Period of claim: September 2019 to August 2025

Focus and relevance

Engineering practice research is the study of engineers and their work contexts. It forms a core part of engineering education research by providing educators with the empirical basis for what happens in practice to inform curricula and teaching. Despite calls for reform to better align engineering education with engineering practice, there remains a lack of empirical evidence on what engineers do and their work contexts. This lack of evidence contributes to the misalignment between what is taught and what engineers do (Buckley et al., 2022; Trevelyan & Williams, 2019).

The call for more longitudinal studies on practicing engineers is sustained (Brooks et al., 2011; Hess et al., 2017; Leydens, 2008; Pons, 2016; Shah et al., 2014), and to quote Heywood "There is a need to continue and refine studies of changing patterns in the workforce, particularly with respect to changes to individual careers over their lifetimes. There is also a need to investigate in fine detail the jobs that engineers do and the knowledge they use in fulfilling these tasks In particular, there is a need to know what engineers do in small organizations because the models educators have of what the process of engineering is are derived from large organizations. Without such knowledge it is difficult to see how an adequate statement of curriculum goals can be reached" (2014, p. 744).

The BeLongEng Project was initiated by Principal Investigator Crossin in late 2019 to address this research gap. The BeLongEng Project is a prospective longitudinal study of practicing engineers from Australia and New Zealand, and was designed with the aim to provide empirical evidence to support understanding of how engineering practice is changing. The study will inform both engineering education and professional practice. The guiding research questions include:

- What factors shape change in engineering practice (e.g., technological, organisational, and individual) over time?
- What are the career trajectories of engineers, and how do these vary by discipline and career stage?
- How do external factors (such as policy and new technology) impact engineering practice?
- How does professional identity, belonging, and inclusion change over time?
- How does the nature of engineering work evolve, and what drives this change?

These questions are designed to generate evidence that can inform curriculum design, workforce development, and policy, making the research highly relevant to engineering education and practice. More specific research questions are developed in sub-studies within the broader study.

Context and contribution

The BeLongEng Project is situated within engineering practice research and draws from broader educational and social science frameworks. Cross-sectional and longitudinal studies are types of observational study designs used to collect empirical evidence. Cross-sectional studies compare people or groups of people at a point in time; example studies from engineering practice include Ahmed and Wallace (2004), Kwasitsu (2003) and Pons (2015). Cross-sectional studies are ineffective for studying causality as subsequent studies rely on different samples, resulting in weaker statistical power. In contrast, longitudinal studies use repeated observations to investigate outcomes, and the factors that influence these outcomes, over time, and help to distinguish between age effects, cohort effects, and period effects that can arise from cross-sectional studies. Longitudinal studies typically track the same individuals, or people with similar characteristics over time. Retrospective longitudinal studies rely on collecting data at one time point on participants' past, and as such, are prone to recall bias. Conversely, prospective studies capture current or more recent data. Data collection points in retrospective longitudinal studies are referred to as waves. Longitudinal data can be quantitative or qualitative. Repeated quantitative measurements from multiple waves enables the investigation of causality and increases statistical power.

Longitudinal studies typically focus on medical and social science fields (e.g. Jones et al., 2018; Roberts et al., 2018; Solomon et al., 2018), including the careers of medical professionals (Anderberg et al., 2019; Joyce et al., 2010). Despite prevalence in other fields, longitudinal studies in engineering education and engineering practice literature are rare; with about a dozen studies to date (Ashforth et al; 2007; Ball et al., 1994; Brunhaver et al. 2018; Dahlgren et al., 2006; Eraut, 2007; Fouad and Singh, 2011; Friesen, 2011; Passow, 2011; Sheppard et al, 2009; Trevelyan and Tilli, 2008; Western et al, 2006; Windsor, 1999). Many of these studies have limitations; for example, participants' data in the Passow study were anonymised at each survey point, meaning that response data were not paired across data waves. In addition, the majority of these prior longitudinal studies on engineers focus on early-career engineers and typically terminate within five years post-graduation providing limited insights into the changes occurring later in engineering practice. The BeLongEng Project addresses the limitations of these previous studies by using a prospective cohort design to track individual engineers over

time, enabling paired data analysis and causal inference. The research will contribute to multiple bodies of knowledge, including engineering education and curriculum reform, career development and workforce studies, engineering identity research and longitudinal study designs.

Research validity/credibility and reliability/dependability

The BeLongEng Project is grounded in a post-positivist epistemological framework, and adopts a life course approach to career and individual development. We used the Systems Theory Framework (STF) as a foundation for the study, which was developed by Patton and McMahon (2014) in response to divergence in career development models. A simplified schematic of the STF for this study is in Figure 1.

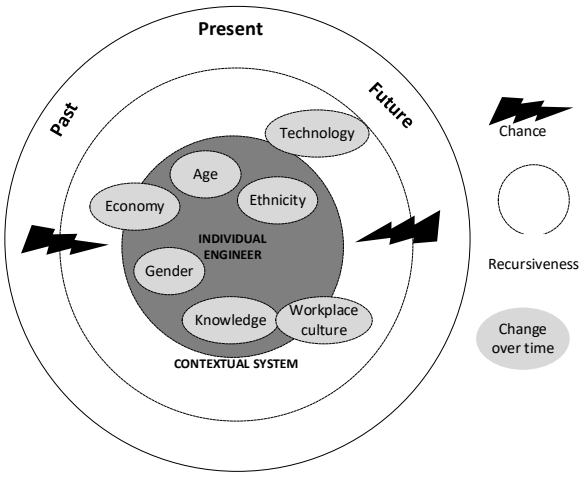

Figure 1. Schematic of Systems Theory Framework

The STF places the engineer at its core within an individual system (dark grey) encompassing intrapersonal factors (light grey) such as gender, age, skills, knowledge, and ethnicity. This context is shaped by a broader system (white), which includes social factors (e.g., workplaces, education) and environmental influences (e.g., geography, politics, employment conditions). Broken lines show the permeability between the systems, with variables changing over time and by chance. Our study uses STF as a dynamic model between engineers, their immediate contexts, and wider society coupled with a prospective longitudinal cohort design, to track engineers over a 20-year period (2022–2042).

The study design initiated in early 2020 through the establishment of an initial research team comprising of engineering practice and engineering education academics. (Enda Crossin [Canterbury], Sally Male [Melbourne], Anne Gardner [UTS], Les Dawes [QUT], Gerard Rowe {Auckland]). An external advisory board was formed in the early stages of the study to provide strategic guidance the project, including its design. The advisory board included representatives from Engineers Australia, Engineering New Zealand | Te Ao Rangahau, ACE New Zealand (a peak-body group representing engineering consultancies), the Australian Council of Engineering Deans, the New Zealand Council of Engineering Deans, and engineering representatives from Māori and Aboriginal and Torres Strait Islander communities. The establishment of this advisory board mirrors best-practice governance structures in other longitudinal studies, including the *Growing Up in Australia* study and *Building a New Life in Australia: The Longitudinal Study of Humanitarian Migrants*. The establishment of an advisory board with tangata whenua (people of the land) embeds Treaty of Waitangi | Te Teriti o Waitangi principles by fostering partnership in the design of the study, enabling active Māori and other indigenous participation, and protecting the interests of all study participants. A key outcome from the advisory board was to expand the research team to include organisational psychology academics (Katharina Näswall, Fleur Pawsey). The research team was later expanded to include Sarah Dart, with Anne Gardner, Sally Male and Les Dawes moving into support roles, and Gerard Rowe retiring.

The main method used in the study a survey, which is repeated and paired over multiple data waves. Data are then analysed using parametric and non-parametric multivariate statistical techniques. The survey was designed using a pilot study, before being finalised for the main study. Variables for the pilot study's survey were identified through workshops, interviews, and focus groups with 24 engineers (industry and academia), led by organisational psychology student, Jessica Richards (2021). In parallel to this work, the research team used a Johari's Window approach (Luft & Ingham, 1955) to explore open, blind, hidden, and unknown variables in engineering practice. The variables identified through the pilot study and research team were then collated, and validated scales associated with these variables were compiled into a pilot survey. The pilot survey was tested for face and content validity on a sample of practicing engineers (n = 40). The final survey includes four main question banks: demographics, work characteristics, psychometrics, and engineering activities. The development of a taxonomy of engineering activities by Crossin, Richards and Dart, was a significant piece of work from the study design, the publication of which is the 5th most read AJEE article of all time, and will form the foundation of other studies of engineering practice. Further variables are calculable from the survey data. In total, about 600 variables were collated in the first data wave. A data dictionary describing the BeLongEng survey is published on the study's website, supporting transparency and reproducibility. Cronbach's alphas for the psychometric variables ranged from 0.62 to 0.91, with most within acceptable reliability thresholds (Tavakol & Dennick, 2011), and were wholly consistent with the Cronbach alpha's reported in the original studies.

The study was approved by University of Canterbury's Human Ethics Committee (HREC 2021/157), with subsequent

ratification by QUT and UTS. This trans-Tasman ratification is significant; it is the only known New Zealand-based study which demonstrated reciprocity with Australia's human ethics framework.

Participant recruitment included advertising in engineering peak-body magazines and e-zines, social media, and invitation emails sent via 24 tertiary institutions who offer engineering qualifications in Australia and New Zealand. In return, the tertiary institutions were provided bespoke reports highlighting findings from their sub-samples. We estimate that over 63,000 people were invited to join the study via their *alma mater* engineering institution. No monetary incentives were used for participants due to lack of funding.

The first data wave recruited a total of 889 participants. Retention between the first and second wave was 62%, consistent with other longitudinal studies (e.g., Passow, 2012). Improvements to survey design and participant engagement strategies improved retention between the second and third data wave to 75%. The BeLongEng Project is now the only known study which has paired individual responses of hundreds of engineers across at least three data waves.

Transportability was embedded in the study design through three key mechanisms. First, the survey employs existing validated instruments and coding schema (e.g. ANZSIC Industry Classifications), enabling outcome comparisons between BeLongEng participants and other studies. Second, external researchers from Australian and New Zealand institutions can apply to access participant data to enable collaboration and other engineering practice studies. This mechanism is a world-first for engineering practice research. To date, two external research applications have been approved. Finally, the ethics protocol includes provision to invite BeLongEng participants into related studies, including those using different methodologies (e.g., ethnographic studies).

The credibility of the study has been widely recognised. Engineers Australia and Engineering New Zealand have acknowledged the importance of the study in workforce development strategies, Figure 2. Recently, the Royal Academy of Engineers (UK) identified the BeLongEng Project as exemplar, which is helping their consideration of establishing a similar study in the United Kingdom, Figure 3

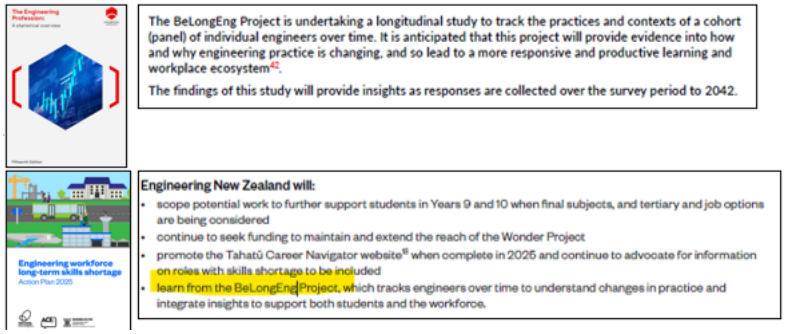

Figure 2. Recognition of applicability by EA and Eng. NZ.

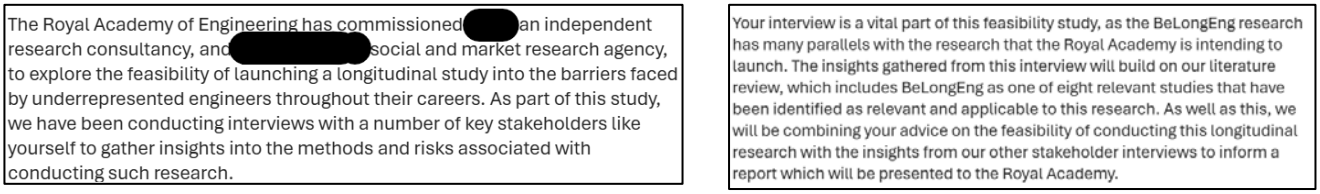

Figure 3. Recognition of transferability by Royal Academy of Engineers, UK.

Results and generalisability/transferability

The first wave of data (n = 889) provides baseline measures into engineering practice across a range of disciplines. Participants of the baseline were more likely to be younger, female, and more highly qualified, compared to the general engineering population. This skew offers opportunities to track underrepresented groups and longer career trajectories (Crossin et al. 2022).

Of the 889 participants, 790 identified to at least one discipline. A study of the engineering practices of this sub-sample (Crossin et al., 2023a) identified that graduate engineers were more engaged in advice-seeking and hands-on tasks, while experienced engineers were more management-based. Women engineers were more involved in people-related activities. These new findings complement existing evidence that engineering activities are experience differentiated and is a new piece of evidence indicating that engineering activities can be gender segregated.

Recent research on the BeLongEng participants focussed on understanding factors relating to their attrition and retention within the engineering profession, with Engineers Australia and Engineering New Zealand foundation funding and commissioning two sub-studies (Djung et al., 2024; Williams et al., 2024). Multivariate statistical analysis identified that engineers in Australia had greater job satisfaction and commitment when they experienced belonging at work, meaningful work, along with supportive supervisors. Meaningful work was also an important factor for engineers in New Zealand, but other factors were subtly different, with psychological safety, and peer support identified as important. In both sub-studies,

those with high intentions to leave often depart within a year. These insights were shared with engineering employers at Engineering New Zealand's Thrive! 2025 Conference, equipping employers with clear priorities on how they can improve workplace culture and foster longer, meaningful careers.

Immediate future research priorities for the study will be to better understanding the determinants of attrition and retention in the engineering profession, the alignment between competency frameworks and actual engineering activities, the impact of new technologies (e.g., AI) on engineering work and the differences in practice by engineering discipline, organisation size, and demographic strata.

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