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The BeLongEng Project – protocol and baseline data for a prospective longitudinal cohort study of engineers in Australia and New Zealand

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ABSTRACT

CONTEXT
Engineering practice research focusses on what engineers do (Stevens, Johri, & O'Connor, 2014). There is continued interest in the future of engineering work, and how engineering curriculum can respond to these future changes. Despite this interest, the empirical evidence on how engineering practice has changed is scant (Mazzurco, Crossin, Chandrasekaran, Daniel, & Sadewo, 2021; Stevens et al., 2014; Trevelyan, 2007)

PURPOSE OR GOAL
The aim of the BeLongEng Project is to provide empirical evidence for policy change in engineering education and engineering practice. The goal of this paper is to describe the study protocol and baseline cohort, including analysis of the cohort's demographics.

APPROACH OR METHODOLOGY/METHODS
The BeLongEng Project is a prospective longitudinal cohort study. Data waves will be collected over a 20-year time horizon using an online survey. In the baseline survey, collected in 2022, data were collected on participants' demographics, psychometric factors and the engineering activities they undertake at work.

ACTUAL OR ANTICIPATED OUTCOMES
We summarise the survey design, recruitment method, ethics, and data management protocols. The baseline cohort includes 889 participants. Participants were more likely to be women or female, from New Zealand, and be higher qualified, relative to the engineering population across Australia and New Zealand.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY
The BeLongEng Project has recruited a large cohort of engineers living in or who studied in Australian and New Zealand who will be followed prospectively to explore trends and relationships for engineering work, and the context in which the participants work. The project represents a significant opportunity for engineering education academics to draw upon empirical research to better understand the practice of engineers, and how this practice is changing.

KEYWORDS
Engineering practice, future of work, longitudinal

Introduction

Engineering practice and the contexts in which engineers work is ever-evolving. It has been forecast that Australian school leavers will change careers five times and will have worked with 17 different employers by retirement (Foundation for Young Australians and AlphaBeta, 2016, 2017; McRindle Research, 2014). The rise of automation is forecast to impact on the engineering profession (Frey & Osborne, 2013), with engineers spending less time undertaking routine technical tasks, and more time engaging with industry partners and undertaking strategy and decision-making work (Foundation for Young Australians and AlphaBeta, 2017). These factors are coupled with continued pressure for engineers to possess and maintain strong professional skills, including active learning, interpersonal skills, time management and problem-solving skills (Prinsley & Baranyai, 2015). It has been suggested that engineers of the future will need to be adaptable, flexible, resilient and creative to manage the challenges associated with globalisation (Crosthwaite, 2019). Finally, engineers of the future will likely demand increased work-life balance, translating in the need for flexibility in the way, where and how they work (PricewaterhouseCoopers, 2017).

Forecasts of the skills needed for engineers are not new, and some forecasts have not changed in decades, e.g. the need for collaboration skills (Bates, Martinelli, Lloyd, Stradling, & Vines, 1992; Lloyd, Ferguson, Palmer, & Rice, 2001). Concurrently, researchers have recognised a misalignment between engineering education and practice (Mazzurco et al., 2021; Trevelyan & Williams, 2019).

Engineering practice research seeks to understand the work that engineers do and their work contexts and is a fundamental aspect underpinning engineering education reform (Stevens et al., 2014). Despite this fundamental importance, the empirical research on engineering practice, including how this has changed remains sparse (Mazzurco et al., 2021; Stevens et al., 2014; Trevelyan, 2007).

Some engineering practice studies are cross-sectional in nature, typically comparing the differences in practice between groups of engineers, for example graduates and experienced engineers (Pons, 2015). Other engineering practice studies are longitudinal in nature, tracking engineers over time (Brunhaver et al., 2015). However, such longitudinal studies have historically focused on early-career engineers, and have terminated within 5 years post-graduation, limiting the insights into the long-term changes occurring in engineering practice.

The lack of empirical evidence of engineering practice, and how changes to engineering practice, was the catalyst for the BeLongEng Project. The BeLongEng title is intended to capture the longitudinal nature of the project, the focus on engineering, as well as what it means to be an engineer and belonging. The BeLongEng Project aims to provide evidence for policy change in engineering practice and education; addressing the lack of empirical research on engineering practice. In this paper, we described the research protocol for the BeLongEng Project.

Methods

The BeLongEng Project is a prospective longitudinal cohort study. Data will be collected over a 20 year time period, with the baseline recruitment survey in 2022, with follow-up surveys at 1, 3, 5, 7, 10, 15 and 20 years.

Our population of interest is people with engineering qualifications, who have either graduated from a tertiary institution, or who are immigrants, in Australia and New Zealand. The formal participant criteria were 1. Participants must have a) a 2-, 3-, or 4- year engineering qualification from an Australian or New Zealand tertiary institution; or b) a postgraduate engineering qualification from Australia or New Zealand; or c) rrecognition as having equivalent standing to at least a graduate level through membership to a professional engineering society in Australia or New Zealand, or d) live in Australia or New Zealand and be eligible for membership to Engineers Australia or Engineering New Zealand, and 2. Participants must expect to be working for at least the next 10 years. The first criterion is our definition of an engineer, which was derived by considering working definitions from peak bodies. The second criterion was imposed to ensure the recruitment of participants who would likely to be working through the majority of the study period.

Survey design

Determinants and outcomes of interest were identified through workshops with the project team members, coupled with interviews with practicing engineers in a pilot study, described elsewhere (Richards, 2021). The identified determinants and outcomes included demographics, education background, work experience, attrition and retention factors for those in, and who have left, the engineering profession, social capital, mentorship, workplace culture, continual professional development, work characteristics, stress and well-being, standing in the profession, activities at work, satisfaction, adaptability, and sense of identity. An aspirational time limit to complete the survey was set to 45 minutes, based on the time to complete similar longitudinal surveys.

The baseline survey included four sections; demographics, work characteristics, psychometric measures and engineering activities. A summary of the measures in these sections are reported in Table 1. Where possible, display and skip logic were used to limit the questions to only those relevant to participant's work context.

Survey questions relating to demographics and job characteristics were developed using existing measures from longitudinal studies (Tustin et al., 2012), Australian and New Zealand classification systems, census, labour workforce survey, and validated instruments on workplace flexibility and disability status. The gender variable is from the Australian Bureau of Statistics (2021), and includes binary sex identifiers. Questions relating to continuous professional development (CPD) were developed from CPD categories defined in Engineers Australia and Engineering New Zealand's CPD systems. New questions were developed for the nature of mentee support based on (reference). Where possible, data are coded to existing Australian and/or New Zealand classification systems, including for ethnicity, country, first language, study field, occupation, industry, and for Māori participants, iwi (tribe) and hapū (clans or descent groups) affiliation. For fields with standard classifications (e.g. occupation, industry), participants chose from an auto-fill list or entered in a free-form response. Free-form responses will be subsequently coded to the classification systems.

The engineering discipline classification system was derived by compiling lists of disciplines from different sources, including from Australian and New Zealand education and industry classification standards, and lists of disciplines commonly recognised by professional bodies. Lists of engineering tertiary institutions and engineering qualifications were developed by compiling lists of institutions offering current or past accredited 2-year (Dublin Accord), 3-year (Sydney Accord) or 4-year (Washington Accord) engineering programmes, and the name of each qualification. Similar qualification endorsements were clustered, for example Chemical Systems, Chemical, and Chemical Technology were combined to Chemical (including Systems and Technology).

Most psychometric measures and the engineering activities used 5-point Likert scales. Psychometric measures were based on existing instruments. The activities comprised of 86 generic engineering activities, collapsible into a set of 21 generic activity descriptors. The engineering activities and descriptors were developed from the O*Net classification system for engineering jobs, coupled with a review of empirical engineering practice literature. Engineering activities were measured using 5-point Likert scales for frequency and importance. The pilot survey (n = 40) was used to test face and content validity, and the survey was finalised in 2021. A summary of the determinants and outcomes of interest are reported in Table 1. The full codebook, including references for the different measures, will be made available on the project website.

Table 1: Summary of determinants and outcomes in survey

Demographics	Work characteristics	Psychometrics	Engineering activities
• Year of birth • Age • Gender • Ethnicity • Māori descent • Iwi/hapū affiliation • Aboriginal or Torres Strait Islander descent • Country of birth • Residency characteristics • Number of child and adult dependants • First language • English proficiency • Family background • Highest engineering qualification • Other highest qualification • Study characteristics • Disability status	• Employment and labour force status • Hours worked • Employee or employer • Occupation • Industry • Income • Employer size • Location of work • Language at work (other than English) • Work patterns • Working away from home • Workplace flexibility • Job departure characteristics • Professional society membership • Chartered Professional status • Registered engineering status • Engineering discipline • Mentee (protégé) characteristics • Continuing professional development	• Role overload • Technology • Techno-insecurity • Techno-productivity • Workplace mistreatment • Organisational support • Meaningful work • Organisational psychological safety • Work life balance • Career aspirations • Job security • Perceived external employability • Wellbeing • Stress • Engineering identity • Career satisfaction • Workplace flexibility • Belonging • Five factor personality • Career commitment • General Self-Efficacy • Work locus of control • Turnover intentions • Innovation and flexibility • Global engineering competency (behavioural)	• Getting Information • Monitoring processes, materials or surroundings • Inspection processes, materials or surroundings • Handling and moving objects • Interacting with equipment • Estimating characteristics • Judging the qualities of things, services or people • Processing and evaluating information • Analysing data or information • Making decisions and solving problems • Thinking creatively • Updating knowledge • Managing inventories and waste • Documenting and recording information • Communicating with others • Resolving conflicts and negotiation • Training and teaching others • Guiding, directing and motivating others • Providing advice to others • Planning and organising • Other activities

Recruitment

The baseline recruitment data wave was deployed from February 2022 to June 2022. Additional data waves on the same cohort of participants will occur in May of 2023, 2025, 2027, 2029, 2032, 2037 and 2042, with a 6-week survey period. Recruitment pathways included paid advertising in engineering peak-body magazines and e-zines, paid social media advertising (LinkedIn), articles published by the project's peak body supporters, and invitation emails via 24 tertiary institutions in Australia and New Zealand. We did not track the mode by which participants joined the study. No monetary incentives were used for participants. Participants could choose to join a participant club to attend networking events hosted after each data wave.

Participants joined the study by following a link to an anonymous Qualtrics survey, and, following a consent process, by passing the participant criteria and entering personal information. Participants then progressed to the remainder of the project survey. Participants who did not complete the survey were sent a reminder email within two weeks before the end of the recruitment period. Participants who completed and submitted the survey were included in the baseline study.

Census data

We use Australian 2016 and New Zealand 2018 census data from the Australian Bureau of Statistics' Table Builder (2022) and StatsNZ to check the representativeness of the sample, relative to the population who hold at least a level 6 qualification in Engineering and Related Technologies. We did not adjust the population estimates to account for population change over time. We combined qualification level strata of these census data to account for differences between the Australian and New Zealand qualification systems.

Ethics, data management and publishing

The pilot study was granted ethics approval by by the University of Canterbury Human Ethics Committee (HREC Reference 2021/41). An ethics application for the main study was subsequently reviewed and approved the University of Canterbury's Human Research Ethics Committee (HREC Reference 2021/157). Participants consented to joining the project through an online form at the start of the survey.

The main risks for participants pertain to disclosure of sensitive demographics (e.g. ethnicity, gender), psychological, social and sensitive issues. These risks were managed by allowing participants to opt-out of answering sensitive questions (e.g. ethnicity, stress), and by providing participants with details for support services. The social risks were associated with a likelihood that some participants will be known by the researchers. This risk is mitigated through de-identification of data, described below.

Participants were assigned a unique identifier during their completion of the survey. After the survey period closed, data were de-identified by removing identifiable information from the database. The personal identifiable data linked to the unique identifier are stored in a separate location to the de-identified data, and are only accessible by the principal investigator. De-identified participant data are electronic, and are stored on a secure, password protected cloud-based storage system, only accessible by project team members named in the ethics application.

Results from the study will be aggregated for reporting in peer-reviewed journals, presentations, conferences and workshops with academia, industry and engineering peak bodies. In addition, the project's advisory board (which includes representatives from engineering peak bodies) will be consulted to identify opportunities for dissemination and impact. To protect identification of participant, the threshold for reporting participants' data (minimum cell size) is 5. Aggregated results will shared with the tertiary institutions who assisted with participant recruitment. Researchers external to the project team will be able to apply to access de-identified data, and any external researchers will need to adhere to additional ethics protocols, including review of manuscripts the principal investigator.

Results

We received a total of 889 completed and submitted responses to the baseline survey. The time to complete the baseline survey was characterised by a positive-skew distribution (time values were clustered towards shorter times); likely a result of some participants (in the right hand side of the distribution) resuming the survey after a period of time. The majority of participants appeared to have completed the survey in one session, with an average completion time of 45 minutes.

A summary of participant gender, age, country of residence and highest engineering qualification is reported in Table 2. Some participants nominated completing a diploma in engineering, which is a Level 6 qualification in the New Zealand system, and a level 5 qualification in the Australian system. Participants' self-reported engineering discipline are reported in Table 3. The majority (n = 558) of participants listed multiple engineering disciplines, with project management, civil, management, software, mechanical, construction, water/wastewater and manufacturing engineering each representing at least 10% of the nominated disciplines. 80 participants indicated that they do not practice engineering.

Table 2: Participant numbers by gender, age, location, and highest engineering qualification level.

Variable	Attribute	Sample Number	(%)	Census estimate (%)
Gender	Man or Male	635	(72%)	85%
	Woman or Female	239	(27%)	15%
	Non-binary	11	(1%)	N/A
	Another term	<5	N/A	
	Prefer not to say	<5	N/A	
Age	20-24	63	(7%)	5%
	25-29	184	(21%)	12%
	30-34	165	(19%)	13%
	35-39	113	(13%)	12%
	40-44	98	(11%)	11%
	45-49	108	(12%)	9%
	50-54	80	(9%)	9%
	55-59	61	(7%)	8%
	60-64	11	(1%)	7%
	65+	6	(<1%)	14%
Country of residence	Australia	451	(51%)	82%
	New Zealand	349	(39%)	18%
	Canada	7	(1%)	N/A
	England	9	(1%)	
	Singapore	8	(1%)	
	United States of America	20	(2%)	
	Other	45	(5%)	
Highest engineering qualification	Diploma	11	(1%)	21%
	Advanced Diploma	<5	N/A	
	Associate Degree	<5	N/A	
	Bachelor / Bachelor with Honours	588	(66%)	62%
	Graduate Diploma	7	(1%)	
	Postgraduate Certificate	5	(1%)	
	Postgraduate Diploma	8	(1%)	
	Masters	183	(21%)	13%
	PhD or Doctorate Degree	75	(8%)	3%
	Other	8	(1%)	N/A
	None	<5	N/A	N/A

Table 3: Participant engineering discipline. Number of participants and the percentage of sample are not unity due to participants nominating multiple disciplines.

Discipline	Number (%)	Discipline	Number (%)
I do not practice engineering	80 (9%)	Infrastructure	80 (9%)
Aerospace	23 (3%)	Management	137 (15%)
Agricultural	7 (1%)	Manufacturing	91 (10%)
Architectural	7 (1%)	Maritime or Naval	19 (2%)
Asset Management	59 (7%)	Materials	36 (4%)
Automotive	14 (2%)	Mechanical	107 (12%)
Biomedical	22 (2%)	Mechatronic	31 (3%)
Building Services	38 (4%)	Minerals processing	13 (1%)
Chemical	36 (4%)	Mining	21 (2%)
Civil	183 (21%)	Petroleum	16 (2%)
Computer Hardware	26 (3%)	Process	55 (6%)
Construction	100 (11%)	Project Management	196 (22%)
Electrical	83 (9%)	Rail	27 (3%)
Electronic	55 (6%)	Renewable Energy	57 (6%)
Environmental	58 (7%)	Robotics	19 (2%)
Fire	6 (1%)	Software	135 (15%)
Food	17 (2%)	Structural	68 (8%)
Forestry	<5 (N/A)	Subsea / Ocean	9 (1%)
Geotechnical	27 (3%)	Systems	75 (8%)
Health and Safety	14 (2%)	Transportation	67 (8%)
Industrial	48 (5%)	Water/Wastewater	92 (10%)
Humanitarian	<5 (N/A)	Other	57 (6%)
Information and Communications	59 (7%)		

Discussion

On average our participants are more likely to be a woman or female, younger, more highly qualified, and reside in New Zealand, relative to the population in Australian and New Zealand with qualifications in engineering and related technologies (Table 2). The relatively higher representation of women or females in the cohort is promising; we were initially concerned that if we achieved typical representation for this stratum, that potential attrition of these participants from the study would have led to under-representation. We do not know the reason for the higher representation of women or females in the cohort, but this could be associated with a willingness to participate in a project which has the potential to inform how the profession could improve support of women or female engineers. Similarly, the higher representation of those with Masters or PhD qualifications could be associated with participants who value the importance of research. The higher representation of participants from New Zealand, relative to the population, is likely the result of a relatively higher proportion New Zealand engineering education institutions who assisted in recruitment (8 of 16) compared with those in Australia (16 of 42), and potentially associated with reluctance from invitees outside of New Zealand to join a study that was led by a New Zealand institution. The skew away from older participants (65+) is likely due to the criteria for our participants to be expecting to work for at least the next ten years; this would have excluded some close to retirement from participating. In Australia, between a quarter and half of engineering graduates do not work in engineering jobs (Palmer, 2021, Trevelyan and Tilli 2010). Little is known about the practice of these graduates including their employment outcomes (Palmer 2018) and the engineering skills that are applied in other fields. Recruiting participants who left the engineering profession was a challenge in this project. Despite these challenges, the participants who no longer associate to an engineering discipline (Table 3), coupled with their job and industry classification data, will provide valuable insights into their work and work contexts. The skew towards younger people (under the age of 29) may also represent an opportunity to better track these participants.

Future work

We plan to further analyse the baseline data, including demographic classification, and calculation of additional descriptive statistics. We will calculate internal consistency for multi-item measures, and use exploratory and confirmatory factor analysis to better understand the relationships within the data. We intend to further refine the survey, including identifying similar items and assessing correlations between these items. Following the second data wave, we intend to employ multi-variate statistics to begin to explore the effect of time.

We also intend to introduce a mechanism for researchers external to the project team to apply for access to de-identified data for their own research. To apply, external researchers will need to describe the aims, objectives, methods for their research, including which field(s). External researchers will be prevented from accessing higher risk data, particularly relating to psychological measures, and where there is a risk of re-identifying participants. Identifying information will never be shared with external researchers.

We will deploy the next data wave in May 2023. Finally, we are considering deploying a similar instrument for another cohort, focussed on recent engineering graduates. A second cohort will allow for additional cross-sectional comparisons, and may increase the relative participation of graduates who do not work in engineering.

Conclusions

In this study, data will be collected analysed on the career trajectories of people with engineering qualifications from Australia and New Zealand, along with work-context factors. Understanding these trajectories and the factors that influence them will assist engineering educators, researchers, and the broader engineering industry to describe expected outcomes, and to plan to improve work and educational programmes to better prepare engineers for the changing nature of work. This study will make an important contribution to the very limited longitudinal data on engineering practice.

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