Developing a self-report measure of students' interest and motivation for studying Engineering

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Structured Abstract

BACKGROUND
The first year student experience can impact on student retention and progression. Some students choose to withdraw from higher education because of transitional issues relating to mismatched or ill-formed goals or a sense of feeling isolated, rather than intellectual issues. Others might change institutions or enrol in different courses at the same university. The current project was designed to encourage commencing students to engage in career decision making processes before they enrol to ensure they have clear expectations of the courses they will study.

PURPOSE
This national project aims to identify the key characteristics of the incoming first year engineering students that influence successful transition to university life and likely success in first year engineering courses.

DESIGN/METHOD
Commencing students across the five partner universities – the University of Southern Queensland, the University of Queensland, the University of Technology Sydney, the University of Newcastle, and the University of New England – completed a series of self-tests to identify their attitudinal, motivational and cognitive strengths. This paper outlines the process of developing a new 31-item self-report measure of students' 'Interest and Motivation for Studying Engineering' for application in this research project.

RESULTS
Factor analytic results from 285 first-year engineering students indicated that the newly developed self-report measure comprised seven factors: Functional/Creative; Idealistic; Conceptual Engagement; Organised; Inquisitive; Self-efficacy and Career Goals. Regression analyses were used to ascertain which of these factors reliably predict early academic success, as measured by grade point average (GPA) and persistence, respectively. Conceptual Engagement was shown to be a key predictor of GPA in students' first semester of study. In contrast, the Organised subscale positively added to the prediction of Persistence beyond the Functional/Creative subscale. Further research is warranted to track student progress over time, however, these analyses were beyond the scope of the current paper.

CONCLUSIONS
This self-report measure was a component of the non-cognitive Get Set quiz designed to help students better understand the skills and knowledge required in an engineering degree and to be an engineer. It is argued that personalised feedback enables commencing students to self-reflect on their prior experiences, knowledge, and skills and to be better prepared for their engineering studies.

KEYWORDS
Interest and motivation for engineering, student transition, first year student experience.

Introduction

Recent studies have attempted to address the critical skills shortage in engineering by examining the key issues in engineering education (Godfrey & King, 2011; King, 2008; King, Dowling, & Godfrey, 2011). These studies have aimed to develop strategies to build student numbers in engineering programs and to enhance progression and graduation rates. The current national project outlined in this paper is funded by the Australian Government Office for Learning and Teaching, and builds on this earlier work by examining the knowledge, interests and skills of the incoming first year engineering cohort.

Get Set for Success Quiz

The Get Set for Success engineering project is led by researchers from the University of Southern Queensland (USQ), in collaboration with the University of Queensland (UQ), the University of Technology Sydney (UTS), the University of Newcastle (UoN), and the University of New England (UNE). Our main goal is to develop an online Engineering Career Appraisal Tool (EngCAT) which will be available to prospective engineering students to self-assess their readiness for, and interest in, undertaking study in engineering.

Initial data were collected from first year engineering students at each of the participating universities in Semester 1, 2012. An online battery of self-assessment tests (Get Set quiz) was developed for this project based on diagnostic pre-testing used by a number of the participating universities, and other standard measures. The tests were presented in two separate phases. The first phase involved a series of items measuring spatial, mathematical, physics, and chemistry knowledge and abilities. A total of 731 students completed phase 1 testing across the five partner universities.

The second phase of the testing was carried out during weeks 3 or 4 of Semester 1, 2012. This online questionnaire consisted of a 50-item personality inventory, a 52-item learning approaches inventory, and a new 31-item scale measuring interest in and motivation for studying engineering. It was anticipated that these non-cognitive traits would be useful predictors of student success. A total of 273 commencing students completed phase 2 testing. Students can benefit from completing the questionnaire by reflecting on and responding to the detailed individualised feedback provided.

This paper reports on the process of developing a short questionnaire for measuring students' interests and motivations for studying engineering.

Measuring Interests and Motivation in Studying Engineering

While cognitive ability and previous academic success are predictive of future academic success, a broader range of attitudes and abilities are also important. Lowe and Johnston (2008) observed that academic success in high school was only moderately correlated with success in university engineering courses, and they suggested that measuring non-cognitive aspects including interest and motivation could improve the prediction of success in first year. The instrument they developed in consultation with professional and industry organisations was a 6-item structured questionnaire asking students about things such as specific aspects of their life which demonstrated their interest in engineering, and something they had created and an indication of how it demonstrated engineering design. Responses to these items were then scored on a scale from 0 to 5 depending on the relevance of their answer and the extent to which their responses related to the nature and understanding of engineering as a discipline. Lowe and Johnston found that scores on these items were particularly useful in discriminating among applicants with lower range tertiary entrance results. First year results for students who were lower on the selection scale, and who were therefore more likely to be at risk of not succeeding in the program, were improved when student admission criteria included interest and motivation scores.

The project team decided to build on the work of Lowe and Johnston (2008), by using the traits they had identified as being relevant to professional engineers and demonstrated as being predictive of academic success. However, as the Get Set quiz was to be an online tool for broad application across a number of institutions, it was necessary to reformat the items. Open ended questions provide rich data but responses are expensive and time consuming to analyse. For this reason it was decided to rewrite the items as statements which could be endorsed or refuted using a Likert response scale. In order to obtain “best” responses to the Lowe and Johnston items, team members who were professional engineers were invited to provide their responses and these were then written in statement form. In order to avoid response bias, four items were designed to be negatively scored (e.g., Item 16: “*I believe that most problems require complex solutions”;* Item 19: *“I would like to be an engineer because I like to work independently of others”;* Item 23: *“If I find a solution to a problem, I like to stick with that solution”; and* Item 27:*“If a solution to a problem does not emerge quickly, I prefer to move on to another task”*). Additional items relating to self-efficacy and goal setting for studying in general were also included. The statements generated by this process were then trialled with postgraduate engineering students and 31 items (23 relating to interest, 8 relating to motivation) that were highly endorsed were retained for use.

Results

The scale was included in the Get Set quiz of pre-semester tests conducted with commencing engineering students (*n* = 285) at the five partner Australian universities. The reliability of the scale was investigated using SPSS, indicating that the items had good internal consistency (α = .87). However, the negatively valanced items showed low inter-item correlations (< .3), and the usefulness of these items would be further explored. In order to evaluate the structure of the questionnaire and determine if and how any of the items clustered to form subscales, factor analysis was conducted. An initial investigation of all 31 items using Principal axis factoring (PAF) produced 8 factors with eigenvalues greater than 1, accounting for 62% of variance. However, some factors contained complex items loading on two factors, and some items did not load on any factor at all. The negatively scored items clustered onto 2 factors, and it appeared that their only commonality was their negative valence. As these four negative items appeared problematic in terms of content and scale structure, they were eliminated from further investigation. It was also decided that, as the interest items were specific to engineering while the self-efficacy and goal setting items were more general in scope, a clearer factor structure might emerge if the two sets of items were considered separately.

PAF analysis was then conducted on the remaining 19 interest items, resulting in the emergence of 5 factors which together accounted for 56% of variance. There were no complex loadings, but item 7 (“*Someone I respect and admire is an engineer”)* failed to load on any factor. The details of this analysis are presented in Table 1.

Table 1: Pattern matrix of interest in engineering items – Principal Axis Factoring: Oblimin with Kaiser Normalisation (n=285)

Variable	**Factor 1 Functional/ Creative**	**Factor 2 Idealistic**	**Factor 3 Conceptual engagement**	**Factor 4 Organised**	**Factor 5 Inquisitive**
Item 1					-.81
Item 2					-.67
Item 4			.68		
Item 7					
Item 9	.79				
Item 10	.60				

Item 11	.40				
Item 12					-.41
Item 13		.54			
Item 14		.69			
Item 17	.60				
Item 18	.32				
Item 21		.35			
Item 22	.36				
Item 24		.51			
Item 26			.44		
Item 28				.46	
Item 29				.48	
Item 31				.56	
Eigenvalues	5.23	1.58	1.56	1.27	1.01
% of variance	27.51	8.34	8.21	6.68	5.32
Correlation matrix					
Factor 1	1.00				
Factor 2	.37	1.00			
Factor 3	-.00	.12	1.00		
Factor 4	.37	.24	.12	1.00	
Factor 5	-.46	-.22	-.31	-.28	1.00

The items loading to define the five ‘interest in engineering’ factors shown in Table 1 are outlined below.

Factor 1: Functional/Creative
9. I like to design and build things.
10. I like to find solutions to practical problems.
11. I usually sketch a diagram to start working out a problem.
17. I have created something using engineering design principles.
18. The first step I would take when solving a problem is to define the problem.
22. I am a creative thinker.

Factor 2: Idealistic
13. I want to have a job that could save the world
14. I want to adapt systems so that they are more sustainable and have less environmental impact.
21. Chemistry is fascinating.
24. I like communicating my ideas to others.

Factor 3: Conceptual Engagement
4. I love maths.
26. Physics is fun.

Factor 4: Organised
28. I am a logical thinker.
29. I like to manage projects.
31. I like to focus on details.

Factor 5: Inquisitive
1. I like to know how things work.
2. I like to know how things work better.
12. I have an enquiring mind.

Factor analysis of the remaining 8 motivation items resulted in a complex solution. Two factors had eigenvalues greater than 1 and accounted for 64% of the variance. Most items loaded onto both factors, but items 3 *("I have high standards for academic work")* and 25 *("I have academic goals")* did load positively onto the second factor and an argument could be made on conceptual grounds to support the assertion that these items form a factor separate from the other items which relate to self-efficacy. Further work will be necessary to define each of these factors and to improve their psychometric properties. A summary of the factor analysis is presented in Table 2.

Table 2: Pattern matrix of motivation items – Principal Axis Factoring: Oblimin with Kaiser Normalisation (*n*=285)

Variable	Factor 6 Self-efficacy	Factor 7 Career Goals
Item 3	.43	.31
Item 5	.69	
Item 6	.82	-.46
Item 8	.55	
Item 20	.75	-.36
Item 25	.68	.34
Item 30	.59	
Eigenvalues	3.44	1.01
% of variance	49.10	14.45
Correlation matrix		
Factor 6	1.00	
Factor 7	.06	1.00

The items loading to define each 'motivation for study' factor shown in Table 2 are listed below.

Factor 6: Self-efficacy
5 I have pictured myself being successful in my chosen profession.

6. I am confident I have the ability to learn the necessary concepts to be successful in my degree.
15. I am confident I have the ability to learn the necessary communication skills to be successful in my degree.
20. I am confident I can complete my degree.
30. I am confident I have the necessary writing skills to be successful in my degree.

Factor 7: Career Goals
3. I have high standards for academic work.
25. I have academic goals.

Analysis of the overall scale and the subscales identified by the preceding factor analyses showed that the total scale had a satisfactory reliability coefficient. However, some of the subscales need to be augmented with additional items to improve their internal consistency. See Table 3.

Table 3: Reliability measures for Interest and Motivation for Studying Engineering Scale (*n*=285)

Scale	Cronbach's α
Total scale	.83
Subscales	
Functional/Creative	.75
Idealistic	.63
Conceptual Engagement	.54
Organised	.48
Inquisitive	.76
Self-efficacy	.84
Career Goals	.61

The predictive value of the scale was investigated. Using regression, two variables indicating academic achievement in Semester 1, 2012 – Grade Point Average (GPA) and whether or not the student was still enrolled at the end of the first semester (Persistence) – were regressed onto the various interest and motivation subscale scores. When evaluating the key predictors of GPA, the only subscale which was significant was the Conceptual Engagement subscale ($\beta = .25$, $t = 3.17$, $p < .01$). The regression predicted 8% of the variance in GPA ($R^2 = .08$). Two subscales were shown to predict whether or not a student would still be enrolled at the end of semester 1 (Persistence). These were Functional/creative ($\beta = -.23$, $t = -2.37$, $p < .05$), and Organised ($\beta = .18$, $t = 2.13$, $p < .05$). The regression analysis predicted 7% of the variance in Persistence ($R^2 = .07$). A summary of these analyses are found in Table 4.

Table 4: Hierarchical regression of Grade Point Average (GPA) and Persistence on Interest and Motivation for Studying Engineering subscales

Dependent variable	**Independent variables**	β	sr^2

GPA	Functional/Creative	.07	.00
	Idealistic	-.05	.00
	Conceptual Engagement	.25	.05**
	Organised	-.01	.00
	Inquisitive	-.03	.00
	Self-efficacy	.03	.00
	Career Goals	.06	.00
		R^2 = .08 R^2(adj) = .05	
Persistence	Functional/Creative	-.23	.03*
	Idealistic	.00	.00
	Conceptual Engagement	.04	.00
	Organised	.18	.02*
	Inquisitive	.04	.00
	Self-efficacy	.00	.00
	Career Goals	.09	.00
		R^2 = .07 R^2(adj) = .03	

Note. * $p < .05$, ** $p < .01$

Discussion and conclusion

This project aims to identify key characteristics of the incoming first year engineering students that influence successful transition to university life and likely success in first year engineering courses. To this end, commencing students across the five partner universities completed a series of self-tests to identify their attitudinal, motivational and cognitive strengths (see Burton, 2013; Burton, Albion, Shepherd, McBride, & Kavanagh, 2013; Burton, Dowling, Kavanagh, O'Moore, & Wilkes, 2012).

This paper reports on initial findings from Phase 2 only, specifically examining the psychometric properties of the short questionnaire developed to measure commencing students' interests and motivations for studying engineering. It was anticipated that this scale would prove to be useful in helping predict the successful academic progress of engineering students and as such could be a valuable addition to screening and pre-entry testing for engineering programs. Indeed, the questionnaire was shown to be a reliable, seven-factor measure and while further work is recommended to refine the subscales and strengthen their internal consistency estimates, the scale was able to provide some prediction of student achievement and progress.

The key predictors of academic success (as measured by GPA and Persistence) were the Conceptual Engagement, Organised, and Functional/Creative subscales. Conceptual Engagement reflects students' interest in maths and physics concepts, and it is not surprising that this emerged as a key predictor of GPA in students' first semester of study, given that cognitive abilities have reliably been shown to positively predict academic success over time in engineering programs (e.g., Burton & Dowling, 2009; Burton et al., 2012). However, the content measured in this scale went beyond mere cognitive ability in these areas, by tapping into students' attitudes to and enjoyment of these subjects. Students who did well in maths and physics and who engaged with these topics in a positive way were most likely to be rewarded with success in first year engineering courses. On the other hand, it is somewhat disconcerting to note that functional and creative interests were a negative predictor of short-term student persistence, which could suggest that the curriculum in first semester is not designed to engage those interests. There is a danger that some students who may be high in creativity, practicality, and innovation may be lost to the profession as a consequence of their first year experience. In contrast, the Organised subscale positively added to the prediction of Persistence, indicating that an interest in showing attention to detail may help students to persist with their engineering studies over time. Further research is warranted to track student progress, however, these analyses were beyond the scope of the current paper.

Data from the current cohort across the five partner universities is currently being used to inform the development of EngCAT, an online career assessment tool that will enable prospective engineering students to better understand the traits and skill sets relevant to success in engineering studies.

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Acknowledgements

This national project was funded by the Australian Government Office for Learning and Teaching. This project involved collaboration among five partner universities – the University

of Southern Queensland, the University of Technology Sydney, the University of Queensland, the University of Newcastle and the University of New England.

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