Characterising the first year cohort knowledge

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***Abstract**: Over the past 5 years, the incoming engineering cohort at The University of Queensland has changed significantly in terms of both size and competence. Concerns have been raised by academics teaching courses in the first year engineering curriculum, as it is apparent that there is a misalignment between the level of competency in maths and science that academics assume the students possess, the skills sets that students actually possess, and the skills required to successfully navigate through first year engineering. A pilot on-line competency test, encompassing chemistry, physics, mathematics, and thermodynamics was run at the beginning of first semester 2009. The results were used to inform first year lecturers of the cohort knowledge base, and underpin future work which will support 'at-risk' students. This paper details preliminary results, the feedback obtained from staff and students, and ongoing research.*

Introduction

Due to a push for more engineers from the Queensland Government, the intake of First Year Engineering (FYE) students has grown from 521 in 2005 to 970 in 2008. To facilitate this, the entry score was lowered from an OP cut-off of 6 in 2005 to 9 in 2008 (OP 1 is the highest). These facts, coupled with the diversity of student's origins and academic backgrounds have contributed to a decrease in student satisfaction and a growth in attrition (6.1% in 2004 to 10.4% in 2006, *Review of First Year Engineering,* 2008). Lecturers are reporting a lack of prerequisite assumed knowledge and skills in the FYE cohort and students are experiencing difficulties with material that requires this knowledge. Students faced with such fundamental knowledge hurdles become quickly dissatisfied and may withdraw from the engineering program, thus contributing to the growing attrition rate.

Whilst there are mechanisms in place to increase the OP cut-off back to 6, the diversity of student academic backgrounds will continue to be a problem that needs to be addressed. Identifying the knowledge gaps of the incoming cohort forms the initial step in the solution, as it will allow targeted systems to be developed and implemented to ensure that students are not disadvantaged by their previous education. This support will, in turn, improve student learning, results and retention rates, as well as student satisfaction. This paper presents the preliminary results from a pilot-scale Competency Test (CT) which was run at the beginning of semester 1, 2009.

The Competency Test (CT)

Preliminary identification of the threshold concepts (Meyer & Land, 2003) in mathematics, physics, chemistry and thermodynamics was made through interviews with teaching academics. This was followed by the identification of existing tests: 13 relevant tests were identified, yielding 500 items. A set of 60 multiple-choice questions was selected by a three-step selection process: preliminary selection by the authors; further selection by academics teaching first year; and a workshop to discuss and finalise the test items. The final CT consisted of 46 content questions and 14 questions addressing motivations and learning approaches. The latter questions are not reported in this paper. Students were told the correct answer immediately after answering each question.

The CT was administered via Surveymonkey during O-Week. An iPod touch was offered as an incentive; completion was voluntary and had no bearing on the students' marks. The 351 CT participants represent 37% of the total 2009 FYE cohort, giving a 97% confidence in the results. The CT cohort was similar in make up to the overall FYE cohort: domestic students made up 83% of CT cohort compared to 90% of the overall FYE cohort; and 62% of the CT cohort had an OP rather than a QTAC rank compared to 63% of the overall FYE. The OP scores of the CT cohort ranged from 1 to 11; the lower OP students were not enrolled in the BE. The majority (74%) were enrolled in a BE, followed by BE/BSc (10%); other programs were BE/Com and BE/Business/Management.

Overall 176 students of the CT cohort had taken Maths C, 205 students had studied Physics, and 181 students had taken Chemistry. In combination, 41% had taken all three subjects, 26% had taken two subjects, and 5% had taken only Physics. High school subject information could not be found for the remaining 28% of students. Again these numbers are representative of the FYE cohort. Eleven students received an overall CT score (OCTS) of 0; nine of these students did not attempt a single question with the other two students attempting one question incorrectly. It is possible that these students registered only to secure a place in the draw for the i-touch. Most of the students scoring 0 in a particular section of the CT did not attempt any questions. The number increased as the students proceeded through the CT: 11 for chemistry, 36 for thermodynamics, 38 students for physics, and 43 for maths. The reasons for this are probably varied; for example it could be due to time limitations, boredom, or the fact that the questions may have been found to be difficult. It is not possible to make any conclusions based on the data gathered. Where irrelevant, this 'null cohort' has been removed from the results. The null cohort achieved a Grade Point Average (GPA) of 4.8±1.3 at the end of Semester 1 2009. Five students achieved a failing GPA (<4; 4 is equivalent to a Pass), 1 student achieved a GPA of 7 (High Distinction), and 7 students achieved a GPA of 6 or above (Distinction). This demonstrates that the null cohort probably did not attempt the CT for reasons other than a knowledge deficiency.

Results and Discussion

Concept knowledge

A comparison was undertaken for questions used by other cohorts (Table 1). Interestingly the results show that the UQ cohort is similar to other reported cohorts and this may suggest that the value of the CT 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.

Table 1 Cohort comparison [Cohorts: A = USA, 1st year chem, N=1418 (Mulford &Robinson, 2002), B = UQ, 1st year chem, N=557 (Lawrie, 2009), C = NZ, 1st year engineering, N= 560 (Smaill et al., 2008)]

Question	UQ 2009	Other Cohorts
Heat can be described as: ***a)Energy flow from one body to another,*** b)Friction from particles rubbing together, c) A reading on a thermometer, d) The absence of cold, e) A substance that makes objects feel warm	74% correct	70% (A) 74% (B)
True or false? When a match burns, some matter is destroyed.	84%	89% (A) 85% (B)
Iron combines with oxygen and water from the air to form rust. If an iron nail were allowed to rust completely, one should find that the rust weights: a) Less than the nail it came from, b) The same, c) ***More than the nail it came from,*** d) It's impossible to predict	62%	50% (A) 50% (B)
Refer to the diagram [of an electric circuit]: If you increase the resistance C, what happens to the brightness of bulbs A & B? a) A stays the same, B dims, b) A dims, B stays the same, c) A and B increase, **d)** ***A and B decrease,*** e) A and B remain the same	38%	37% (C)

Table 2 lists the concepts tested and the percentages of correct answers. For each subject, the questions are ordered from the highest percent of correct answers to the lowest. *Question No* refers to the order in which questions appeared in the CT. This data was distributed to academics involved with the FYE cohort in Week 2 for incorporation in their teaching as relevant. Preliminary feedback from these academics indicates that they found these results useful, as they gave an overall picture of the cohort's understanding of core concepts. This allowed some modification of teaching, including

paying more attention to those concepts poorly understood by students, and starting, for example, 'with a simpler concept and examples' before moving to more complex knowledge.

Table 2 Concept understanding of the overall CT cohort

Question No	Concept	Correct answer
Chemistry (N=12)		
18	Conservation of mass with heat	84.4%
17	Condensation	78.6%
9	Heat definition	73.7%
10	Thermal equilibrium	69.5%
11	Intermolecular forces	64.2%
15	Acid/base chemistry	63.7%
19	Mass conservation	61.9%
16	Evaporation	41.6%
20	Condensation	38.3%
13	Equilibrium	33.5%
14	Equilibrium	19.0%
12	Intermolecular forces	13.7%
Physics (N=9)		
30	Balancing moments	95.0%
34	Graph interpretation (velocity)	90.5%
31	Equilibrium of forces	82.3%
35	Graph interpretation (acceleration)	76.3%
32	Units, numbers & ordering by size	65.6%
28	Projectile motion	62.7%
27	Gravity	54.9%
29	Newton's 3rd law	48.1%
33	Ohm's law	40.5%

Question No	Concept	Correct answer
Mathematics (N=20)		
36	Simple fraction	98.1%
45	Simple derivative	91.3%
44	Function substitution	90.9%
39	Expand two brackets	88.8%
38	Solving equation	88.5%
40	Factorise quadratic	87.9%
50	Simple integral	84.4%
41	Solving quadratic	77.9%
43	Trig application	77.5%
37	Algebraic fraction	69.7%
46	Optimisation	66.3%
42	Simplifying powers	62.4%
49	Chain rule	61.6%
51	Indefinite integral	61.2%
53	Area under graph	59.0%
52	Definite integral	55.6%
55	Composition of function	51.8%
47	Logs	48.5%
48	Product rule	41.7%
54	Integral with initial condition	13.8%
Thermodynamics (N=5)		
22	Density=m/v	84.1%
23	Gas law	66.0%
26	Energy	65.4%
24	Energy total	48.0%
25	Work/heat conservation mass	15.3%

Cohort performance (Concepts)

Table 3 gives the OCTS as well as scores achieved in the individual sections; it does not include the null cohort. Students with better OP scores (OP 1 to 3) did better on the CT. For these students, 57 out of 112 students (51%) scored above 70% compared to 20 out of 106 (19%) students with OP 4 to 11. A higher percentage of students with OPs lower than 3 (55%) scored between 40% and 70% which confirms the findings of the '*First Year Experience Report'* (2008) which showed that 'students with OP scores above 6 do better in examinations than those with lower OP Scores' (p. 21).

Table 3 Student performance

Correct answers (%)	Number of Students				
	OCTS (N=343)	Chemistry (N= 340)	Thermodynamics (N=315)	Physics (N=313)	Mathematics (N=309)
100	-	7	16	28	17
90 – 99	11	15	-	-	39
80 – 90	31	30	70	52	56
70 – 80	67	43	-	71	52
60 – 70	85	47	108	54	58
50 – 60	52	71	-	43	38
40 – 50	41	35	78	34	30
30 – 40	16	31	-	25	7
20 – 30	10	19	32	3	8
10 – 20	6	30	-	3	2
2 – 10	21	11	-	-	1
0	2	1	11	-	1

Focusing on students who scored above 70% and had an OP of 1 to 3, 47 out of the 57 students had done the three high school recommended courses – Mathematics C, Physics and Chemistry. Among the 10 students who hadn't undertaken all three recommended high school courses, 9 had no Mathematics C and one had no Physics. All 9 students without Mathematics C had VH (Very High)

in Mathematics B and one correctly answered all 20 questions in the maths component of the CT. For students with OP 4 to 11, 11 of the 20 students who scored above 70% in the CT had undertaken all three recommended high school courses.

Almost half of the international students fully completed the CT compared to 36% of the domestic cohort. For the international students, 47% had an OCTS of between 70% and 100% compared to 26% of the domestic students. The lack of familiarity with the Australian education system and the expected prerequisite knowledge could have motivated more international students to do the test and to take it seriously.

Individual performance (Concepts)

Eleven students obtained an OCTS greater than 90% (Table 4). This 'top cohort' answered all questions. Eight students from the CT cohort achieved a GPA of 7; none of these students were part of the 'top cohort'. All were domestic students with six achieving an OCTS of greater than 59% and the other two identified as part of the null cohort. Interestingly 7 of these students achieved a VH in Maths B, Chemistry and Physics and 4 of these 7 students also achieved a VH in Maths C. Only two students hadn't done Maths C and one student hadn't done Chemistry; all students had taken Physics.

Table 4 Top CT Cohort (91-100% OCTS, N=11)

Student	Competency Test Results (%)					OP or International	School Marks				GPA Sem 1 / 2009
	OCTS	Chem	Thermo	Physics	Maths		Maths B	Maths C	Chem	Physics	
1.	96%	100	80	**100**	95	International					**6.44**
2.		92	**100**	89	**100**	2					**6.50**
3.	93 %	**100**	**100**	**100**	85	2	VH	H	H	VH	**6.75**
4.		**100**	80	**100**	90	1	VH	H	VH	VH	**6.00**
5.		92	80	89	**100**	International					**5.67**
6.		92	80	**100**	**100**	1	VH	VH	VH	VH	**6.75**
7.	91%	**100**	60	**100**	90	2	H	H	VH	H	**5.00**
8.		92	80	89	**100**	1	VH		VH	VH	**6.75**
9.		92	80	**100**	90	1	VH	VH	VH	VH	**6.75**
10.		83	80	89	**100**	International					**6.25**
11.		75	**100**	**100**	95	International					**6.75**

Of more interest is the 'bottom cohort': 64 students with an OCTS less than 39%. Fifty-seven of these were domestic students; 35 had an OP and 20 had QTAC Ranks. As previously mentioned, 11 students had an OCTS of 0 and this was due to their not attempting any questions. Almost all students who scored between 22% and 39% attempted to answer all the questions. Nineteen students with scores between 2% and 7% attempted only the questions in chemistry – the first component of the CT. In the case of students who attempted all the questions, the scores can be seen as reflecting their true knowledge. Details of the 'bottom cohort' are given in Table 5 – the 32 students who answered less than 5 questions are not reported in this table. In future years, this cohort will be targeted with support material and recommendations for extra study in order to bridge this apparent knowledge gap.

A comparison of the CT cohorts' GPA against the OCTS seems to suggest that the test is fairly reliable in predicting academic success. If a pass on the CT is considered to be an OCTS greater than or equal to 50% and a passing GPA is considered to be greater than or equal to 4, then 68% of students passed both, 4% of students failed both, 25% failed the CT only, and 3% received a failing GPA but passed the CT. In terms of success, the OCTS was also indicative of the level of final performance: as the OCTS increased, the ratio of students achieving a GPA above 6 to that of students achieving a GPA from 4 to 4.9 increased.

Initial results indicate that the correlation between OCTS and performance in a particular course is difficult to quantify and that it may not be possible to identify a student 'at risk' given their performance on the CT. Hence the value of the CT may be that students self-identify and seek out help as relevant. This theory is currently being further investigated as detailed results from 1st semester are analysed. Feedback from the students indicated that 28% of the students were glad that they did the CT because it made them '*feel more confident' and 63% said 'it gave me an insight into the knowledge that I need for 1st year*'. Eighty-eight percent found the CT useful because '*it flagged*

Table 5 Bottom Cohort Performance (<39 % correct) (N=64)

Student	Competency Test Results (no. correct answers/ no. questions attempted/% correct)					Entry	School Marks				GPA
	Overall	Chemistry (12 questions)	Thermodynamics (5 questions)	Physics (9 questions)	Maths (20 questions)		Maths B	Maths C	Chemistry	Physics	Semester 1/2009
1.		5/12 42%	2/5 40%	3/9 33%	8/20 40%	QTAC 92	H		H		3.75
2.	18/46	2/12 17%	2/5 40%	3/9 33%	11/20 55%	OP 1	VH	VH		VH	4
3.	39% correct	0/0	0/0	5/9 56%	13/20 65%	OP 3	VH			VH	6.75
4.		3/12 25%	2/5 40%	4/9 44%	9/20 45%	OP 6	H			S	5.75
5.	(5 students)	3/12 25%	2/5 40%	2/9 22%	11/20 55%	OP 7	H	H	S	H	5
6.		6/12 50%	2/5 20%	4/9 44%	2/20 30%	QTAC 96	VH	H	H		5
7.	17/46	8/12 67%	5/5 100%	4/6 44%	0/0 0%	QTAC 92	H		H	H	4.75
8.	37% correct	5/12 42%	1/5 20%	7/9 78%	4/8 40%						Withdrew
9.		2/12 17%	2/5 40%	4/9 44%	9/20 45%		H				4
10.	(8 students)	1/12 8%	1/5 20%	6/9 67%	9/20 45%	OP 1	VH			VH	5
11.		4/12 33%	3/5 60%	5/9 56%	5/20 25%	OP 7	H		S	H	6.25
12.		2/12 17%	0/0 0%	3/9 33%	12/20 60%	OP 7	H	H	H	S	4.5
13.		4/12 33%	2/5 40%	3/9 33%	8/20 40%	OP 7	S			S	5
14.	16/46	5/12 42%	1/5 20%	1/9 11%	9/20 45%	QTAC 91					5.5
15.	35% (2 students)	2/12 17%	2/5 40%	3/9 33%	9/20 45%	OP 8	S	S	S	S	4.5
16.	15/46 33%	3/12 25%	2/5 40%	3/9 33%	7/20 35%	OP 3	VH		VH	VH	5
17.	14/46	2/12 17%	0/5 0%	4/9 44%	20/8 40%	QTAC 98	VH	VH	H	VH	5.67
18.	30% correct	4/12 33%	0/5 0%	5/9 56%	20/5 25%	OP 6	S		H		4.5
19.		2/12 17%	1/5 20%	6/9 67%	20/5 25%	OP 7	H	S		S	3
20.	(4 students)	1/12 8%	3/5 60%	4/9 44%	20/6 30%	OP 8			H		4.25
21.	13/46 28%	4/12 33%	2/5 40%	9/5 56%	2/20 10%	QTAC 88	S		S	s	2
22.	12/32/46	5/12 42%	0/5 0%	9/2 22%	5/6 25%						4.5
23.	26% (2 students)	6/12 50%	3/5 60%	6/3 33%	0/0 0%	Int					1.75
24.	11/46	3/12 25%	0/5 0%	9/4 44%	4/20 20%	QTAC 90	H			H	4.33
25.	24% (2students)	10/12 83%	1/5 20%	0/0 0%	0/0 0%	Int					6.00
26.	10/46 22% correct	2/12 17%	4/5 80%	3/9 33%	1/ 2 5%	QTAC 95	H	H	S	H	Withdrew
27.	8/46	8/11 67%	0/0 0%	0/0 0%	0/0 0%	OP 2	VH	VH	VH	H	5.25
28.	17% (2 students)	7/9 58%	5/1 20%	0/0 0%	0/0 0%	OP 2	VH		VH	H	5.75
29.	7/46 15% correct	2/12 17%	5/1 20%	4/5 44%	0/0 0%	QTAC 97	VH	H		H	3.33
30.	6/46 13% correct	2/12 17%	5/3 60%	1/2 11%	0/0 0%	QTAC 88	H			S	6
31.	5/46	5/12 42%	0/0 0%	0/0 0%	0/0 0%	Int					4.7
32.	11% (2 students)	5/5 42%	0/0 0%	0/0 0%	0/0 0%	QTAC 99	VH	VH	VH	VH	3.5

some things that I have forgotten and need to review' or '*I have a better idea of what I know and what I don't know*' (83 %), and 52% were glad they did the CT as '*It will help my lecturers to tailor their courses to my needs*'. Additional comments expressed students' surprise at how much they'd forgotten and needed to revise '*I realise there is a lot that needs to be remembered for first year engineering'* and '*It tells me which area I would have to work on'*. However, 80% of students disliked doing the test because it was '*sort of scary realising all the stuff you forget and you know that you have done it before but just need to refer back to it all again'*.

Conclusions and the Way Forward

A meeting with interested FYE teaching academics to discuss initial results resulted in the following recommendations:

- The CT and the feedback given to the academics are useful and the CT should be employed again next year on a compulsory basis so that the entire FYE cohort is assessed.
- The CT may have 'fright' value and may have contributed to the good marks achieved by the failing CT cohort. Hopefully, students will 'self identify', as the CT does not appear to be a good predictor of academic failure in specific courses, and 'volunteer' for supporting tuition.
- Results should be fed back to the students via a 'course matrix' which indicates where they may have problems and which courses need this knowledge. This will require linking specific skills and knowledge from particular questions to one or more of the FYE courses.
- The 351 students who participated in the CT in semester one will be reassessed to ascertain if their skills and knowledge have improved. This will provide an opportunity to investigate the students' perceptions of the CT now that their first semester of study is complete.

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