Future-proof Engineers with Transformative Calibres

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CONTEXT Inadequate preparation of Engineering students for the 21st-century workplace is becoming a lightning rod for criticism. While STEM skills are set to underpin most of the emerging occupations, decades of efforts to re-engineer tech-based curricula seem to have made little headway in enhancing graduate employability. To date, studies contrasting different stakeholders' views on the essential capabilities of graduate engineers have largely settled on leveraging generic skills in technical curricula. Yet the gap remains wide between academic training and the evolving engineering profession. It is questionable if the incorporation of generic transferable skills into discipline-learning alone is sufficient to produce engineers for the future.

PURPOSE This study aims to provide new and structured insights into focuses of Engineering students and employers/industry stakeholders on career/employability development.

APPROACH This study adopts a framework approach to re-calibrate the professional preparation agenda. The Career Information Literacy Learning Framework (CILLF) is a framework created with STEM academics' inputs. It provides a mechanism to generate differentiators of focuses on career/employability development between Engineering students and employers/industry stakeholders. The Career Information Literacy (CIL) survey was conducted with final year Engineering capstone unit students (n=63, response rate 64%) at a STEM faculty in an Australian university (n=517, response rate 44%). A parallel, concurrent CIL survey with STEM employers targeting these students was conducted (n=62, response rate 78%). CIL profiles between student cohorts and between students and employers were compared.

RESULTS Profile analysis and Hotelling's T^2 test revealed no significant focal difference between final year Engineering capstone unit students and their STEM peers. However, significant difference existed between the Engineer student cohort and their potential STEM employers in focuses on career/employability development. Further Wilcoxon Rank Sum Test highlighted that Employers distinguish generic (cross-discipline), situated (discipline-specific) and transformative (trans-discipline) aspects of career/employability development, with the transformative aspect being most the prominent and desirable. However, such emphases were not discernible by the Engineering students.

CONCLUSIONS The CIL analysis uncovers that transformative capabilities are highly desired by STEM employers but remain largely under-detected by Engineering students. This discovery broadens the previously limited notion of adding generic skills to discipline-based learning to arrive at satisfactory professional preparation of future engineers. It also opens up a new line of inquiry into constituents of transformative capabilities.

KEYWORDS Engineering education, STEM employability, Career information literacy, Capstone units

Introduction

Inadequate preparation of Engineering students for the 21st-century workplace is becoming a lightning rod for criticism. While STEM skills are set to underpin most of the emerging occupations, decades of efforts to re-engineer tech-based curricula seem to have made little headway in enhancing graduate employability. To date, plenty of studies contrasting different stakeholders' views on the essential capabilities of graduate engineers have largely settled on leveraging lists of "additional" skills in technical curricula. Yet the gap remains wide between academic training and the evolving engineering profession. It is questionable if the mere incorporation of generic, transferable skills into discipline-learning is sufficient to produce engineers for the future.

We contend that, fundamentally, it is problematic to conflate employability development with *lists* of additional skills. Lists often lead to the production of itemised attributes which can be too generic for specific cohort needs, or too prescriptive to be applied across different programs of study. Conceptually, lists are also limited in their ability to show complex relationships between concepts. Such skills lists may be even less effective in the context of the engineering discipline given its multi-disciplinary and multi-faceted nature.

To capture the interrelated elements in career and employability development, we need a relational, structural thinking model with contextuality of fundamental learning, career development and discipline approaches. This model can serve as a tool to measure elements of career and employability development in higher education.

Purpose

This study adopts a framework approach as a way to re-calibrate the professional preparation agenda. It aims to provide new and structured insights into focuses of Engineering students and employers/industry stakeholders on career/employability development. To this end, we refer to the Career Information Literacy Learning Framework (Lin-Stephens et al., 2017, Figure 1).

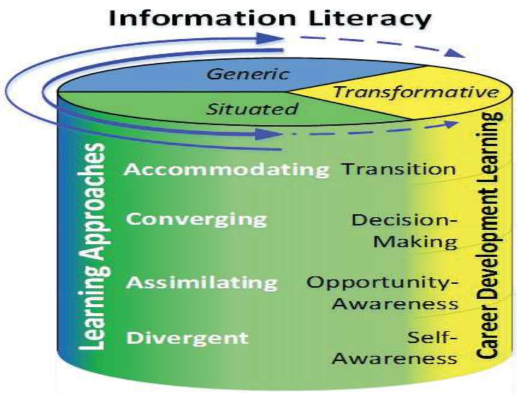

Figure 1: The Career Information Literacy Learning Framework (Version 2.0) (Lin-Stephens et al., 2017)

The Career Information Literacy Learning Framework (CILLF) (Lin-Stephens et al., 2016, 2017) unites three key theoretical frameworks in learning and teaching to form one conceptual device to gauge career and employability development in the context of higher education learning. It integrates models of Kolb and Kolb's (2015) learning approaches, Watts' (2006) career development learning, and Lupton's (2008) information literacy into a single framework which juxtaposes elements of Generic (cross-discipline), Situated (discipline-specific), and Transformative (trans-discipline) learning.

Following successful validation of the framework with data from academics, employers and students (Lin-Stephens et al., 2016, 2017), the CILLF is used here to delineate the relationship between several key aspects of university learning, which are by nature discipline-based, generic, transformative or career development related. In addition, we aim to use the CILLF to capture students' and employers' varying focuses on these aspects.

Approach

Applying the Career Information Literacy Learning Framework

The CILLF is a framework created with STEM academics' inputs. It provides a mechanism with differentiators of focuses on career/employability development between Engineering students and employers/industry stakeholders. By identifying these focuses, we can detect whether differences exist between student cohorts, and between students and employers.

Based on the CILLF, Career Information Literacy (CIL) survey instruments were developed. The CIL survey contains the CILLF attributes (Table 1.) with choice items coded according to these attributes (Table 2). The CIL survey provides a structural way for students to gauge their focuses on career and employability development, and for employers to discern key selection requirements of their ideal candidates to hire. We can then compare the CIL profiles between student cohorts as well as between students and employers.

Table 1: CILLF coding reference

Learning Approaches	***Career Development Learning***	***Information Literacy***		
		Generic	Situated	Transformative
Diverging	Self Awareness	***DSG***	***DSS***	***DST***
Assimilating	Opportunity Awareness	***AOG***	***AOS***	***AOT***
Converging	Decision Making	***CDG***	***CDS***	***CDT***
Accommodating	Transition Learning	***ATG***	***ATS***	***ATT***

We pose two research questions to understand Engineering students' focuses on career and employability development.

RQ1: Does the Engineering student cohort share the same focuses on career and employability development as their STEM peers?

RQ2: Does the Engineering student cohort chare the same focuses on career and employability development as their STEM employers?

Data collection

The Career Information Literacy (CIL) survey was administered to 34 final year capstone unit students at a STEM faculty in an Australian university. The survey was administered at the end of semesters face to face. This paper reports findings from the Engineering student cohort. A parallel, concurrent CIL survey was conducted with STEM employers who approached this faculty via the Career and Employment Service to recruit STEM students.

Data analysis

Profile analysis and Hotelling's T^2 test were deployed to analyse the similarity of score profiles between cohorts. Two hypotheses were tested to check the significance of different patterns- Parallelism and Coincidence. In addition, Wilcoxon Rank Sum Test was used to determine differences between Generic, Situated, and Transformative learning.

Table 2. Questions 1& 2 for Students and Employers/Industry Stakeholders

QN	Students	Employers/Industry Stakeholders	Code
Q1	**How important are the following to you for your next career move?**	**What do you value in a candidate?**	
1.1	Understanding your own interest, skills values, strengths, etc.	Their self-understanding of interests, skills, values, strengths, etc.	DSG
1.2	Your discipline-based knowledge, skills and approaches	Their discipline-based knowledge, skills and approaches	DSS
1.3	Ability to critically reflect on your motivation and behaviour in making career transitions	Critical reflective ability on one's motivation and behaviour in making career transitions	DST
1.4	Knowledge of broad career options	Knowledge of broad career options	AOG
1.5	Knowledge of specific work opportunities & industry requirements to which your disciplinary learning would be an asset	Knowledge of specific work opportunities & industry requirements to which their disciplinary learning would be an asset	AOS
1.6	Motivation and knowing how to contribute to any work in a meaningful way	Motivation and knowing how to contribute to any work in a meaningful way	AOT
1.7	Ability to evaluate your preferred career choices	Ability evaluate one's preferred career choices	CDG
1.8	Ability to target specific jobs, based on relevance of your personal profile, learning, experiences and circumstances	Ability to target specific work, based on relevance of one's personal profile, learning, experiences, and circumstances	CDS
1.9	Ability to think outside of the box in career decision making	Ability to think outside of the box in career decision making	CDT
1.10	Sound skills to handle job application & recruitment process	Sound skills to handle job application & recruitment process	ATG
1.11	Ability to effectively show how you can add value to an employing organisation based on who you are and what you study	Ability to effectively show how one can add value to an employing organisation based on who they are and what they study	ATS
1.12	Ability to challenge your existing practices and take critical actions to adapt to changing environments	Ability to challenge one's existing practices and take critical actions to adapt to changing environments	ATT
1.13	Other (please specify):	Other (please specify):	
Q2	**What contributes to your employability?**	**What influences your hiring decisions?**	
2.1	Degree relevance & specific skills	Degree relevance & specific skills	
2.2	Generic/transferable skills evidenced in a range of activities (work experience, extracurricular activities, volunteering, etc.)	Generic/transferable skills evidenced in a range of activities (work experience, extracurricular activities, volunteering, etc.)	
2.3	Application quality and interview performance	Application quality and interview performance	
2.4	Prior contact with employers through work-integrated programs, internships, networking, volunteering, paid and unpaid work, etc.	Prior contact with candidates through work-integrated programs, internships, networking, volunteering, paid and unpaid work, etc.	
2.5	Referral/recommendation	Referral/recommendation	
2.6	Other (please specify):	Other (please specify):	

Results

Demographic and activity-based features of the Engineering student cohort and the whole of STEM faculty's cohort are summarised in Table 3. The Cronbach's alpha value for the Engineering cohort is 0.90, giving us confidence of the robustness of estimates derived from the statistical tests. The Engineering student cohorts' response rate is also very high (64%).

Table 3. CIL survey capstone unit student respondents' characteristics (Engineering cohort vs Whole of STEM faculty cohort)

	Engineering cohort	STEM whole faculty
Total number of responses (n)	63	517
Total number of enrolment (N)	98	1176
Response rate	64%	44%
Male	89%	67%
Female	8%	32%
Age		
19 or under	0%	0.4%
20-25	81%	81%
26-30	13%	10%
31-40	3%	6%
41+	3%	3%
Activities in the past 12 months		
Part time work	68%	75%
Job search	48%	49%
Unpaid work experience	40%	28%
Student groups/societies	33%	28%
Volunteer or community work	19%	30%
Full-time work	17%	11%
Project work involving external clients	13%	21%
Professional association involvement & networks	11%	8%
Overseas exchanges or studies	8%	6%
Average total paid work history	3 years 1 months	4 years 2 months
Average total unpaid work history	3 months	10 months
Plan within 1 year of completing degree		
Work	86%	73%
Further study	24%	37%
Other	3%	10%

Table 4 outlines the STEM employer/industry stakeholder respondents' characteristics. (n=62, N=80, response rate 78%).

Table 4. CIL STEM Employer/Industry Stakeholder Survey Respondent Characteristics

	Frequency	Percentage
Organisation type		
Large enterprise (200+)	28	46%
Small/Medium Enterprise (< 200)	25	41%
Government	5	8%
Not for profit	4	7%
Male	24	39%
Female	38	62%
	Length of time	
Average experience in workforce	13 years 3 months	
Average experience in hiring	7 years 5 months	

Profile analysis illustrates the similarity and difference of score profiles between cohorts. Following this, Hotelling's T^2 test detects parallelism and coincidence of the score profiles to establish if differences are significant.

Parallelism: Cohorts are concluded as different in their focuses on career and employability development if their CIL profiles are not parallel, i.e. they exhibit incongruent scores across key measurements.

Coincidence: If the cohorts' profiles are parallel between variables, we test further to see if the cohorts' scores are at equal levels across variables. Cohorts are concluded to have different profiles if they do not have the same value for each measurement (non-coincidental).

As we can see from Figure 2 and 3, the Engineering student cohort's CIL profiles does not present significant difference from their STEM peers for both Q1 (CIL questions) and Q2 (supplementary questions). Please note that the data points in Figure 2-5 are connected to assist visibility; therefore, the lines do not represent trends.

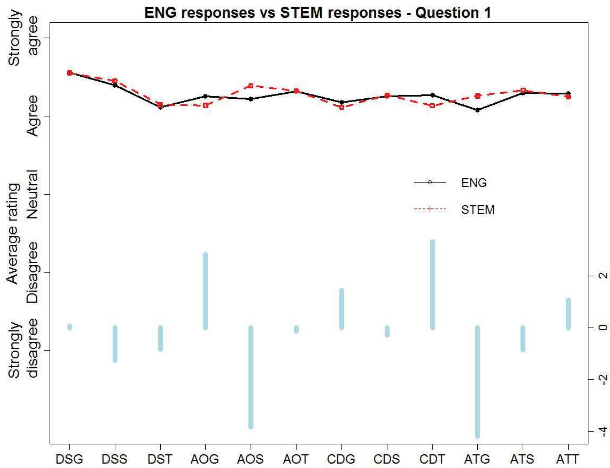

Figure 2. Q1 Responses Engineering Cohort vs. Other STEM Peers

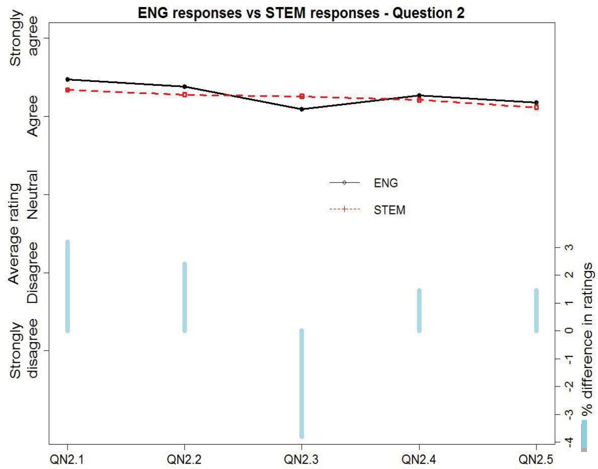

Figure 3. Q2 Responses Engineering Cohort vs. Other STEM Peers

Hotelling's T^2 (Table 5 and Table 6) confirmed that there is no statistically significant difference between the Engineering student cohort and their STEM peers.

For RQ1, therefore, we conclude that there is no intra-cohort difference between Engineering students and other STEM students in their focus on career and employability development.

Table 5. Hotelling's T^2 Test Results Q1 Engineering Cohort vs. Other STEM Peers

Hypothesis	Hotelling's T^2	Critical Value	P-value
Parallel	13.57	20.277	0.48
Coincident	0.026	3.86	1.00

Table 6. Hotelling's T^2 Test Results Q2 Engineering Cohort vs. Other STEM Peers

Hypothesis	Hotelling's T^2	Critical Value	P-value
Parallel	7.17	9.61	0.21
Coincident	0.336	3.86	1.00

However, for RQ2, profile analysis and Hotelling's T^2 test revealed significant differences in focuses on career/employability development between final year Engineering capstone unit students and their potential employers.

Figure 4 and 5 show the very different CIL profiles between Engineering student respondents and their STEM employers.

Hotelling's T^2 (Table 7 and Table 8) confirmed the CIL profile difference between the Engineering student cohort and STEM employers to be significant.

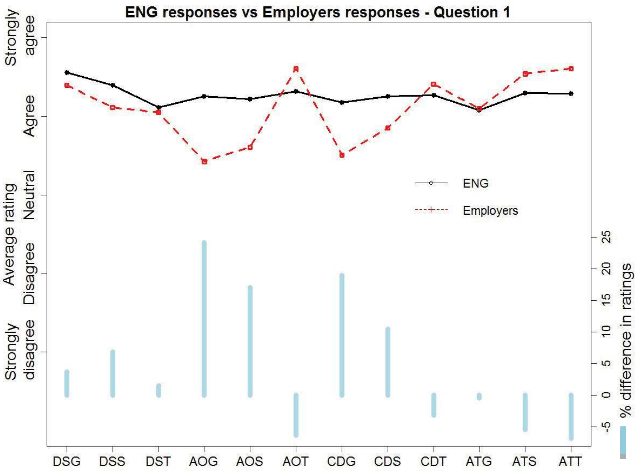

Figure 4. Q1 Responses Engineering Cohort vs. STEM Employers

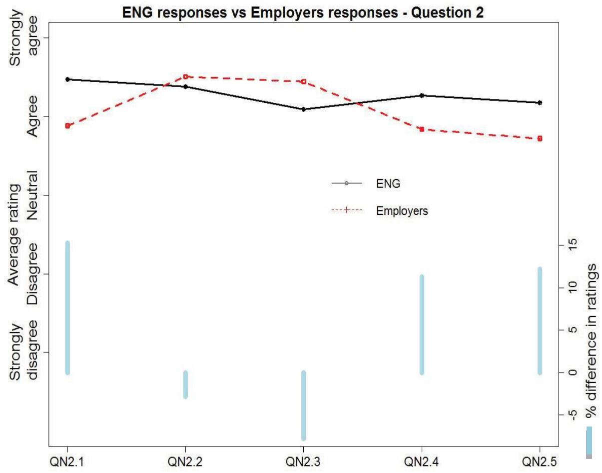

Figure 5. Q2 Responses Engineering Cohort vs. STEM Employers

Table 7. Hotelling's T² Test Results Q1 Engineering Cohort vs. STEM Employers

Hypothesis	Hotelling's T²	Critical Value	P-value
Parallel	104.72	22.99	1.37E-10

Table 8. Hotelling's T² Test Results Q2 Engineering Cohort vs. STEM Employers

Hypothesis	Hotelling's T²	Critical Value	P-value
Parallel	46.22	10.04	3.05033E-07

Wilcoxon Rank Sum Test was used to investigate the differences further. The CIL scores of the Engineering student cohort's (Table 9) and STEM employers (Table 10) were compared to determine differences between focuses on Generic (cross-discipline), Situated (discipline-specific) and Transformative (trans-discipline) learning.

Table 9. CILLF Profile of Engineering Students

Learning Approaches	*Career Development Learning*	*Information Literacy* Generic	Situated	Transformative
Diverging	Self Awareness	*DSG 4.80*	*DSS 4.76*	*DST 4.50*
Assimilating	Opportunity Awareness	*AOG 4.24*	*AOS 4.57*	*AOT 4.50*
Converging	Decision Making	*CDG 4.26*	*CDS 4.35*	*CDT 4.20*
Accommodating	Transition Learning	*ATG 4.29*	*ATS 4.28*	*ATT 4.54*
	Average	*4.40*	*4.50*	*4.44*

Table 10. CILLF Profile of STEM Employers/Industry Stakeholders

Learning Approaches	*Career Development Learning*	*Information Literacy* Generic	Situated	Transformative
Diverging	Self Awareness	*DSG 4.39*	*DSS 4.11*	*DST 4.05*
Assimilating	Opportunity Awareness	*AOG 3.43*	*AOS 3.61*	*AOT 4.61*
Converging	Decision Making	*CDG 3.51*	*CDS 3.85*	*CDT 4.41*
Accommodating	Transition Learning	*ATG 4.10*	*ATS 4.54*	*ATT 4.61*
	Average	*3.86*	*4.03*	*4.42*

Although there seemed to be a higher focus of the Engineering cohort on Situated (discipline-specific) learning, the Wilcoxon Rank Sum Test did not confirm a statistical significance with this sample (Table 11). However, the test (Table 12) showed that Employers distinguished between Generic, Situated and Transformative aspects of career/employability development learning, with Transformative learning being the most prominent and desirable. In contrast, such emphases were not clearly discernible by the Engineering students.

Table 11. Wilcoxon Rank Sum Test Results (Engineering student)

Intra-category comparison p-values matrix	*Average scores*	*Career Information Literacy*		
		Generic	Situated	Transformative
Generic	*4.27*	-	*0.739*	*0.684*
Situated	*4.29*	-	-	*0.045*
Transformative	*4.24*	-	-	-

Table 12. Wilcoxon Rank Sum Test Results (STEM employers)

Intra-category comparison p-value matrix	*Average scores*	*Career Information Literacy*		
		Generic	Situated	**Transformative**
Generic	*3.86*	-	*0.013*	***<0.001***
Situated	*4.03*	-	-	***<0.001***
Transformative	***4.42***	**-**	**-**	-

Conclusions

The study successfully demonstrated a structural approach to understanding the STEM professional preparation from cross-discipline, discipline-specific and transformative aspects.

The CIL analysis uncovers that transformative capabilities are highly desired by STEM employers but remain under-detected by Engineering students. This discovery broadens the previously limited notion of adding generic skills to discipline-based learning to arrive at satisfactory professional preparation of future engineers. Further work on ‘transformatives’ is crucial. Equally interesting is that Engineering students did not differ significantly from their STEM peers in their focuses on employability and career development, given that the Engineering discipline has distinct professional accreditation requirements and is often viewed as embodying more vocational orientation than the rest of the STEM cohorts.

We acknowledge potential limitations to this study. Due to the sample size, the engineering students were analysed as a cohort; therefore, no separate analysis was done for sub-fields of engineering. In addition, the STEM employer sample is drawn from employers who approached the STEM faculty to recruit students; therefore, may not be representative of all STEM employers. Furthermore, the study was conducted in one institution only. Replication of the study in other institutions may provide further insights into STEM employability.

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