DEVIATION FROM STEM PEERS AND EMPLOYERS IN EMPLOYABILITY FOCUSES: THE CASE OF MATHS, STATS, PHYSICS AND ASTRONOMY STUDENTS

Serene Lin-Stephens[a], Maurizio Manuguerra[b], James Downes [C], Judith Dawes[C], Carolyn Kennett[d], John Uesi[b]

Presenting Authors: Maurizio Manuguerra (maurizio.manuguerra@mq.edu.au), James Downes (james.downes@mq.edu.au)
[a]Career and Employment Service, Faculty of Science and Engineering, Macquarie University, 2109, Australia
[b]Department of Statistics, Macquarie University, 2109, Australia
[c]Department of Physics & Astronomy, Macquarie University, 2109, Australia
[d]Department of Mathematics, Macquarie University, 2109, Australia

KEYWORDS: Career information literacy, Employability, STEM education, Capstone units

ABSTRACT

STEM employability is a non-homogenous phenomenon with mixed outcomes for graduates from different disciplines. A myriad of factors may contribute to the diverse employability. We examine the heterogeneity of career and employability development focuses among different STEM student cohorts and employers within a curricular context. A structured framework of Career Information Literacy (CIL) was utilised to map STEM students' and employers' focuses on career and employability. This paper presents findings from the Mathematics, Statistics, Physics and Astronomy cohort.

Data was collected from final year capstone unit students at a STEM faculty in an Australian university (n=517, response rate 44%). Of which, Maths, Stats, Physics and Astronomy (MSPA) students were analysed as a cohort (n=80, response rate 73%). Concurrent data collection took place with STEM employers and industry stakeholders who engaged this faculty in recruitment and employability activities (n=62, response rate 78%). Upon comparing student cohorts' focuses on career and employability development with their peers and employers, we found MSPA students differ from both their STEM peers and employers. Most other STEM student cohorts differ from employers, but not their peers. The implications point to a different career development need of this cohort to fully realise the benefits of their education.

Proceedings of the Australian Conference on Science and Mathematics Education, Monash University, 27-29 September 2017, pages 154-159, ISBN Number 978-0-9871834-6-0.

BACKGROUND

STEM employability is an intriguing phenomenon attracting global attention from policy makers, educators, employers and industry stakeholders (Office of the Chief Scientist, 2012, 2013). Propelled by graduate expectations, industry demands and governmental agendas, concerned parties have studied STEM employability from various empirical and strategic angles, including gender balance, racial representations, labour market demands and supply, varying graduate outcomes, professional identity, and curriculum design (Broadley, 2015; Petocz & Reid, 2010, Riegle-Crumb et al., 2010; Xue & Larsen, 2015), to name a few. The breadth of topics covered in the STEM employability studies reflects a grave concern of meeting current and future workforce needs through STEM education.

Specifically, despite the strong demand for STEM graduates, many STEM students still face underemployment and unemployment. Recent analyses on mixed STEM graduate outcomes based on fields of work and study (Xue & Larson, 2015) signalled a need to examine the heterogeneity of STEM employability. However, two significant challenges exist. Firstly, to date, a multitude of industry reports, academic papers and government publications have produced wish-lists of skills for STEM students upon completion of degrees. However, little attention is paid to the structural embedment of career and employability development within the curriculum. Secondly, there is also a lack of knowledge of and studies on STEM students' predispositions towards career and employability development. The complexity of the heterogeneous STEM employability is poorly understood.

Addressing issues of STEM employability will mean addressing STEM students' career needs throughout students' university learning journey (Rayner & Papakonstantinou, 2016; Sarkar et al., 2016). It is time we adopt a structural approach to explore the intricacy of integrating generic, discipline-specific and personal career preparation learning into university programs of study.

Furthermore, differences between student cohort and employer needs should be identified within that investigation.

AIMS

To afford structural, holistic thinking of generic, discipline-based, and personal/professional development learning within the curriculum, and to identify student cohorts' and employers' needs, a conceptual tool was created to juxtapose key types of learning and gauge to which extent students and employers value or focus on them. A two-year project spanning across disciplines in a comprehensive STEM faculty in an Australian university produced the Career Information Literacy Learning Framework (CILLF) (Figure 1). The CILLF unites three key theoretical frameworks of learning approaches, career development learning and information literacy. It is informed by and tested with academic, employer, and student inputs and data (Lin-Stephens et al., 2016, 2017).

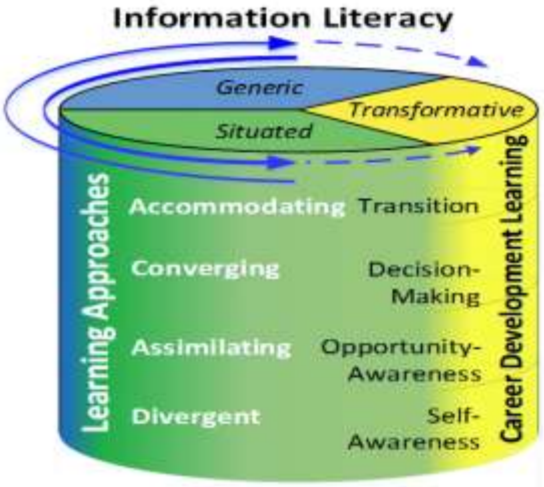

Figure 1. The Career Information Literacy Learning Framework (Version 2.0) (Lin-Stephens, et al. 2017)

The Career Information Literacy Learning Framework is used here to:

- delineate the relationship between key aspects of university learning, including generic, discipline-based learning, transformative, and career development learning
- capture varying focuses in aspects of learning held by academics, students and employers; thus furthering our understanding about heterogeneity in STEM employability

In this paper, we report the use of this framework to map students' and employers' focuses on career and employability development within university learning. In particular, we present the comparison between the cohort of Mathematics, Statistics, Physics and Astronomy (MSPA) students and their STEM peers, as well as the comparison between the MSPA cohort and STEM employers.

METHOD

Applying the Career Information Literacy Learning Framework (CILLF)

The Career Information Literacy Learning Framework (Lin-Stephens et al., 2016, 2017) integrates three theoretical frameworks: learning approaches (Kolb and Kolb, 2015), career development learning (Watts, 2006) and information literacy (Lupton, 2008) (Figure 1 & Table 1). It associates career development learning with fundamental learning approaches by highlighting career development learning as a function of learning approaches. The framework posits learning as an ability to work with information and specify three relevant domains in the higher education context: Generic (cross-discipline), Situated (discipline-specific) and Transformative (trans-discipline).

Table 1. CILLF Codes

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***

The CILLF was previously used to code data collected from academics with success (Lin-Stephens et al., 2016). Subsequently, Career Information Literacy (CIL) survey instruments were devised for data collection from students and employers (Lin-Stephens et al., 2017). The CIL survey contains answer items for students and employers to map their focuses on career and employability development. Choice items were devised to denote conceptions/values in the CILLF according to Table 1.

We posed two research questions to test the heterogeneity of the STEM employability being studied. Here we report findings from the Mathematics, Statistics, Physics and Astronomy (MSPA) cohort. RQ1: Does the MSPA student cohort share the same focuses on career and employability development as their STEM peers?

RQ2: Does the MSPA student cohort share the same focuses on career and employability development as STEM employers?

Applying Profile Analysis and Hotelling's T^2 test

Profile analysis and Hotelling's T^2 test were used to study the similarity of score profiles, particularly the significance of the various patterns or effects. We tested two hypotheses for the means of the groups being compared:

- Parallelism - If the groups' profiles are not parallel between variables, the two groups are considered different across the key measurements. If they are parallel, the groups exhibit similar trends in scores across the dimensions, but not necessarily the same values. Hence the next step to test coincidence.
- Coincidence - If the groups' profiles are at equal levels across variables, they are coincident as having the same value for each dimension. If not, the two groups are different.

Standard ordinal regression was used to confirm the results obtained. Specifically, the validity of the results was confirmed by controlling for demographic covariates and checking for linearity of the ordinal scale.

Data Collection

The CIL survey was administered to students in the 34 capstone units in the STEM faculty being studied (n=517, N=1176, response rate 44%) at the end of semesters in one academic calendar year, primarily face to face. Web survey links were provided to those who could not attend lectures in person. Six final year capstone units resided in Mathematics, Statistics, Physics and Astronomy (n=80, N= 110, response rate 73%).

In the same period, data was collected from STEM employers who approached this STEM faculty to engage students in recruitment and employability activities, for example participation in careers fairs, employer presentations, etc. to attract students to work in relevant STEM opportunities (n=62, N=80, response rate 78%).

RESULTS

Demographic and activity-based characteristics of the MSPA cohort and the whole of STEM cohort are summarised in Table 2. Employer/industry stakeholder respondent characteristics are presented in Table 3.

We compared the characteristics of the MSPA cohort and whole of STEM cohort. Chi-square tests did not find any significant difference between the MSPA and the whole of STEM cohort at p <.05. We found no significant difference between the MSPA cohort and the general STEM cohort in terms of gender, age, or residency composition. Nor were there any statistical remarkable differences in terms of activities completed in the past 12 months, total work and unpaid work history, and plans within one year of degree completion. The Cronbach's alpha value for the MSPA cohort was high (0.82), giving us confidence in the internal consistency of the student responses.

Table 2. CIL Capstone Unit Student Respondents' Characteristics
Math, Stats, Physics & Astronomy Cohort vs. Whole of STEM Faculty

	MSPA cohort	STEM whole faculty
Total number of responses (n)	80	517
Total number of enrolments (N)	110	1176
Response rate	73%	44%
Male	60%	67%
Female	30%	32%
Domestic	63%	67%
International	6%	8%
NA	31%	25%
Age		
19 or under	0%	0.4%
20-25	84%	81%
26-30	11%	10%
31-40	5%	6%
41+	0%	3%
Activities in the past 12 months		
Part time work	79%	75%
Job search	35%	49%
Student groups/societies	25%	28%
Unpaid work experience	18%	28%
Volunteer or community work	28%	30%
Project work involving external clients	34%	21%
Full-time work	10%	11%
Professional association involvement & networks	3%	8%
Overseas exchanges or studies	4%	6%
Average total paid work history	4 years	4 years 2 months
Average total unpaid work history	9 months	10 months
Plan within 1 year of completing degree		
Work	76%	73%
Further study	33%	37%
Other	5%	10%

Table 3. CIL STEM Employer/Industry Stakeholder Survey Respondents' Characteristics

	Frequency	Percentage
Organisation type (n=62, N=80, response rate 78%)		
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	

Despite the similarity between MSPA student characteristics and their STEM peers (Table 2), Profile analysis and Hotellings T^2 test showed that MSPA cohort's CIL profile differs from their STEM peers (Figure 2 and 3). Hotelling's T^2 tests show that the profiles are parallel but not coincident (Table 4 and 5). Therefore, for RQ1, the MSPA student cohort differ from their STEM peers in their career and employability development. The MSPA cohort rated the CIL items consistently lower than their STEM peers.

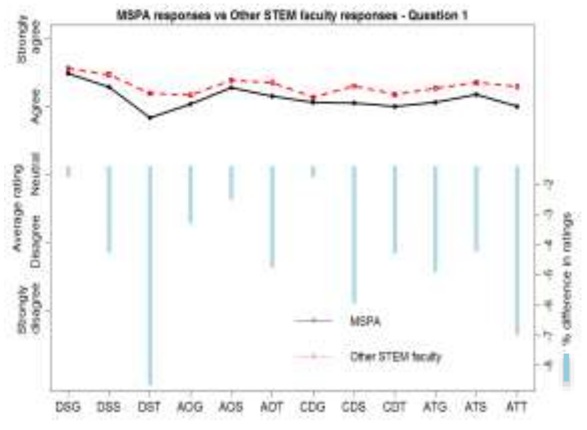

Figure 2. Q1 Responses
MSPA Cohort vs. Other STEM Peers

Table 4. Hotelling's T^2 Test Result Q1 (MSPA cohort vs. STEM peers)

Hypothesis	Hotelling's T^2	Critical value	P-value
Parallel	14.79	20.28	0.28
Coincident	9.94	3.86	<0.01

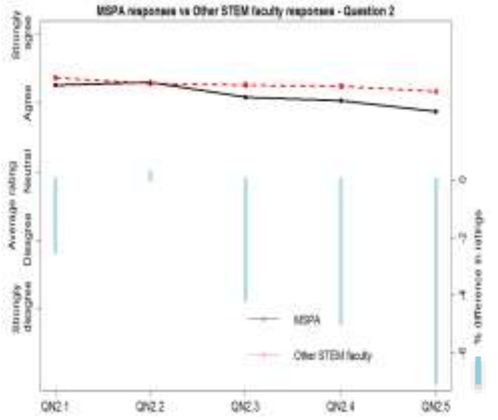

Figure 3. Q2 Responses
MSPA Cohort vs. Other STEM Peers

Table 5. Hotelling's T^2 Test Result Q2 (MSPA cohort vs. STEM peers)

Hypothesis	Hotelling's T^2	Critical Value	P-Value
Parallel	5.93	9.61	0.32
Coincident	6.33	3.86	<0.01

For RQ2, we performed the same procedure on the MSPA cohort and STEM employers. We found even greater differences between the MSPA cohort and STEM employers (Figure 4 and 5). MSPA students' and employers' scores across the measures are distinctly different as confirmed by Hotelling's T^2 Test (Table 6 and 7).

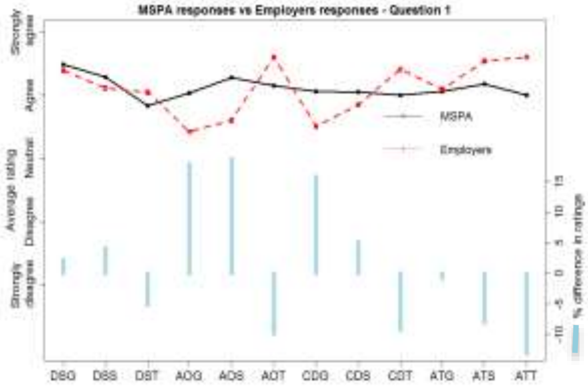

Figure 4. Q1 Responses
MSPA Cohort vs. STEM Employers

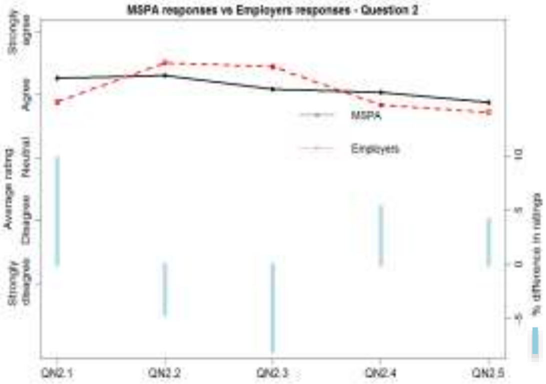

Figure 5. Q2 Responses
MSPA Cohort vs. STEM Employers

Table 6. Hotelling's T^2 Test Result Q1 MSPA Cohort vs. STEM Employers

Hypothesis	Hotelling's T^2	Critical value	P-value
Parallel	124.74	22.08	4.009E-13

Table 7. Hotelling's T^2 Test Result Q2 MSPA Cohort vs. STEM Employers

Hypothesis	Hotelling's T^2	Critical Value	P-Value
Parallel	25.55	9.96	0.000329962

We used CILLF to map student cohort and employer results (Table 8 and 9) and found that MSPA students focus on their discipline-based learning most while employers highly value the transformative learning. The transformative items refer to critical reflective abilities and actions (challenging the status quo), meaning-seeking behaviour, and outside-of-the-box thinking.

Table 8. CIL Scores of MSPA Students

Learning Approaches	***Career Development Learning***	***Information Literacy***		
		Generic	Situated	Transformative
Diverging	Self-Awareness	*DSG 4.48*	*DSS 4.28*	*DST 3.83*
Assimilating	Opportunity Awareness	*AOG 4.04*	*AOS 4.28*	*AOT 4.16*

Converging	Decision Making	*CDG 4.07*	*CDS 4.05*	*CDT 4.01*
Accommodating	Transition Learning	*ATG 4.06*	*ATS 4.17*	*ATT 4.00*
	Average	*4.16*	*4.20*	*4.00*

Table 9. CIL Scores 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*

Wilcoxon Rank Sum Tests were used to compare information literacy groups and determined that MSPA students focused on situated (discipline-based) items most and rated transformative items significantly lower than the generic and situated items (Table 10). There was no significant difference between the generic and situated learning focuses. In contrast, for employers, generic, situated and transformative learnings are distinctly different. The transformative items are particularly emphasised by employers (Table 11).

Table 10. Wilcoxon Rank Sum Test Results- MSPA Student

Intra-category comparison p-value matrix	*Average scores*	*Career Information Literacy*		
		Generic	Situated	Transformative
Generic	*4.16*	-	*0.88*	*0.0117*
Situated	***4.20***	-	-	*0.003*
Transformative	*4.00*	-	-	-

Table 11. Wilcoxon Rank Sum Test Results- STEM Employers Results

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

In this paper, we present the Career Information Literacy Learning Framework which structures several key university learnings in one single framework. In addition, we successfully demonstrated the use of this framework in gauging student and employer career and employability development focuses. We found the MSPA cohort differ from their STEM peers and identified a gap between the MSPA cohort and employers. These findings further our understanding of the heterogeneity of STEM employability.

As this is part of a larger study we are able to see that most other STEM student cohorts share similar focuses (Lin-Stephens, forthcoming). The fact that the MSPA cohort CIL profile deviates from that of their STEM peers suggests that the MSPA students may have different needs in career and employability development. Whilst their degrees may satisfy their aptitude for acquiring specific technical skills and knowledge, MSPA students may benefit greatly from curricular facilitation which incorporates industry and employer perspectives. Mathematics, Statistics, Physics and Astronomy are a key cluster of STEM disciplines that provide students with strong numeric and quantitative thinking skills. Strengthening their employability will mean a direct contribution to a stronger STEM workforce.

We note that due to sample size this study is limited to analysing the MSPA capstone unit students as a cohort only, despite the high response rate. Likewise, the STEM employer sample is based on proactive employers only; therefore may not be representative of all STEM employers.

ACKNOWLEDGEMENT

This study is funded by Macquarie University Learning and Teaching Grant 2015-2016 and Strategic Priority Grant 2016-2017. We thank the academics, students, employers/industry stakeholders, PVC Learning & Teaching, the Career and Employment Service, and the Library who contributed to this project.

REFERENCES

Broadley, K. (2015). Entrenched gendered pathways in science, technology, engineering and mathematics: engaging girls through collaborative career development. *Australian Journal for Career Development, 24*(1), 27-38.

Kolb, A. Y. & Kolb, D. A. (2005). *The Kolb Learning Style Inventory- Version 3.1 2005 Technical Specifications*, Hay Group.

Lin-Stephens, S., Smith, S., Peso, M., & Pang, V. (2016). The career information literacy learning framework: A case study of information systems, information technology and engineering capstone units of an Australian university. *Proceedings of Pacific Asia Conference on Information Systems 2016*, 52. Retrieved 11th Sep 2017, from http://aisel.aisnet.org/pacis2016/52

Lin-Stephens, S., Smith, S., Richards, D., Pang, V., Uesi, J. & Athanasou, J., (2017). Students and employers don’t see eye to eye: the case of information systems, information technology and engineering. *Proceedings of Pacific Asia Conference on Information Systems 2017*, July.

Lupton, M. (2008). *Information Literacy and Learning*. Adelaide: Auslib Press.

Office of the Chief Scientist. (2012). *Health of Australian Science*, Australian Government, Canberra.

Office of the Chief Scientist. (2013). *Science, technology, engineering and mathematics in the national interest: a strategic approach*. Australian Government, Canberra.

Petocz, P., & Reid, A. (2010). On becoming a statistician- a qualitative review. *International Statistical Review*, *78*(2), 271-286.

Rayner, G., & Papakonstantinou, T. (2016). The nexus between STEM qualifications and graduate employability: employer’s perspectives. *International Journal of Innovation in Science and Mathematics Education*, *24*(3), 1-13.

Riegle-Crumb, C., Moore, C., & Ramos-Wada, A. (2010). Who wants to have a career in science or math? Exploring adolescents’ future aspirations by gender and race/ethnicity. *Science Education*, *95*(3), 458-476.

Sarkar, M., Overton, T., Thompson, C., & Rayner, G. (2016). Graduate employability: views of recent science graduates and employers. *International Journal of Innovation in Science and Mathematics Education*, *24*(3), 31-48.

Watts, A. G. (2006). *Career development learning and employability*, York: The Higher Education Academy.

Xue, Y., & Larson, R. C. (2015). STEM crisis or STEM surplus? Yes and yes. *Monthly Labour Review*, May, Bureau of Labour Statistics, US Department of Labour.