Examining First Year Students' Preparedness for Studying Engineering

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BACKGROUND
This national project builds on recent studies that have aimed to develop strategies to enhance enrolment, progression, and graduation rates in engineering programs. Implementing these strategies will help to address the critical skills shortages in the engineering profession in Australia. To ensure the outcomes have wide applicability, the project team has deliberately drawn students from five universities that cover the spectrum of Australian universities and engineering programs: the University of Southern Queensland, the University of Queensland, the University of Technology, Sydney, the University of Newcastle, and the University of New England.

PURPOSE
The purpose of this paper is to report on initial descriptive data of this longitudinal project which will examine the knowledge, motivation, personality, and learning approaches of first year engineering students and how well they each predict subsequent retention and academic performance. These outcomes are yet to be achieved and are beyond the scope of this paper.

DESIGN/METHOD
An online battery of self-assessment tests was developed for this project based on diagnostic pre-testing used by a number of the participating universities, and other standard measures. The battery measures cognitive abilities (e.g., spatial, maths, physics, and chemistry) and non-cognitive abilities and traits (e.g., personality traits, career interests, and approaches to learning) of first year engineering students. Retention and academic results at the end of first year will be used as outcome variables, and regression analyses will be used to ascertain which of these variables are reliable predictors of academic success. Focus group data will enable some qualitative amplification of these results.

RESULTS
Outcome variables for the project will not be available until the end of 2012, however, this paper reports on preliminary descriptive and cognitive data from 505 first-year students commencing engineering studies at the five partner universities in Semester 1, 2012. Overall, students reported that they found the self-assessments and personalised feedback helpful in preparing them for their studies. Half of those who completed the cognitive skills quiz scored better than 70% across the range of questions. Results in physics, chemistry and spatial abilities were consistent across programs and study modes. However, students in two-year and three-year programs did not perform as well in maths as those in four-year degree (or equivalent) programs, and external students did not score as well in maths as did students enrolled on-campus. The implications of these findings are discussed.

CONCLUSIONS
First-year engineering students indicated that they enjoyed the opportunity to self-assess their readiness and to be linked with early support where needed. Data from the battery will inform the development of the Engineering Career Appraisal Tool (EngCAT), an online educational resource that will enable school students and mature-age people who might be considering engineering as a career option to self-assess their cognitive and non-cognitive capabilities and skills.

KEYWORDS
First year engineering students, academic success, cognitive abilities, non-cognitive abilities.

Introduction

Australia has had critical skills shortages at all levels of the engineering industry for more than a decade (Engineers Australia, 2008; Kaspura, 2011; King, Dowling, & Godfrey, 2011). The Australian Government (2011) reported that in March 2011 there were still national shortages of engineers in all fields except chemical engineering. During 2011, the Education, Employment and Workplace Relations Committee of the Australian Senate conducted an inquiry into the shortage of engineering and related employment skills and its final report noted that "of the fifty engineering occupations surveyed only 3 were not experiencing skills shortages in 2011. Significantly, a number of these professions have been experiencing skills shortages for protracted periods of time. For example, civil engineers have been in short supply since early 2000" (The Senate, Education, Employment and Workplace Relations References Committee, 2012, p.14).

A number of recent studies have attempted to address this concern by examining the key issues in engineering education (Godfrey & King, 2011; King, 2008; King, Dowling, & Godfrey, 2011). These studies 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.

To ensure the outcomes of the current project have applicability to engineering education at all levels, the project scope includes two different study modes (on-campus and distance), and examples of the two-, three- and four-year engineering programs (or equivalents), that lead to the three levels of membership with Engineers Australia. The project team has deliberately been drawn from five universities that cover the spectrum of Australian universities and engineering programs. While addressing national priorities concerning the critical skill shortages, the project will:

- address the retention and progression needs of each participating university;
- examine factors that predict whether students persist with their studies or leave their undergraduate engineering program prior to completion; and
- propose changes to entry requirements, pathways, and support mechanisms in order to enhance enrolment, retention and progression rates.

This paper reports on the initial findings of this longitudinal project.

Retention, progression and diversity

Attrition of first year engineering undergraduate students remains a major concern (Godfrey & King, 2011). Many research projects have sought to identify factors that affect student attrition, with a substantial focus on factors such as homesickness or financial pressures during university life (Long, Ferrier, & Heagney, 2006). However, recent American research indicates that many first year engineering students become discouraged when they perceive their performance to be inferior to their peers; they switch majors or drop out of college entirely (Hutchison-Green, 2008). It is therefore important for educators to help first year students experience early success and gain confidence during their transition to university. Although some attention has been paid to career choice and its impact on academic success (Brown et al., 2008; Kahn, Nauta, Gailbreath, Tipps, & Chartrand, 2002), there is considerable scope to explore this relationship in specific discipline areas such as engineering. For example, one reported factor is that inappropriate discipline choice is an important determinant of student withdrawal (Yorke & Longden, 2008). This project aims to identify strategies to better support students academically and ensure that they make informed decisions regarding choice of study major.

All five partner universities are currently responding to retention, progression and diversity issues but their varying contexts mean they are addressing different aspects of those issues.

At the University of Queensland (UQ), over 70% of commencing students will graduate with an engineering degree. Most students who leave do so within the first year which has an average attrition rate of 14.5% (2005 – 2011). Approximately 30% of this 14.5% pass all courses they attempt suggesting that attrition is not based on a lack of academic ability. Interviews with students who had switched from engineering to other studies at UQ established that most had decided to do engineering very late in their school career, often based on incomplete or inaccurate information.

The first year attrition rate in engineering programs at the University of Technology, Sydney (UTS) is approximately 13%, although it has varied by up to 5% over the last few years. Additional data mining on student success and retention rates is now taking place.

Attrition from the first year engineering programs at the University of Newcastle (UoN) dropped from 26% in 2007 to 22% in 2009. Approximately 13% of commencing engineering students ceased their studies at UoN in 2009. In subsequent years the attrition rate has dropped to around 10% per annum with the majority of these also ceasing tertiary studies at UoN.

At the University of Southern Queensland (USQ), the engineering and surveying faculty reviewed the progression rates of the students in a number of cohorts (Godfrey & King, 2011). The review showed that:

- the attrition rate of the domestic, part-time, distance education students in the 1999 and 2003 Associate Degree in Engineering cohorts was between 50% and 60%; and
- the attrition rate for the domestic, on-campus and distance education students in the 1999 and 2003 Bachelor of Engineering and dual degree cohorts was between 39% and 45%.

The first year attrition rate in the engineering technology program at the University of New England (UNE) from 2009-2011 was approximately 37%. Most of the UNE students are supported by government or local authority traineeships and many gain entry via an alternative pathway based on a letter from their high school principal.

Australian universities have relaxed entry scores and subject prerequisites to increase enrolment and enhance diversity in engineering programs (Kavanagh, O'Moore, & Samuelowicz, 2009). This means that today's students come to university with varied educational backgrounds and via different entry pathways (Brodie & Porter, 2009). However, it also indicates that many first year students typically lack the prerequisite knowledge and skills that underpin the first year engineering curricula (Kavanagh et al., 2009). These first year students therefore experience difficulty in mastering the content and other fundamental knowledge hurdles and quickly become dissatisfied with their first year engineering studies (Kavanagh et al., 2009). They then often withdraw from their engineering programs, thus contributing to the growing attrition rate.

Similarly, research evidence indicates that students of all disciplines enter university with expectations about the learning experience which influence their approach to study (Krause, Hartley, James, & McInnis, 2005) but that these students are often poorly informed about the nature of their coursework (Krause et al., 2005). This project aims to redress this imbalance by building on earlier works in the field (e.g., Godfrey & King, 2011). The focus is not on selecting students for engineering courses based on their prior knowledge *per se*, but on the relationships between the interests, experiences, knowledge and skills of commencing students that influence their career decisions. Empowering first year students to identify their knowledge gaps, and giving them some idea of the learning experience at university, is an important first step in addressing this retention issue. This enhanced self-awareness enables targeted support systems to be implemented to ensure that students are linked with additional support where necessary.

Research questions

Research into retention and progression often focuses on student experiences post-enrolment. However, this project aims to focus on the initial phases of student engagement with the university and identify the key factors that impact on successful transition past the first year hurdle. It is hoped that this will allow the identification of factors that influence students':

- choice of engineering studies;
- academic success;
- satisfaction with engineering studies;
- satisfaction with university study; and
- decision to persist or leave their engineering studies.

Identification of these factors will allow the development of an engineering career appraisal tool (EngCAT) and strategies to:

1. Attract those students who are most suited to the engineering discipline, and to assist them to make an informed career choice.
2. Better inform engineering schools regarding decisions about entry standards, and alternative entry pathways.
3. Support student transition and entry into the engineering profession.

Get Set for Success Methodology

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. The self tests used were:

- Get Set for Success Phase 1: a 52 item multiple choice online cognitive quiz that assesses students' maths, physics, chemistry, and spatial abilities.
- Get Set for Success Phase 2: an online set of questionnaires consisting of:
  - International Personality Item Pool (IPIP, Goldberg, 1992) – 50 items measuring five factors of personality;
  - Approaches to Study Skills Inventory for Students (ASSIST, Entwistle, 1981) – 52 items measuring three approaches to learning; and
  - Interest and Motivation for Studying Engineering – 31 items newly developed for application in this research project.

Students received immediate individual feedback from the online quizzes and surveys which they can use to help them focus their study efforts. This personalised feedback focuses on empowering the individual to self-reflect on their prior experiences, knowledge, and skills and to better inform them of the pre-requisite skill sets and knowledge that underpin entry into engineering programs. Feedback from Phase 1 was customised for each partner university to allow students to see at a glance the courses they are well-prepared for and the ones they might need to revise or seek additional support for their particular degree and major. The feedback includes links to online sites that contain resources that they can use to address any identified gaps in knowledge.

The Phase 2 questionnaires were designed to help students better understand the skills and knowledge required in an engineering degree and to be an engineer. The personalised feedback on their personality and approaches to learning is also of great value to students as they reflect on ways they can direct their study efforts towards a successful and productive outcome.

This paper reports on preliminary descriptive and cognitive data from Get Set Phase 1 testing. The cognitive skills quiz was deployed across the five partner universities in Semester 1, 2012.

Preliminary Results

While 661 students across the five partner universities commenced the cognitive quiz, only 505 completed it. The majority of students dropped out while completing the maths items which were the first batch of questions; if students completed all maths items they tended to persevere and complete all remaining quiz items (i.e., chemistry, physics, and spatial).

UQ asked commencing students to complete the cognitive skills quiz prior to the start of their first semester of studies, indicating that Phase 1 was compulsory. They subsequently had a high completion rate (93.1%). In contrast, the other partner universities invited students to complete the cognitive quiz in the first few weeks of the first semester and had variable completion rates - USQ 50.6%; UoN 54%; UTS 36.6%; and UNE 75%, respectively. The later timing of Phase 1 testing may have impacted on the student experience and explain these lower completion rates.

At the end of the cognitive quiz, students responded to a series of questions to assess their reactions to completing the quiz. Table 1 summarises students' attitudes to completing the cognitive skills quiz.

Table 1: Student Attitudes to Completing the Cognitive Skills Quiz (*N* = 505)

Response options	% response
Benefit from doing quiz?	
It gave me insight into the knowledge I need for 1st year	60.0
It flagged some things I have forgotten and need to revise	82.0
I feel this is the beginning of my learning journey at uni	28.7
It made me feel that my needs were being assessed	28.9
No, it achieved none of the above	2.0
Are you glad you did it?	
Yes, I have a better idea of what I know and don't know	73.3
Yes, I have a better understanding of 1st yr knowledge expectations	62.0
Yes, I feel more confident	25.9
I'm not glad I did it at all	4.0
What actions will you take as a result?	
Revise my high school notes	59.4
Find a relevant text book	40.0
Ask someone who knows for help	24.6
Do nothing as I'll pick it up during semester	17.2
Do nothing because I did well	8.1
What did you dislike about doing the quiz?	
I haven't disliked doing it at all	38.4
I forgot a lot of what I knew during the holidays	43.4
It has scared me	11.3
It was stressful	6.3

It didn't help	1.8
It was time consuming and boring	7.9
I was still in a holiday mood	34.9

Overall, the majority of students who completed the cognitive skills quiz responded positively, indicating that it flagged things they needed to revise, and gave them insight into what was needed for first year. Most indicated an intention to take some action to revise material they had forgotten. While a small proportion of students did not see the value of the quiz, more than 25% of those who responded found it a confidence-boosting experience.

Overall, more than 50% of those who completed the cognitive quiz scored at 70% and above, with only one student achieving a perfect score. Figure 1 summarises the overall cognitive quiz data.

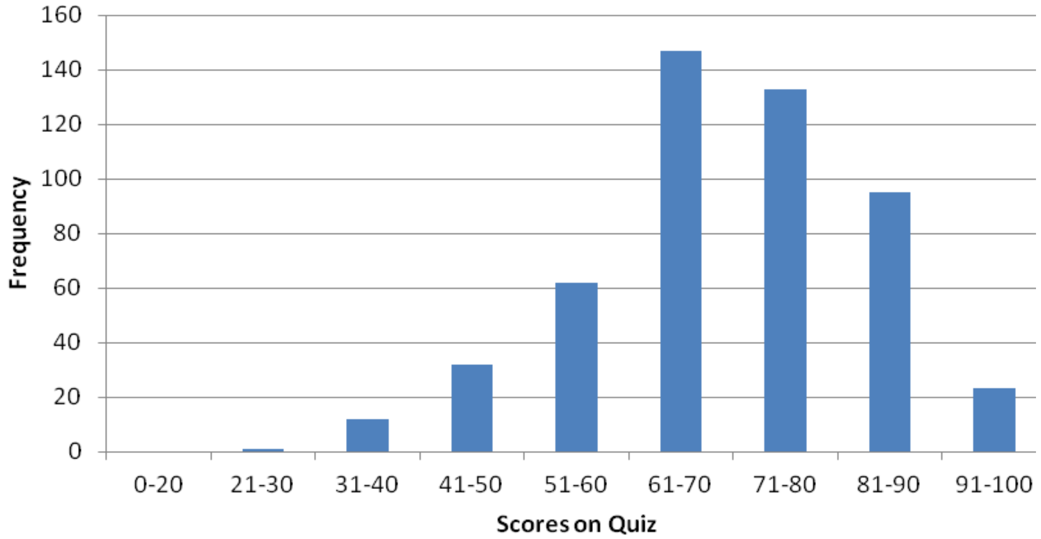

Figure 1: Bar graph of scores on cognitive skills quiz (*N*=505)

Descriptive statistics for cognitive skills performance by course type and study mode are shown in Table 2. Multivariate analyses indicated that there were no significant differences across course types (p >.05) or study modes (p > .05) for each of the physics, chemistry and spatial ability test results. That is, there were no observed differences in scores on physics, chemistry or spatial abilities between students enrolled in two-, three-, or four-year (or equivalent) programs, nor were there differences in these cognitive skills for on-campus students compared to their external counterparts. The low mean average score on the chemistry test is worthy of note. Even though 69% of students indicated that they had studied chemistry at high school, it appears this knowledge is not easily recalled for use in first year engineering studies.

In contrast, there were significant group differences in maths scores. External students' maths scores were significantly lower than those studying on-campus, $F(1, 496) = 12.77$, $p < .01$. There were also significant differences across course type, with students enrolled in four-year programs outperforming their counterparts in maths, $F(1, 496) = 16.92$, $p < .01$. A *post hoc* Tukey's test indicated that students in two- and three-year programs did not perform as well in the maths tests as did those in four-year degree (or equivalent) programs ($p < .01$). This finding is as expected, given that the Australian Tertiary Admission Rank (ATAR) and maths entry requirements for these programs are lower than those for four-year programs (Universities Admissions Centre, 2012).

Table 2: Comparison of Cognitive Skills Quiz by Course Type and Study Mode

	Course Type	Study Mode	Mean Score	SD	n
Maths	4 yr program (or equivalent)[a]	ONC	30.2	4.8	432
(score out of 36)		EXT	23.0	6.7	31
	3 yr program [b]	ONC	21.7	8.8	7
		EXT	18.6	7.0	8
	2 yr program [c]	EXT	17.5	7.8	15
Chemistry	4 yr program (or equivalent)	ONC	13.1	5.3	432
(score out of 24)		EXT	9.5	3.8	31
	3 yr program	ONC	11.7	6.0	7
		EXT	10.0	4.9	8
	2 yr program	EXT	10.7	5.5	26
Physics	4 yr program (or equivalent)	ONC	19.0	4.4	432
(score out of 28)		EXT	17.1	5.1	31
	3 yr program	ONC	17.0	5.1	7
		EXT	15.1	6.1	8
	2 yr program	EXT	18.2	4.6	26
Spatial ability	4 yr program (or equivalent)	ONC	10.0	2.4	432
(Score out of 12)		EXT	9.7	2.4	31
	3 yr program	ONC	11.1	1.1	7
		EXT	10.5	1.8	8
	2 yr program	EXT	9.4	2.5	26
Total quiz score	4 yr program (or equivalent)	ONC	72.3	12.1	432
		EXT	59.2	13.4	31
(score out of 100)	3 yr program	ONC	61.6	15.2	7
		EXT	54.3	14.5	8
	2 yr program	EXT	55.9	15.8	26
	All students	ONC	72.1	12.2	439
		EXT	57.2	14.4	65

Note. ONC = On-campus mode, EXT = External or distance mode.

Discussion and Conclusion

The Get Set quiz consists of two phases, self assessments of both cognitive (Phase 1) and non-cognitive (Phase 2) skills. Data are gathered in four core areas: cognitive competencies (e.g., mathematical, physics, chemistry and spatial skills), career decision making (including career interests and motivation), learning approaches, and personality. This paper reports on initial findings from Phase 1 only. The non-cognitive data are yet to be analysed. They will be combined with the cognitive quiz data, and student performance to identify key predictors of academic success.

Initial findings from our longitudinal project suggest that students studying in different program types and modes differ in their mathematical skills. The other three cognitive skills - physics, spatial, and chemistry skills - appear equivalent across cohorts. It is a particular concern that students studying in the external mode showed lower entry level mathematical skills than those studying on-campus. This finding is consistent with Smith and Ferguson's (2005) finding that online learning has significantly higher attrition rates in maths versus non-maths courses; whereas on-campus attrition rates are about the same for maths and non-maths courses. This adds an extra dimension of difficulty to students who are studying at a distance and adapting to a new study culture and discipline of study. Additional academic support is needed to ensure these often mature students successfully transition into the university and into their engineering program. Indeed, such mature-age learners are often balancing full-time work with their studies and are returning to tertiary studies after a long break. Thus, employing online learning technologies that provide opportunities for distance students to engage in lively discussions, ask questions, and receive feedback will help them to develop their problem solving and mathematical capabilities (Smith & Ferguson, 2005).

Overall, there was a positive student response to the Get Set for Success cognitive quiz and self report surveys. Initial feedback from students who engaged with the process suggests positive outcomes are likely to arise from students' participation in the quizzes.

The current students will be tracked through first year and the key predictors of academic success, as measured by GPA and retention, will be identified. These analyses are beyond the scope of this paper as GPA was not available at the time of writing. However, it is anticipated that the preliminary data reported here will build towards a more comprehensive understanding of factors impacting on student attrition. A critical review of the first year student experience will also help to determine whether students find the personalised feedback from the Get Set for Success quizzes useful in supporting their learning in first year engineering studies.

The project team will conduct focus groups at each partner university during Semester 2 to help provide further insight into how we can encourage more students to participate. The focus groups will also include career-specific questions to establish how prior experiences might influence career decisions to study engineering. Results from these focus groups will then be used to validate the key predictors identified through the self assessments and to isolate the factors that impact on students' decisions to persist with their studies during first year.

In addition, data from the current cohort across the five partner universities will be 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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