Ready for first year? The use of pre-teaching diagnostic tests to prompt greater preparation and engagement among first year engineering cohorts at The Universities of Auckland and Queensland

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***Abstract**: Having learnt of The University of Queensland's successful use of an on-line competency test for new undergraduate students prior to the start of their first semester, The University of Auckland launched its own 'Ready For First Year Quiz' in 2011. This paper provides direct comparisons on each institution's motivation for the quiz, analysis of the cohort completing the quiz, their engagement with the quiz, and preliminary feedback from staff and students on the usefulness and effectiveness of the quiz. The impacts of both campuses' quizzes upon student behaviour and performance are also compared and recommendations are made for future improvement.*

Introduction

In 2009 The University of Queensland (UQ) introduced an on-line competency test (PFFY – Preparing for First Year) for all new first-year engineering (FYE) students to help address concerns about a perceived lack of prerequisite knowledge and growth in attrition exacerbated by a lower entrance standard due to an increased intake quota. Despite a more stable admissions climate, the ability to select students from the highest-achieving cohort of school-leavers entering university, and high levels of retention among FYE, The University of Auckland (UofA) – based upon the experience of UQ - identified potential benefits from introducing its own 'Ready for First Year Quiz' (RFYQ) in 2011.

The main purpose of the original UQ test was

> 'to inform first year lecturers of the cohort knowledge base, and underpin future work which will support 'at-risk' students...'
>
> '...[allowing] targeted systems to be developed and implemented to ensure that students are not disadvantaged by their previous education (Kavanagh, O'Moore and Samuelowicz 2009).'

However, in retrospect, each test cohort's performance has been reasonably consistent and in keeping with first-year lecturers' prior anecdotal perceptions of student weakness and knowledge gaps, which then suggested 'that the value of the [test] lies not in informing academics of the cohorts' weaknesses, as this may be a constant, but in alerting individual students to gaps in their knowledge' (Kavanagh et al. 2009). Also, while the UQ test has proved to be a fairly reliable predictor of academic success in FYE, it does not appear to be a reliable predictor of the 'academically at-risk'. Consequently, the test has become more a vehicle for raising students' awareness of their individual areas of weakness and/or lack of knowledge, as well as providing explicit references to which courses will assume or require this knowledge, and providing resources for review as relevant.

It was this 'awareness-raising' that appealed to UofA FYE lecturers who, despite the supposed calibre of their FYE students, had noted a recurring lack of ability or awareness in a number of areas of assumed knowledge based upon data from several years' course-specific diagnostic tests implemented in the first week of semester and/or performance in on-course assessment. UofA was particularly interested in the finding that UQ students were inspired to seek out opportunities to remedy knowledge

gaps or weaknesses prior to the start of class: purchasing course-books earlier, revising sections from high school text-books, enrolling in preparation courses, etc. There was also a sense at UQ that their students may now be more likely to self-identify and seek out help as relevant (Kavanagh et al. 2009).

UQ-UofA Comparisons

Cohort Analysis

The UQ and UofA cohorts are remarkably similar in make up as shown in Table 1. The most notable differences are the extra year of schooling in NZ, and the choice available in the common first year.

Table 1 Cohort Analysis (All numbers approximate)

	Uof A	**UQ**
No. admitted/ year	620	1000
% domestic students	90	88
%. school leavers	90 (13 years at school)	80 (12 years at school)
% female	24	20
Entry requirements	• Demonstrated ability in Calculus and Physics to Year 13 school standard. • No requirement for Chemistry or Biology. • Rank score based on school results. • BE highest rank score at Uof A.	• Completion of at least one of Year 12 Advanced Maths, Physics or Chemistry. • No requirement for Biology. • Rank score based on school results. • BE rank score lower than Law and Health degrees at UQ.
First year specifications	Common (100% compulsory) *Courses*: mechanics, electrical & digital systems, materials science, mathematical modelling, engineering computation & software development, engineering biology & chemistry, and engineering design	Common (~50% compulsory) *Courses*: mathematics, physics, chemistry, mechanics, electrical systems, materials science, computation & software development, thermodynamics, and engineering design

Both UofA's and UQ's Faculty of Engineering have a high calibre, high-achieving intake compared to other faculties and institutions. Nevertheless, the experience of FYE lecturers has suggested there are distinct gaps in assumed knowledge among this cohort, leading to speculation that students are not being exposed to the 'full' Calculus and Physics curricula in NZ, and/or students did not develop an embedded understanding of certain topics, having acquired only a surface level of learning which they then 'lose' prior to starting their degrees. At UQ this is compounded by students not being required to have all three of Advanced Maths, Physics, and Chemistry. Approximately 50% of students have all three subjects, 30% have not studied Advanced Maths, 8% have not studied Physics and 23% have not studied chemistry. Fortunately most students (91%) have studied at least two of the three subjects.

At UQ, students are required to make up any 'missed' high school courses. At UofA there is no such obligation. Applicants will not be successful in gaining admission if they cannot demonstrate appropriate background achievements in Calculus and Physics; it is assumed that any missing Biology or Chemistry knowledge will be acquired in the FYE Biology and Chemistry course which all students must take, including those with prior knowledge/ ability in these disciplines.

Knowledge Tested

Table 2 details the differences between the two tests. Both were undertaken in the student's own space with students encouraged to complete the quiz before the commencement of Semester 1.

Table 2 Comparison of the tests

	Ready for First Year (UofA)	Preparing for First Year (UQ)
Questions	45x multiple choice: • 10x Mechanics • 10x Electrical • 10x Engineering Biology & Chemistry • 10x Mathematical Modelling • 5x Engineering Computation & Software Development 39x questions on Year 13 knowledge. 6x questions on FYE courses.	59x multiple choice: • 20x Mathematics • 17x Physics • 8x Chemistry • 14x Motivation, perceived difficulties, learning styles etc. All questions on Year 12 knowledge.
Timing	60 minutes expected duration	Not timed
Promotion	• Compulsory, though not enforced • Dean's welcome letter • New student email + follow-up if quiz not completed • Orientation publications/ website	• Compulsory, though not enforced • FYE Program Guide (mailed to students with enrolment package) • Follow up email if not completed • Advising & O-week sessions
Post-test response	• Students able to view performance/ results on-line • Students receive generic email with links to resources to review knowledge • Academics emailed cohort level results	• Students able to view performance/ results on-line • Students receive links to resources to review knowledge on-line • Results illustrated against course requirements • Academics emailed cohort level results

Unlike the PFFY quiz which asked students about assumed knowledge, the RFYQ included six questions assumed not to be covered by any prior learning – three biology, one chemistry, and two engineering computation (programming) problems. These questions were included to illustrate the type of problems/ material students could expect to encounter during their first-year studies and so provide students with the opportunity to begin learning about new disciplines as well as refresh prior knowledge. When comparing prior knowledge assumptions with UQ, it was noted that UQ would have assumed no knowledge for eleven of the RFYQ questions: the same six as highlighted by UofA and a further five in the electricity section: basic DC circuits and magnetic forces. This anomaly is thought to be the result of the difference in schooling in Australia (12 years) and NZ (13 years).

In addition to the multiple choice solutions to each problem, both institutions provided students with two generic responses – 'Can't remember how to do it' and 'Never seen it before' –to discourage wild guesses and thus allow the identification of concepts with which the cohort was genuinely unfamiliar.

Both tests were compulsory, but not enforced although both universities did send follow-up emails to students reminding them of the requirement and stressing the importance of doing so as quickly as possible. The rationale for this was that new students were more likely engage with compulsory requirements than with optional tests, however much they were incentivised. UQ's experience bears this out, with only 37% of FYE participating in 2009 when the test was optional with an 'iTouch prize-draw' inducement, compared to 63% twelve months later when changed to a compulsory requirement. In 2011, UQ and UofA recorded 72% and 88% participation rates respectively.

Once the tests were completed, students were able to view their results on-line. UQ also provided on-line guidance towards available resources to review knowledge, and mapped results against course requirements to help illustrate the need for appropriate knowledge. This has anecdotally resulted in a more considered selection of courses with students postponing courses requiring previously unstudied material until they have taken the relevant pre-requisite course. UofA was unable to provide the same level of guidance, but did send each student a generic email containing a range of resources available to assist pre-semester preparations. FYE lecturers at both institutions received cohort level results (e.g. 93% of students can balance a see-saw, and 58% of students can calculate a definite integral).

Performance (2011)

Table 3 details the performance of UofA students in 2011. Where there is an overlap of question types, UQ results for 2011 have been included in square brackets. Interestingly the overall performance of students at UofA and UQ are comparable but as previously mentioned, UofA included 6 questions that were not assumed knowledge and the UQ cohort contained only 50% of students who had studied high school Advanced Mathematics, Physics and Chemistry therefore the similarity of the overall numbers may be a coincidence.

Table 3 UofA - Correctly answered questions (N=592 UofA, N=769 UQ)

Question type	Mean	Median	Std Dev
All data (45x) [59x UQ]	63.8 [64.6]	67 [68]	20.8 [21.9]
Mechanics (10x) [4x UQ]	66.3 [73.5]	60.0 [73]	17.0 [18.4]
Electricity (10x) [2x UQ]	49.6 [42.0]	46.5 -	23.1 [5.7]
Biology & Chemistry (10x) Chemistry only [8x UQ]	63.9 [51.1]	68.0 [52.5]	18.0 [20.9]
Mathematical Modelling (10x) Mathematics [20x UQ]	74.9 [73.4]	79.5 [73.5]	17.2 [18.0]
Software Development (5x)	65.2	67.0	25.8

Further, the table shows that both UofA and UQ FYE students were most comfortable with mathematical modelling problems, but tended to find the electricity related problems to be the most difficult/challenging. At UofA, this was further highlighted by the wide spectrum of the number of correct responses for specific mechanics problems which achieved a 96% successful answer rate, compared to certain electricity problems which accumulated only 24% of correct responses.

UQ students performed better on the mechanics questions and worse on the chemistry questions than UofA students. The latter finding is counter intuitive given that UofA students are not required to study high school chemistry whereas 77% of the UQ cohort has. UofA did not ask FYE students to indicate their level of academic background in Mathematics, Chemistry and Physics before commencing the competency test. This was an opportunity missed as the PFFY collects this data and uses it to manage any potential mismatch in student assumptions and experience in future years.

At UofA, the 'Never seen it before' and 'Can't remember how to do it' response options were generally used at a low rate – their mean percentage was less than 3% for both of the responses. However, for selective questions the responses were considerably higher – e.g. the mathematical modelling question "$\int_0^{\sqrt{\pi}} x \sin(x^2)\,\mathrm{d}x$ is:" saw 14% of students (N=85) answering 'Can't remember how to do it' and the biology question "Which of the following statements about biomolecules (organic molecules produced by living organisms) is false" saw 19% of students (N=113) answer 'Never heard of it'. While weaknesses in these areas were anticipated, the selective use of these responses has helped to inform FYE lecturers as to this particular blind spot for students.

At UQ, the 'Never seen it before' and 'Can't remember how to do it' responses were used far more frequently: overall the combined usage was approximately 10%, the combined usage for Mathematics was 10%, for Chemistry 12%, and for Physics 5%. In Mathematics, questions on the area under the curve (23%), logs (30%) and integrals with initial conditions (36%) scored highly. In Physics, a question on the conservation of work and heat attracted a combined response of 17% and in chemistry two questions on equilibrium were the highest scored with 19% and 48%. It is postulated that being able to indicate that they had not previously studied a subject, gave students the confidence to use these responses and thereby provide a more accurate snapshot of the overall cohort knowledge level.

Performance (Longitudinal)

Longitudinal results for the UQ incoming cohort across 3 years are shown in Table 4. Interestingly the spike in correct answers experienced in 2010 did not match with either the cohort's average high

school rank score - the 2011 cohort had the highest - or their performance in Semester 1 exams - the lowest of the three cohorts. Therefore there appears to be no correlation between cohort performance on the PFFY and high school or Semester 1 achievement. However it can be seen that the incoming cohort is always strongest in mathematics and weakest in chemistry.

Table 4 UQ - Correctly answered questions

Question type	Average % answering correctly		
	2009	2010	2011
Number of Students	351	623	769
Mathematics (20x)	69 ± 21	77 ± 17	73 ± 18
Physics (17x)	64 ± 22	73 ± 19	64 ± 23
Chemistry (8x)	54 ± 24	61 ± 18	51 ± 21

Student performance, when analysed by UofA FYE lecturers, did not reveal anything new but rather tended to confirm prior experience and assumptions about cohort strengths and weaknesses. UQ lecturers have found that the variation between cohorts is generally small (±5%) but occasionally can be significant. For example, condensation is always poorly understood with 38% of students showing understanding in 2009, 47% in 2010, and only 21% in 2011. Whilst the reason for this fluctuation is unknown, definitive strategies can be put in place to ensure students' misconceptions are dispelled.

Outcomes

Given that UofA's main motivation for adopting the RFYQ was to raise FYE students' awareness as to their individual weaknesses and encourage them to seek redress prior to the start of semester, the initiative has been relatively successful as per the experience at UQ. However, the inability of UofA to send out individualised feedback to students reduced the opportunity to address students' knowledge gaps and motivate them to engage with resources prior to the start of semester.

Increased enrolment was observed in pre-semester calculus and physics preparation courses: 'Superstart Mathematics' noted an increase from 90 students in 2010 to 124 in 2011 (a 37% increase), and 'Launch Into Physics' experienced a 90% increase from 20 enrolments in 2010 to 38 in 2011. In addition, a survey of FYE students (N=438) conducted at the end of first semester indicated that 34% agreed or strongly agreed that the quiz had been helpful in preparing them for their first year studies, 20% disagreed or strongly disagreed, 40% were 'neutral', and 6% answered 'N/A'. Whatever the student response, the fact remains that simply by participating in the tests, students would have reviewed knowledge and thereby been better prepared for their first semester. It is understood that as the tests are performed in the students own time and space, there is scope for collusion and using textbooks or the web to answer questions. However, the tests are not for assessment and, it is argued that in the process of finding the correct answer, students are effectively reviewing knowledge.

The survey also indicated that only 15% agreed or strongly agreed that they were motivated to access resources and review knowledge as a consequence of the quiz (53% disagreed/ strongly disagreed and 26% were neutral), however the high RFYQ participation rate (88%) was seen as a positive outcome in raising awareness of what students could expect in their FYE courses. UofA can only speculate that if it had been able to provide more specific feedback on individual students' performance, with direct links between areas of weakness, the courses requiring this knowledge and resources to help fill knowledge gaps, then the positive survey response rate would have been higher.

Of those that were inspired to follow up the RFYQ with pre-semester preparation, the most common response (16%) was to review school notes, past exam papers and text-books, with others enrolling in University preparation programs, purchasing and reviewing course text books early, and/or accessing course materials on-line. Responses also indicated that students accessed material on subjects for which no prior learning was a pre-requisite – e.g. electricity, biology and chemistry – which appears to justify the motivation to include unfamiliar discipline problems in the RFYQ. However, it should be noted that students were not aware that this knowledge was not assumed.

Unlike UQ (Kavanagh et al. 2009), UofA is unable to ascertain whether those that prepared in advance for first year performed better than those that did not. Nor is there any obvious impact upon FYE

student performance: some Semester 1 courses recorded slightly higher grade distributions whilst others were slightly lower.

Review of the inaugural implementation of the RFYQ initiative indicated that it was important to understand the FYE cohort's academic background, and to gather student feedback on the usefulness of the quiz in preparing them for first-year. The PFFY achieves this very effectively by incorporating additional questions, and then following up with end of course surveys, and ad hoc focus groups or polls taken during orientation and early in the semester. Interestingly, both UofA and UQ noted that many students appeared to have forgotten much about the quiz by the end of first semester and the discipline areas it covered. Consequently, there is a need to generate and record feedback at a number of intervals following the completion of the tests in order to get a true understanding of how the tests can be best employed, to better understand student motivations, and also to improve the initiative.

Recommendations for future implementation

A number of conclusions and recommendations have come out of the comparison of the two tests:

1. Pre-teaching diagnostic tests are instrumental in managing the knowledge gap between incoming student and academic expectations. They appear to motivate many students to review concepts and raise awareness of areas of weakness. In addition, students can use this knowledge to plan their program if their results are reported against knowledge required for various courses. However the tests are not generally a predictor of the cohort's incoming knowledge or performance at university.
2. The tests can be used to introduce students to new concepts they will be required to tackle during first-year courses. This can encourage students to undertake pre-reading in new discipline areas.
3. There is an advantage to systematically capturing students' own perceptions of their knowledge in that this information can be used to underpin the support of the cohort in general. Students may give a clearer indication of their needs through use of 'Never seen it before' type responses if they are asked about their background at the beginning of the test.
4. In order to improve the initiative, it is vital that students receive formal feedback on their performance to reinforce the need (where relevant) to refresh prior learning and/ or develop new knowledge before the start of semester and thus avoid potential difficulties and/ or academic failure thereafter. Methods should also be employed to monitor how many students are inspired to utilise the resources recommended by the institution – such as directing students to a 'wiki' of resources, so that the volume of web traffic can be captured.
5. Student feedback on the quiz should also be gathered at regular intervals – at the end of the quiz, during orientation, half-way through and at the end of first semester – to help monitor effectiveness and inform possible enhancements. Mechanisms for capturing feedback could include additional RFYQ questions, ad hoc focus groups, and clicker responses in lectures.

Both UofA and UQ will be using the pre-teaching diagnostic tests in 2012. UofA will include questions to more accurately understand the cohort, and UQ will be considering the inclusion of questions related to concepts for which pre-reading would provide an excellent advantage.

References

Kavanagh, L., O'Moore, L., Samuelowicz, K. (2009). Characterising the first year cohort knowledge. In K.E. Sparks & M. Simonson (Eds.), *Proceedings of AaeE Conference, Adelaide*

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