made with some reluctance, was a result of a combination of complexities experienced during the first version of the course as a result of some of the challenges outlined above, along with competing demands on the instructional team limiting their availability. Instead, the course was next offered on each campus without linked classrooms or projects, at Aachen during October 2016–January 2017, and at Stanford during its winter quarter, January–March 2017.

In Germany, the course has been distinguished as good practice project by the DFG (German National Science Foundation) (<http://instrumentenkasten.dfg.de/modellbeispiel/641?locale-attribute=de>). Due to the high engagement and the feedback of the students, the follow up course has been restructured in order to adapt the workload to the credits and to be able to integrate it in the master curriculum of all engineering schools as elective module. The course was then divided into three components, each of which are credited and build upon one another: the lecture part now has more time and room for discussions, a Pop-Up class that encompasses Design Thinking, and the project component. To be able to participate in the project component, the other two courses have to be taken. Interest of students of all faculties is increasing—in 2016–17 more than 45 students participated and in 2017/18 nearly 60 enrolled in the lecture part.

The instructional team from Stanford initiated a “Faculty College” project during 2016–17 to engage additional faculty members at Stanford from both engineering and the humanities and social sciences to build upon the work of this pilot, and further develop the course at Stanford. Thirty-three undergraduate and graduate students took the second version of the course, which included more extended small group discussions, as well as reading and writing assignments designed to enhance learning; this version of the course did not include a Pop-Up class or a project, but several students undertook related projects through one of several options of second courses offered during Spring Quarter 2017. Fifty-three graduate and undergraduate students enrolled in a third iteration of the course during Winter Quarter 2018, which once again included a project. This third iteration was offered for a grade with the project requirement.

For our teaching team, attempting to gain the considerable benefits of real-time, transnational collaborative learning experiences for students, while also meeting other course objectives, when differences in our institutional calendars were so great, worked against long-term sustainability of

the concurrent version of the course, described in this paper. Yet we would encourage others to identify opportunities for such collaborations that could fit together more easily within institutional structures—the opportunities for all to learn, with far greater nuance, through direct engagement with others in a truly cross-cultural context, are remarkable; while the cost is in time, the reward is in a much richer experience and deeper learning about culture with greater appreciation of how much local context can influence perspectives. Through such work, we will be more likely to provide appropriate education for engineers who can work successfully in global contexts, across cultures, with greater understanding of the diversity within humanity as well as our common interests.

6. Conclusions

It is apparent to us that students, engineering programs, and faculty all can benefit from the development of courses such as the one described and evaluated in this paper. Greater sophistication and awareness of the growing body of research related to culture and diversity in engineering contribute important elements for sound engineering learning and practical applications. Due to local conditions and individual circumstances, such courses are likely to be adapted to specific interests, needs, curricular structures, and opportunities of those proposing, developing, and leading their implementation. Based on the experience of our initial course, we suggest that attempting to address too many opportunities and challenges at once, even with a committed, capable teaching team, may lead to an experience that cannot be sustained due to its complexity.

There will inevitably be “existential” dilemmas in developing such courses. One introductory course can never provide the depth of knowledge, experience and insight that a much longer, deeper course of study can. Other related challenges are ongoing: choosing what to include, and what to omit; considering in what order relevant concepts are most usefully presented; engaging students in meaningful projects when they do not have, and cannot be expected to develop in a short time, deep knowledge of prior work, relevant methods and their limitations, or appropriate analytic tools. There is still a relative paucity of good descriptive and analytic research about engineering cultures. Wading into the territory of culturally sensitive topics can seem perilous at times, risky for faculty who fear to misstep, or inadvertently “trigger” deep emotional response among some students, when others merely experience an academic exercise. Yet the benefits of acknowledging the diversity of humanity, the ways

in which people have constructed our cultures, and the transformative aspects of diversity realized at the deepest level, are potentially great; even an introductory experience can open up windows of understanding that lead to more thoughtful, nuanced design, process improvement, more effective teamwork, and better engineering. As so succinctly stated by one of our students in their official course evaluation form at their institution:

“This course provides a learning and discussion forum for engineering students (and others that are interested) to expand their perspectives on the engineering profession. It is extremely important to have a safe space to for students to learn about gender and culture issues specific to engineering, which is something that is desperately needed.”

In conclusion, the course integrated and highlighted important dimensions for educating engineers of the future. Learning about and experiencing different engineering and national cultures also enabled students to reflect on their own experiences in engineering. Connecting, discussing, and working closely with international colleagues in another country on the topics enriched the learning process on multiple levels. *We encourage others to join us in this new endeavor of expanding engineering limits through culture and diversity.*

Acknowledgements—The RWTH Aachen University team would like to thank RWTH Aachen University for supporting the development of this project and student exchange with funding. Authors from the Stanford University team would like to thank Stanford’s School of Engineering and General Motors Company for seed funding for this pilot course. Our course benefited from the engagement with colleagues at the “d.school”—the Hasso Plattner Institute of Design at Stanford, and from the expertise, time, and generosity of guest speakers from Aachen, Stanford, and other organizations. We also thank our students and those who have gone before us in pushing critical questions about inclusivity and diversity in engineering.

References

1. L. Steuer, A. Bouffier and C. Leicht-Scholten, Diversifying Engineering Education—A Transdisciplinary Approach. In M. Gray and K. D. Thomas (Eds.): *Strategies for Increasing Diversity in Engineering Majors and Careers*, IGI Global, pp. 201–235, 2017.
2. S. Sheppard, K. Macatangay, A. Colby and W. Sullivan, *Educating engineers: Designing for the future of the field*, San Francisco: Jossey-Bass, 2009.
3. Verein Deutscher Ingenieure, Ethische Grundsätze des Ingenieurberufs, <https://www.vdi.de/bildung/ethische-grundsatzel/ethische-grundsatzel/>, Accessed 15 July 2017.
4. J. R. Whinnery, *The World of Engineering*, NY, Ed. McGraw-Hill, 1965.
5. P. D. Galloway, *The 21st-Century engineer. A proposal for engineering education reform*, ASCE Press, 2008.
6. Accreditation Board for Engineering, Technology (ABET), Engineering Accreditation Commission. Criteria for Accrediting Engineering Programs—effective for evaluations during the 2006–07 accreditation cycle, <http://www.abet.org/>, Accessed 13 July 2017.
7. C. Leicht-Scholten, A. Bouffier and L. Steuer, Facing Future Challenges: Building Engineers for Tomorrow. Paper in the

- frame of the 5th International Conference New Perspectives in Science Education, 17–18.03.2016, Florence, pp. 32–37, 2016.
8. J. J. Duderstadt, *Engineering for a Changing World. A Roadmap to the Future of Engineering Practice, Research, and Education—The Millennium Project*, The University of Michigan, 2008.
 9. G. L. Downey and J. C. Lucena, Engineering Selves: Hiring Into a Contested Field of Education. In: G. L. Dowey and J. Dumit: *Cyborgs and Citadels: Anthropological Interventions in Emerging Sciences and Technologies*, Santa Fee: The SAR Press, pp. 117–142, 1997.
 10. S. J. Correll and C. L. Ridgeway, Expectation states theory. In J. Delamater (Ed.): *Handbook of Social Psychology*, New York: Kluwer Academic/Plenum Publishers, pp. 29–51, 2003.
 11. C. Leicht-Scholten, E. Breuer, N. Tulodetzki and A. Wolfram, *Going Diverse. Innovative Answers to Future Challenges. Gender and Diversity Perspectives in Science, Technology and Business*, Leverkusen: Budrich UniPress, 2011.
 12. L. Steuer, T. Berg and C. Leicht-Scholten, *Breaking the habit—new approaches in engineering education*, Paper in the frame of the 43rd Conference of the European Society for Engineering Education, 29.06.–02.07.2015, Orléans, 2015, <https://www.sefi.be/wp-content/uploads/2017/09/60823-L-STEUER.pdf>, Accessed 12 December, 2018.
 13. C. L. Ridgeway, *Framed by Gender*, Oxford: Oxford University Press, 2011.
 14. L. Gardenswartz and A. Rowe, *Diverse Teams at Work. Capitalizing on the Power of Diversity*, Virginia: SHRM, 2003.
 15. K. Phillips, M. M. Duguid, M. C. Thomas-Hunt and J. Uparna, Diversity as knowledge exchange: The roles of information processing, expertise, status and power. In Q. M. Roberson (Ed.): *The Oxford Handbook on Diversity and Work*, Oxford: Oxford University Press, 2012.
 16. K. Crenshaw, Mapping the margins: Intersectionality, identity politics, and violence against women of color, *Stanford Law Review*, **43**(6), pp. 1241–1299, 1991.
 17. S. D. Museum and K. A. Griffin, Mapping the margins in higher education: On the promise of intersectionality frameworks in research and discourse, *New Directions for Institutional Research*, 2011(151), pp. 5–13, 2011.
 18. E. A. Cech and T. J. Waizunas, Navigating the heteronormativity of engineering: the experiences of lesbian, gay, and bisexual students, *Engineering Studies*, **3**(1), pp. 1–24, 2011.
 19. C. Leicht-Scholten, *»Gender and Sciences« Perspektiven in den Natur- und Ingenieurwissenschaften*, Bielefeld: transcript Verlag, 2007.
 20. L. Steuer, *Gender und Diversity in MINT-Fächern—Ursachen des Diversity-Mangels*, Wiesbaden: Springer BestMasters Psychologie, 2014.
 21. H. R. Markus and A. Conner, *Clash!: 8 cultural conflicts that make us who we are*, New York: Hudson Street Press, 2013.
 22. G. Hofstede, Dimensionalizing Cultures: The Hofstede Model in Context, *Online Readings in Psychology and Culture*, **2**(1), 2011.
 23. G. L. Downey, J. C. Lucena, B. M. Moskal, R. Parkhurst, T. Bigley, C. Hays, B. K. Jesiek, L. Kelly, J. Miller, S. Ruff, J. J. Lehr and A. Nichols-Belo, The globally competent engineer: Working effectively with people who define problems differently, *Journal of Engineering Education*, **95**(2), pp. 107–122, 2006.
 24. J. J. Jones, J. F. Dovidio and D. L. Vietze, *The Psychology of Diversity: Beyond Prejudice and Racism*, New Jersey: John Wiley & Sons, 2013.
 25. P. Hinds, L. Lei and J. Lyon, Putting the Global in Global Work: An Intercultural Lens on the Practice of Cross-National Collaboration, *Academy of Management Annals*, **5**(1), pp. 135–188, 2011.
 26. H. Hinderer, Complexities of intercultural engineering across organizations, *Interculture Journal: Online-Zeitschrift für interkulturelle Studien*, **11**(18), pp. 47–58, 2012.
 27. D. E. Jansen and Z. J. Pudlowski, Global Engineers: Creating Needed Solutions Through Intercultural Competence, *International Journal of Engineering Education*, **25**(6), pp. 1292–1297, 2009.
 28. J. Trevelyan, Reconstructing engineering from practice. *Engineering Studies*, **2**(3), pp. 175–195, 2010.
 29. C. L. Colbeck, S. E. Campbell and S. A. Bjorklund, Grouping in the Dark: What College Students Learn from Group Projects. *The Journal of Higher Education*, **71**(1), pp. 60–83, 2000.
 30. G. L. Downey, J. C. Lucena, B. Moskal, T. Bigley, C. Hays, B. Jesiek, L. Kelly, J. Lehr, J. Miller and A. Nichols-Belo, Engineering Cultures: Expanding the Engineering Method for Global Problem Solvers, *Proceedings of the 2005 ASEE/AaeE 4th Global Colloquium*, 2005.
 31. G. A. Knapp and A. Wetterer, *Achsen der Differenz—Gesellschaftstheorie und feministische Kritik II*, Münster: Westfälisches Dampfboot, 2003.
 32. J. M. Smith and J. C. Lucena, Invisible innovators: how low-income, first-generation students use their funds of knowledge to belong in engineering, *Engineering Studies*, **8**(1), pp. 1–26, 2016.
 33. B. Franzke, Berufswahl heute: Geht es auch weniger stereotyp? Genderaspekte in der Berufswahl und Berufsorientierung, https://lehrerfortbildung-bw.de/allgschulen/alle/gender/m4/01_BF_Gender_in_Berufswahl_und_Berufsorientierung.pdf, Accessed 20 July, 2016.
 34. C. Leicht-Scholten, Exzellenz braucht Vielfalt—oder: wie Gender und Diversity in den Mainstream der Hochschulentwicklung kommt—Human Resources, Gender and Diversity Management an der RWTH Aachen, *Journal Netzwerk Frauenforschung NRW*, **23**, pp. 33–39, 2008.
 35. B. Knoll and B. Ratzer, *Gender Studies in den Ingenieurwissenschaften*, Wien: Facultas Verlags- und Buchhandels AG, 2010.
 36. U. S. Dixit, M. Hazarika and J. P. Davim, *A brief history of mechanical engineering*, Switzerland: Springer International Publishing, 2016.
 37. A. L. Pawley, Shifting the “Default”: The Case for Making Diversity the Expected Condition for Engineering Education and Making Whiteness and Maleness Visible, *Journal of Engineering Education*, **106**(4), pp. 531–533, 2017.
 38. National Academy of Engineering, *Grand Challenges for Engineering: Imperatives, Prospects, and Priorities* Washington: National Academies Press, 2016.
 39. L. Schiebinger, Gendered Innovations: Harnessing the Creative Power of Gender Analysis, *Association for Women in Science*, pp. 28–31, 2016.
 40. M. Peña, Ignoring Diversity Hurts Tech Products and Ventures, <http://ecorner.stanford.edu/articles/4700/Ignoring-Diversity-Hurts-Tech-Products-and-Ventures>, Accessed 04 May 2018.
 41. G. Lichtenstein, A. McCormick, S. D. Sheppard and J. Puma, Comparing the Undergraduate Experience of Engineers to All Other Majors: Significant Differences are Programmatic, *Journal of Engineering Education*, **99**(4), pp. 305–317, 2010.
 42. A. Woisch and J. Willige, Internationale Mobilität im Studium. https://www.daad.de/medien/der-daad/analysen-studien/daad_dzhw_internationale_mobilit%C3%A4t_im_studium_2015.pdf, Accessed 20 July, 2016.
 43. C. Leicht-Scholten and A. Bouffier, Mehrwert durch mehr Perspektiven, Wie eine Brückenprofessur neue Perspektiven in den Ingenieurwissenschaften aufzeigt, *RWTH Themen 21* 2015, pp. 12–14, 2015.
 44. I. J. Busch-Vishniac and J. P. Jarosz, Can Diversity in the Undergraduate Engineering Population Be Enhanced Through Curricular Change? *Journal of Women and Minorities in Science and Engineering*, **10**(3), pp. 255–282, 2004.
 45. Royal Academy of Engineering, *Designing inclusion into engineering education. A fresh, practical look at how diversity impacts on engineering and strategies for change*. <https://www.raeng.org.uk/publications/reports/designing-inclusion-into-engineering-education>, Accessed 12 December, 2018.
 46. T. Kerrey, *Learning Objectives, Task-setting and Differentiation*, Oxford: Nelson Thornes, 2002.
 47. G. M. Walton and G. L. Cohen, A brief social-belonging

- intervention improves academic and health outcomes of minority students, *Science*, **331**, pp. 1447–1451, 2010.
48. G. M. Walton, G. L. Cohen, D. Cwir and S. J. Spencer, Mere belonging: the power of social connections, *Journal of personality and social psychology*, **102**(3), pp. 513–532, 2012.
 49. S. A. Ambrose, M. W. Bridges, M. DiPietro, M. C. Lovett and M. K. Norman, *How Learning Works: Seven Research-Based Principles for Smart Teaching*, Hoboken: Jossey-Bass, 2010.
 50. D. Boud, R. Keogh and D. Walker, *Promoting Reflection in Learning: A Model*. In D. Boud, R. Keough and D. Walker: *Reflection: Turing Experience into Learning*, London: Routledge Falmer, 2005, pp. 7–17.
 51. C. M. Reigeluth, What is Instructional-Design Theory and How is it Changing? Instructional design theories and models: A new paradigm of instructional theory (2), pp. 5–29, 1999.
 52. S. Freeman, S. L. Eddy, M. McDonough, M. K. Smith, N. Okoroafor, H. Jordt and M. P. Wenderoth, Active learning increases student performance in science, engineering, and mathematics, *National Academy of Scientists*, **111**(23), pp. 8410–8415, 2014.
 53. J. Erbeltinger and T. Range, *Durch die Decke denken: Design Thinking in der Praxis*, München: Redline Verlag, 2015.
 54. A. Bergner and U. Rogler, *Do you speak design? Designkommunikation in und von Unternehmen*, Hochschule für angewandte Wissenschaften Coburg, 2013.
 55. T. Brown and B. Katz, Change by Design, *Journal of Product Innovation Management*, **28**(3), pp. 381–383, 2011.
 56. P. A. Almeida and P. Albergaria, Can I ask a question? The importance of classroom questioning. *Procedia—Social and Behavioral Sciences* **31**, pp. 634–638, 2012.
 57. T. Angelo and P. Cross, *Minute Paper*, Classroom Assessment Techniques: a Handbook for College Teachers, 2nd edition, pp. 148–153, 1993.
 58. W. Faulkner, Nuts and Bolts and People’—Gender-Troubled Engineering Identities, *Social Studies of Science*, **37**(3), pp. 331–356, 2007.
 59. C. Hill, C. Corbett, and A. St. Rose. Why So Few, <https://files.eric.ed.gov/fulltext/ED509653.pdf>, Accessed 4 May 2018.
 60. N. A. Fouad and R. Singh, Stemming the Tide: Why Women Leave Engineering. http://energy.gov/sites/prod/files/NSF_Stemming%20the%20Tide%20Why%20Women%20Leave%20Engineering.pdf, Accessed 04 May 2018.
 61. T. Angelo and P. Cross, *Minute Paper*, Classroom Assessment Techniques: a Handbook for College Teachers, 2nd edition, pp. 148–153, 1993.
 62. D. Whittard, *Reflections on the one-minute paper*, Working Papers 20151502, Department of Accounting, Economics and Finance, Bristol Business School, University of the West of England, 2015.
 63. L. Schiebinger, I. Klinge, I. Sánchez de Madariaga, H. J. Paik, M. Schraudner and M. Stefanick (Eds.) (2011–2015). Gendered Innovations in Science, Health & Medicine, Engineering and Environment. For US citations add: genderinnovations.stanford.edu; for EU citations add: <http://ec.europa.eu/research/gendered-innovations/>, Accessed 13 July 2017.
 64. A. Bandura, Self Efficacy: Toward a Unifying Theory of Behavioral Change, *Psychological Review*, **84**(2), pp. 191–215, 1979.
 65. S. Wurdinger, *The Power of Project-Based Learning: Helping Students Develop Important Life Skills*, Lanham: Rowman & Littlefield, 2016.
 66. J. Schlicht, Forschendes Lernen im Studium: Ein Ansatz zur Verknüpfung von Forschungs-, Lehr- und Lernprozessen, http://www.pedocs.de/volltexte/2013/8073/pdf/Fasshauer_JB_berufs_wirtschaftsp_Forschung_2013_Schlicht_Forschendes_Lernen.pdf, Accessed 13 July 2017.

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