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EDITORIAL

Perspectives on engineering education from the world of practice

This special issue on early career engineers responds to a key challenge in engineering education – that of bringing the largely separate worlds of engineering education and engineering practice closer together. There are compelling reasons why the two worlds need to enter into productive dialogue. It is increasingly felt that the gap between what engineering education offers and what the world of engineering practice needs has widened. In her report on the state of engineering education globally, Graham points to the tension between "what engineering science professors want to teach engineers to do, so that they can become young scientists and PhD students, and the needs of government and society, which is to create engineers to contribute to economic development and growth" (2018, 34). Clearly, graduates of professional programmes need to be well-prepared for their future careers and for their future contributions to societal and technical development. So, what role can and should engineering education play in closing the gap between education and practice?

Bringing the worlds of engineering education and engineering practice into a closer relationship poses many challenges and takes considerable courage and persistence on the part of researchers. The two worlds have different purposes (producing learning and doing productive work), have different systems, frameworks of operation, and are governed by different policies. A result of the separation of the two worlds over time, from a higher education perspective, is that much of what happens in the world of engineering practice can appear foreign and indecipherable. Accessing engineering firms in order to interview engineers or observe work practices is difficult as practitioners are protected and restricted by company protocols. Some are working on sites that are unavailable to researchers. Many are busy and have severe time constraints. Novice practitioners, who are a particular focus of this special edition, may not want to participate in a research project or reveal issues that have to do with gender imbalances and other power differentials in workplaces.

Despite the challenges, as the empirical studies in this special issue show, practicing engineers have much to offer higher education. Research on practice can inform engineering education and provide evidence for the choice of curricular modalities, pedagogies, and assessment practices that are effective in preparing students for the world of work. Practicing engineers are particularly needed as collaborators to ensure that engineering programmes stay current in the face of rapid technological change. There are several potential points of contact between engineering education and engineering practice and considerable potential for creative interactions between the two worlds, although sometimes deliberate interventions are necessary to support collaboration. In particular, there are many lessons to be learned from early-career engineers with recent experiences of higher education.

A significant proportion of research contributions in engineering education base their claims on notions such as 'industry needs', 'career success', 'professional development' or 'employability skills'. Yet, empirical evidence from studies of engineering practice that provide support for education interventions in terms of improved workplace performances is still scarce. The authors of the papers in this issue, therefore, are pioneers who have opened windows into the world of engineering practice. Their studies offer insight into how engineering education could be done differently. Incorporating insights gained through encounters with practicing engineers is likely to result in relevant

curricula, pedagogies of practice, and assessments that enable new configurations of technical and professional skills.

The authors are commended for undertaking research activities at a time when accessing practicing engineers has been even more challenging than usual. Early in 2019 the special issue editors put out a call for submissions to a special edition of the European Journal of Engineering Education on early career engineers. There was an overwhelming response to the call, we received 35 extended abstracts of which 22 were invited to be submitted as full papers and 10 of these were accepted for publication. We had hoped to receive the final manuscript submissions by June 2020, but with the pandemic raging, many academics' priorities shifted from their research to the pivot online and finding innovative ways to support students' learning. The authors of the included journal articles are congratulated, not only for making it all the way through to the final publication of this special issue, but for breaking new ground in engineering education.

Beddoes (2021), in this issue, notes the importance of recognising that "socialisation into engineering does not begin after graduation", commenting on the need to appreciate relevant insights gained from pre-university through to those which can be offered by experienced engineers. While this issue emphasised inquiry surrounding early-career engineers, much related understanding can be gained on issues concerning early-career engineers through research spanning this broader spectrum of time. For example, early-career engineers might benefit from a critique of engineering education learning outcomes and from the reflective accounts of more experienced professional engineers. Through the process of developing this special issue, the value which can be offered through these different perspectives became increasingly apparent, with contributions having remits spanning pre-university through to varying degrees of engineering practice experience. Figure 1 displays the articles and focal topics of this issue in the context of a progression from engineering education to professional practice and we then introduce them in the same order.

In the first article, Lowe et al. (2021) introduce the view that disciplinary knowledge is only one dimension of the competencies that engineering students and early career engineers must develop, noting the need for engineers to understand the nature of their profession in terms of its norms, conventions, cultural practices and professional language. With this premise, Lowe

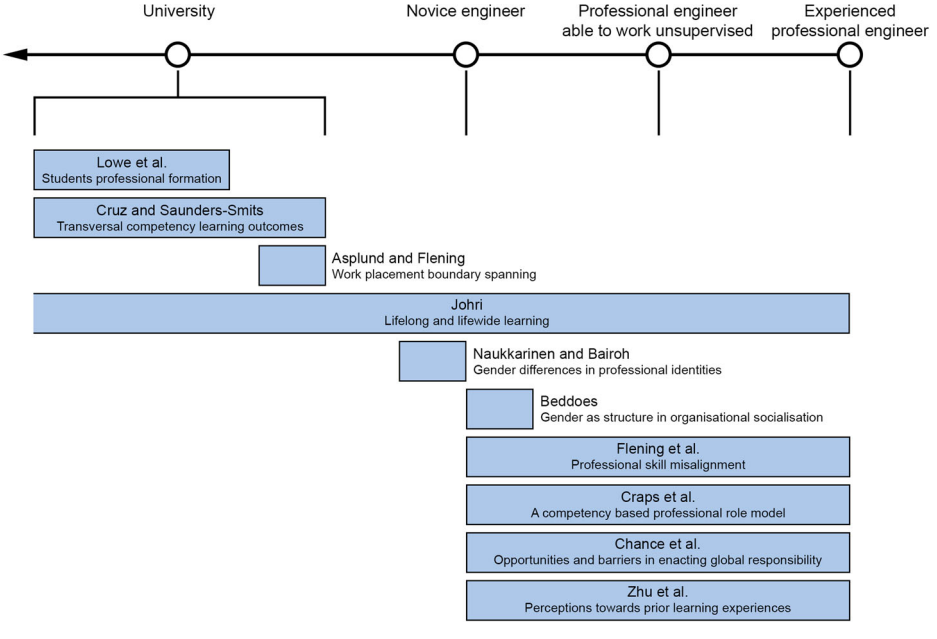

Figure 1. Summary of articles within this issue.

et al. (2021) describe a transformation in work placement models in engineering programmes at the University of Sydney. Engineering students used to engage with a traditional, typically 12 weeks long, work placement late in their degree programmes. However, since 2018 a new and more flexible 'Professional Engagement Program' which sees student self-select into a range of activities relevant to their programme of study, with a dominant focus on professional learning competencies (reflective of Engineers Australia Stage 1 Competency Framework) has been introduced. Following an activity, students record a description of the activity, categorise it, and complete a self-reflection. This study involved a text-based thematic analysis of more than 8500 of these self-reflections with objectives of determining the nature of competencies being explored across activities and gaining insight into the level of learning evidence relative to the revised version of Bloom's taxonomy (Anderson and Krathwohl 2001). A central finding of this study is that activities which are less prescriptive in terms of approaches to be adopted when problem solving are most likely to engage students in thinking about the nature of real-world engineering practice.

In the second article, Leandro Cruz and Saunders-Smits (2021) recognise the divide between industry required transversal competencies and their development in formal engineering education. In their study, which is part of the European PREFER (Professional Roles and Employability of Future EngineeRs) project, they offer a nuanced perspective on industry needs and desired levels of transversal competency development within engineering curricula. Their study involved three phases including determining perceptions of desired mastery levels for transversal competencies from industry stakeholders, comparing the transversal competencies with learning outcomes in two Dutch engineering programmes, and examining the levels of transversal competencies that lecturers perceive their students to achieve. A useful observation of this work was that while lecturers perceived transversal competencies to be developed within their courses, they often did not make this explicit in course syllabi. A further interesting contribution was that lecturers believed that students developed each transversal competency explored within the study to the level desired by industry through at least one course, which seemingly contradicts claims of a divide between industry needs and associated educational provision. This prompted the authors to raise important questions regarding whether transversal competencies are appropriately assessed in engineering education and whether students are aware that they are gaining expertise in them.

In the third article within this issue, Asplund and Flening (2021) frame the concept of boundary spanning as descriptive of people spanning organisational boundaries (Haas 2015) whilst focusing on the use of work placements and the transition between academia and industry for engineering students. Continuing the theme of misalignment between industry and academia, however now in the context of learning outcomes relating to research proficiency, Asplund and Flening (2021) conducted a qualitative, interview-based study with Masters students engaging with thesis projects in collaboration with industry. Initially, the authors interviewed 64 students during the first three months of a six-month Master's thesis project. This was followed by a second round of interviews with 50 of these students following the submission of their theses. From this, they offer a rich understanding of the challenges faced by students while working on a thesis in collaboration with industry, where differences in expectations was interpreted as one of the primary difficulties faced by the students. They also noted benefits from this experience, such as the insight gained by students into authentic engineering practice and the informal skill-building opportunities gained which would aid students transitioning from academia to industry.

In the fourth article, Johri (2021) again raises the issue of the incongruence between formal college or university engineering education and professional skills required of early career engineers. In his study, he implemented a combination of trace ethnography and netnography to provide insight into the lives of two software engineers spanning two decades from their initial development of interest in working with computers into the professional lives. Particular emphasis is placed on the contributions of informal learning experienced on their interest in and competency as software engineers. Examples of the nature of insight provided relate to the participants contributions to open-source software whilst in high school, and their engagement with internships and online

communities. A notable contribution of this study was in the unpacking of how their contributions in online communities supported their identity development as software engineers. Importantly, it was observed that the formal education the participants received was not considered redundant, but rather insufficient in terms of developing expertise. The participants engagement with informal modes of learning was considered useful in alleviating this knowledge gap.

In the fifth article, Naukkarinen and Bairoh (2021) introduce a gender dimension to the study of early career engineers, noting that the cultural landscape of engineering is masculine in many ways which can present challenges for female early career engineers as the climate can be misaligned with their personal identities. In response, they analyse the TEK Graduate Survey data from over 4000 early-career engineers to examine if the perceived importance and development of professional skills differs between males and females, and whether any resulting gender differences can be explained by gender distributions across various fields of engineering education. They conclude that smaller gender differences than theorised were observed in general. The most notable differences were that female early career engineers perceived social and altruistic aspects of engineering, such as communication, ethics, and sustainability, as more important than males. Further, they observed that males valued skills associated with technical innovation more, with females valuing managerial skills more. Altogether, the authors suggest that what females perceive to be important could be de-valued, and thus lead to them themselves being or feeling devalued during their engineering careers.

In the sixth article, citing that higher rates of attrition are observed in females than males, Beddoes (2021) presents a qualitative study exploring gender during the transition to work for early career engineers. With respect to gender, Beddoes makes the case that "an engineering-specific model of gendered socialisation is needed, one that accounts for gender as structure, not simply as a variable" (2) and through her work expands on Korte's (2009) model for organisational socialisation to include power privileges in a multi-directional model of gender structures in organisational socialisation processes and outcomes. Specifically, interviews were conducted with 18 participants, of which 12 self-identified as women and 6 identified as men, who worked in civil and environmental engineering firms in the United States. All participants had graduated from university and taken up their employment positions within the previous three years. Three sets of interviews were conducted with the participants over the course of approximately one year. Among others, questions in the first set of interviews focused on participants' first impressions of their workplaces and the biggest challenges they had faced in their job. Later interviews evoked reflections on what participants had learned and what their biggest challenges had been since the previous interview, what they wished they had known before graduating, as well as further exploring their individual responses to organisational socialisation surveys completed between the two sets of interviews. Through this work, Beddoes found that gender structures influenced organisational socialisation in the areas of relationship-building, work assignments and the division of labour, how performance was perceived, opportunities and the need to learn and adapt in new roles and ways in which people needed to learn or adapt, early-career engineers' sense of belonging, and their satisfaction in their employment.

Flening, Asplund, and Edin Grimheden (2021) further explore professional skills in the seventh article within this issue. In their work, they describe two perspectives offered throughout the pertinent literature, the universality view which is that professional skills are seen as generic and important for all practicing engineers immediately as they commence employment, and the integrative view which is that such professional skills cannot be understood independently of disciplinary technical skills. In light of these views, they present the problem that little is known about how different engineering practice contexts impact on the perceived importance of professional skills. Adopting a social realist theoretical framework, Flening, Asplund, and Edin Grimheden (2021) aimed to investigate differences in how early engineers in different practice-roles but from the same educational background understand engineering expertise. To achieve this, they adopted a two-part survey methodology to test two hypotheses. The first hypothesis was that early career engineers value

professional skills differently depending on their discipline, and the second was that the magnitude of any such difference decreased over time as engineers mature. A sample of 158 early career engineers from who graduated from a Swedish mechatronics programme between 2011 and 2018 responded to the survey. The sample was divided into two groups, one of which reflected early career engineers who saw their role as best described as that of a software engineer, and another which included early career engineers who describe their role as either managerial or relating to a core technical field other than software. Through a quantitative analysis the authors observed evidence to support both hypotheses and through an analysis of survey responses at an item level offer thematic explanations for their observations. Interpreting their results within the specialisation and semantic planes described within their theoretical framework, the authors question the universality view of professional skills highlighting the need to consider disciplinary differences in importance.

The eighth article in this issue also comes from the PREFER project. In their work, Craps et al. (2021a) aim to develop a competency-based professional role model for future engineers, which is validated by different stakeholders in industry and education. In working towards this aim, they recognised that engineers perform a variety of roles drawing on different professional and non-technical skills. For their study, the PREFER model was used as a theoretical framework, which was previously developed by the authors (Craps et al. 2021b), and which presents three roles of engineers including product leadership, operational excellence, and customer intimacy. A mixed methods sequential study was designed wherein 12 expert panels of stakeholders individually ranked competencies in terms of their importance to specific engineering roles, a process followed by group discussion within each panel designed to achieve consensus on 6-10 competencies. A meta-panel was also convened to consolidate the results. The study results in an extension of the PREFER model through the framing of relevant professional competencies associated with pre-existing roles of engineers, which offers the potential to support career development in engineering education and facilitate the development of professional and self-awareness within engineering education and for early career engineers.

In the ninth article, Chance, Direito, and Mitchell (2021) ground their work in the concept of global responsibility. With particular emphasis on civil engineering in the United Kingdom, Chance and colleagues present the important of acting ethically and sustainably, citing causes of why and consequences of when related standards are not adhered to. In response, they conducted a qualitative investigation based on interviews with eight early career engineers and one senior manager from London-based civil engineering firms. The central research question was what they, their employers, and Professional Engineering Institutions, have been doing in terms of sustainable and ethical practices and the collected data was analysed inductively through grounded theory type strategies. The authors present their findings relative to five questions. How do early-career engineers working in London conceptualise and define 'global responsibility'? How have they learned about global responsibility? What aspects of global responsibility do they feel able to influence in their day-to-day work? What associated opportunities and barriers have they encountered? How might professional engineering institutions, higher education institutions, and engineering educators better support early-career civil engineers in their efforts to enact global responsibility? While many insightful conclusions emerged, the authors note that despite the participants likely being proactive relative to the norm, their capacity to affect change in was quite limited. As such, a call is made to other stakeholders such as researchers and academics to become further involved strategically in crucial areas associated with the global responsibility of engineering and engineers.

In the tenth and final article within this special issue, Zhu et al. (2021) note that Chinese scholars have argued that the quality of engineering graduates is not meeting the needs of relevant enterprises. They cite evidence from Chinese employers which indicates that professional skills were considered more important than technical skills, and that a deficit in professional skills with respect to satisfying industry needs has been observed. Based on this, they present two research questions: What are the participants' perceptions towards their prior learning experiences? How have their prior learning experiences contributed (or not contributed) to the development of these knowledge, skills, and attributes? To address these questions, they conducted semi-structured interviews with 22

early- and mid-career engineers to obtain data for a thematic analysis. The participants gave mixed responses in terms of their perceived usefulness of college experiences, both at undergraduate and postgraduate level, with commentary centred around project work and skill development, learning to learn, and the uncertainty of future employment. From their analysis, Zhu et al. (2021) identified two themes associated with the sampled engineers project-work experiences with respect to how this type of activity benefited them in their professional engineering roles. These included 'working on project after project' which related to the accumulation of much project experience and 'reflection on action' where reflection was considered as an intentional activity involving the debriefing and summarising projects as well as reflecting both on the project and themselves.

In conclusion, the articles in this special edition offer critical insights into the nature of engineering practice, as well providing innovative examples of productive engagement between engineering education and the world of engineering practice. By reconnecting with practice, the authors have laid the groundwork for a new form of engineering education, one that takes seriously the preparation of engineering students to meet the many challenges in the process of becoming engineering professionals.

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