Reducing Choice = Increasing Learning or Decreasing Marks?

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Abstract

In early-year engineering mathematics programmes in Dublin Institute of Technology (DIT), students were commonly required to attempt five out of eight questions in their end-of-year examination. As these questions were based on well-defined areas, it allowed students to omit certain topics and still perform impressively. This observation was re-iterated by the fact that the most common problem for which engineers sought help in the Maths Learning Centre last year was basic integration, with 56% coming from second or third year, at which stage they should be very familiar with integration. One way to address the problem is by reducing (or even eliminating) choice questions on mathematics papers in earlier years: if the material covered is necessary groundwork for later years, it should not be possible for students to omit it entirely. In this study, we build upon the results of an anonymous survey to determine students' opinions of reduced choice in early years. Within DIT, last year's changeover from year-long to semester-long modules afforded a natural move from a three-hour end-of-year exam to two two-hour end-of-semester exams. Two new approaches to choice were introduced by the authors. The first, with mechanical engineers, completely eliminated choice: students were required to answer all questions on the end-of-semester papers. The second approach, with building services engineers, replaced the final exam (a choice of five out of eight questions with question one compulsory) by end-of-semester exams featuring a choice of three out of four questions with question one compulsory. This greatly decreased choice without eliminating it. We compare and contrast both approaches, and address the question of whether reduced choice encourages students to learn difficult topics or adversely affects their marks.

Introduction

Within Dublin Institute of Technology (DIT), a wide range of engineering programmes are offered, at both Ordinary and Honours degree levels. The former programmes take three years to complete, and have a prerequisite of a D3 (the lowest pass grade) in Ordinary Level Leaving Certificate Mathematics, the final mathematics exam at the end of secondary school in Ireland. The latter programmes take four years to complete and have a prerequisite of a C3 in Higher Level Leaving Certificate Mathematics. If a student achieves sufficiently high grades in their final examinations in an Ordinary degree, they may enter into the third year of the Honours programme, and so leave with an Honours qualification within five years of commencing their studies.

In first-year engineering programmes, both at Ordinary and Honours levels, the standard format of many end-of-year mathematics exams to date has been to require students to answer five questions out of eight. Due to the fact that these questions were based on well-defined areas, it was possible for students to entirely ignore certain subject areas and still receive a good grade in the exam. This led to serious

difficulties for some students in later years of their programmes, as they lacked the basic mathematical knowledge required to learn more advanced topics.

This approach caused particular problems in calculus, with many students unable to cope with more advanced differential equations due to problems with basic integration. This was noted both anecdotally in the classroom and also in the Students' Maths Learning Centre, in which the most common topic for which engineering students sought help was basic integration, with 56% of the queries coming from second or third year students. It had been observed that students who had successfully completed an Ordinary degree and subsequently entered directly into the third year of an Honours degree programme experienced considerable difficulties with the mathematics component, although they tended to cope well with the more practical elements of the programme. Given that more than half the Ordinary degree students now progress to an Honours programme, this is an area of particular concern.

Many students expressed regret at having omitted integration in earlier years, leading us to conduct an anonymous, online survey to determine engineering students' attitudes towards choice in mathematics exams in the early years of their programmes (Carr (2007)). Students were asked if they had struggled as a result of omitting specific subject areas and if they felt that certain topics should always be compulsory. From the 276 responses received, 64% had avoided integration at some point, and 47% had struggled as a result; 39% had avoided differentiation at some point, and 32% had struggled as a result. A quarter of respondents felt that choice should be removed from at least some maths papers, while a massive 60% felt there should be compulsory questions on certain topics.

Concurrent with this research, DIT was in the process of changing over from year-long to semester-long modules. This afforded a natural move from a single three-hour end-of-year exam to two two-hour end-of-semester exams. Two new approaches were introduced by the authors: in the first of these, choice was completely eliminated, and students were required to answer all questions on both end-of-semester papers; the second approach replaced the final exam (a choice of five out of eight questions with question one compulsory) by end-of-semester exams featuring a choice of three out of four questions with question one compulsory. This greatly decreased choice without eliminating it. We will now look at each of these approaches in greater detail, contrasting the exam results on a question-by-question basis to determine the effects, if any, of these new layouts.

Elimination of Choice: 3rd Year Ordinary Degree Mechanical Engineering

As shown in Table 1 below, third-year Ordinary degree students in mechanical engineering traditionally had to answer five out of eight questions, with large numbers avoiding the integration or differential equations questions (as can be seen from the "Attempts" column) and still achieving good marks. With the changeover to two semesterised maths exams in this programme, the decision was made to make all questions compulsory, in an attempt to ensure students had a good grounding of all relevant areas before obtaining their degree. This would be of particular use to students continuing into the Honours programme.

Questions	**2005** (Pass: 38/51)			**2006** (Pass: 39/55)		
	Mean	***Sigma***	**Attempts**	**Mean**	***Sigma***	**Attempts**
1: Differential Eqns	54	*24*	30	43	*26*	29
2: Integration	37	*20*	23	67	*29*	25
3: Laplace Trans.	45	*26*	39	44	*29*	51
4: Radius of Curvature	44	*25*	6	62	*29*	9
5: Regression	65	*28*	39	65	*23*	53
6: Hypothesis Tests, Control Charts	65	*28*	29	60	*24*	35
7: Gauss-Seidel	67	*28*	40	58	*31*	30
8: Runge-Kutta	75	*25*	38	67	*22*	48
Total	**57**	***20***	**51**	**58**	***22***	**55**

Table 1: Mean mark and standard deviation (sigma) for each exam question in 2005 and 2006. Students had to answer five questions out of eight. The number of students who attempted each question is shown, along with the number who passed the exam.

Table 2 below shows the division of topics and subsequent results for this newly modularised and semesterised version of the course. Obviously, only three sets of results are available at this point in time, but this is sufficient for a preliminary study.

Questions	**Jan 2007** (Pass: 39/53)			**Jan 2008** (Pass: 40/51)		
	Mean	***Sigma***	**Attempts**	**Mean**	***Sigma***	**Attempts**
1: Runge-Kutta	70	*26*	51	80	*24*	50
2: Laplace Trans.	50	*24*	53	61	*29*	51
3: Diff Eqns	52	*32*	49	52	*29*	50
4: Diff Eqns	66	*32*	53	58	*27*	46
Total	**56**	***22***	**53**	**59**	***23***	**51**
	May 2007 (Pass: 47/54)			**May 2008**		
1: Integration	64	*32*	52	Data not yet available		
2: Control Charts	87	*24*	53			
3: Regression	79	*24*	54			
4: Gauss Seidel	72	*31*	51			
5: Hypothesis Tests	78	*30*	50			
6: Confidence Intervals	82	*26*	49			
Total	**70**	***22***	**54**			

Table 2: Mean mark and standard deviation for each exam question in each semester of 2007 and 2008. Students had to answer all questions. The number of students who attempted each question is shown, along with the number who passed the exam.

Reduction of Choice: 1st Year Ordinary Degree Building Services Engineering

Before modularisation, first-year Ordinary degree building services students were required to answer five out of eight questions on the end of year exam. Question 1 was compulsory and consisted of ten short questions covering algebra, trigonometry, differentiation and integration. The remaining questions each covered a specific topic including a question each on differentiation and integration. Due to the format of the

paper it was possible for a student to completely avoid questions considered difficult and concentrate instead on those considered the easier options. This usually resulted in the students avoiding the question on integration with the number of attempts being consistently low (again, as evident in the "Attempts" column of Table 3 below). On average only 45% would attempt the question on integration against 90% for differentiation. As has been stated this led to difficulties in later years with integration.

Questions	**2005** (Pass: 29/40)			**2006** (Pass: 28/35)		
	Mean	***Sigma***	**Attempts**	**Mean**	***Sigma***	**Attempts**
1: Compulsory	73	*19*	40	69	*18*	35
2: Binomial	34	*31*	17	40	*23*	20
3: Graphs	28	*36*	11	5	*0*	2
4: Differentiation	48	*26*	39	42	*23*	30
5: Trigonometry	36	*21*	35	56	*22*	26
6: Integration	36	*19*	23	42	*16*	11
7: Complex Numbers	45	*25*	28	50	*16*	26
8: Stats/ Probability	39	*22*	27	48	*22*	24
Total	**47**	***18***	**40**	**51**	***15***	**35**

Table 3: Mean mark and standard deviation (sigma) for each exam question in 2005 and 2006. Students had to answer five questions out of eight, with question 1 compulsory. The number of students who attempted each question is shown, along with the number who passed the exam.

After modularisation, it was decided to still allow an element of choice but, due to the importance of differentiation and integration, these were incorporated into the same question and made compulsory. The student was required to answer three out of four questions with question 1 compulsory. It is hoped that this approach will lead to students taking integration more seriously and assist them in succeeding years of the course. The division of topics and subsequent marks is shown in Table 4 below.

Questions	**Jan 2007** (Pass:32/49)			Questions	**Jan 2008** (Pass: 22/38)		
	Mean	***Sigma***	**Atmpt**		**Mean**	***Sigma***	**Atmpt**
1: Compuls.	28	*24*	49	1: Compuls.	52	*21*	38
2: Complex Numbers	33	*32*	47	2: Binomial	43	*31*	36
3: Graphs	42	*42*	5	3: Trig	58	*43*	37
4: Trig	56	*56*	46	4: Trig	46	*42*	27
Total	**41**	***40***	**49**	**Total**	**37**	***22***	**38**
	May 2007 (Pass:30/39)				**May 2008**		
1: Diff / Int (Compuls.)	48	27	39	Data not yet available			
2: Max/ Min	57	30	17				
3: Simpson	70	33	31				
4: Stats/Prob	63	30	30				
Total	**58**	**23**	**39**				

Table 4: Mean mark and standard deviation (sigma) for each exam question in 2007 and 2008. Students had to answer question 1, and two of the other three questions.

The number of students who attempted each question is shown, along with the number who passed the exam.

More Detailed Analysis of Calculus Questions

There is a huge amount of information contained within the four preceding tables. However, we are particularly interested in some of the calculus questions, and therefore we now analyse these figures to see what effect, if any, this has had on the numbers answering these questions and the mean mark. Table 5 shows the results for the third-year cohorts' questions on integration and differential equations. The number of students attempting these questions has almost doubled, but this has not had any adverse effect on the marks for the questions, which is an encouraging result.

	Integration			**Differential Eqns**					
Year	**Mean**	***Sigma***	**% Attempts**	**Mean**		***Sigma***		**% Attempts**	
2005	37	*20*	45%	54		*24*		59%	
2006	67	*29*	46%	43		*26*		53%	
2007	64	*32*	96%	52	66	*32*	*32*	93%	100%
2008	n/a			52	58	*29*	*27*	98%	100%

Table 5: Mean and standard deviation for integration and differential equations questions for third-year mechanical engineers from 2005-2008. In 2007-2008, there were two questions on differential equations, which are shown in split columns.

Table 6 shows the results for the first-year cohorts' questions on integration and differentiation. These are now merged into one compulsory question; again, we see a dramatic increase in the numbers answering integration but no subsequent drop in marks (although the marks for 2007 are merged for differentiation and integration).

	Integration			**Differentiation**		
Year	**Mean**	***Sigma***	**% Attempts**	**Mean**	***Sigma***	**% Attempts**
2005	36	*19*	58%	48	*26*	98%
2006	42	*16*	32%	42	*23*	86%
2007	48*	*27**	100%*	48*	*27**	100%*

Table 6: Mean and standard deviation for integration and differentiation questions for first-year building services from 2005-2007. * In 2007, integration and differentiation was combined in one compulsory question, meaning the results are identical.

Mean Marks and Pass Rates

As well as looking at particular questions, which were known to be avoided previously, we must also consider the overall mean marks and pass rates for the exams, to determine if reducing or eliminating choice has had any impact on these. Table 7 below shows the mean marks, standard deviations and percentage pass rates for exams from 2005-2008 for both programmes.

In the case of the third-year mechanical engineering class, the average mark has not been adversely affected by the decision to make all questions compulsory, or by covering most of the difficult questions in the first semester, nor is there any evidence of a reduction in pass rate; if anything, the pass rate in the second semester exam has

increased. This may be as a result of increasing the bar in the first semester, thus encouraging students to perform better in the second semester.

	1st Yr Building Services Eng			3rd Yr Mechanical Eng		
Year	**Mean**	***Sigma***	**Pass Rate**	**Mean**	***Sigma***	**% Pass Rate**
2005	47	*18*	73%	57	*20*	75%
2006	51	*15*	80%	58	*22*	71%
Jan 2007	41	*40*	65%	56	*22*	74%
May 2007	58	*23*	77%	70	*22*	87%
Jan 2008	37	*22*	56%	59	*23*	78%

Table 7: Mean mark, standard deviations and pass rate (%) for exams from 2005-2008

However, looking at both the marks and pass rates for the first-year building services engineering class, an interesting result emerges: the mean mark and pass rate for the first semester has dropped significantly, but the second semester is consistent with previous years. The compulsory question on integration/differentiation was on the exam at the end of the second semester. This suggests that this drop may in fact have considerably more to do with students' transition to semesterisation, rather than the change in the format of the exam, with first-year students less prepared to sit exams a mere twelve weeks after the start of their college career.

Conclusions and Future Work

Third-year mechanical engineering students are now compelled to answer all questions on their maths papers, including both integration and differential equations, which were commonly avoided previously. Almost all students are now attempting these questions. The major concern about this approach was that it would significantly reduce the mean mark or the pass rate. Neither of these has deteriorated; in fact, the students' marks actually increased in the second semester. It must be remembered that we only possess preliminary data at this point, as this is the second year in which this approach has been implemented, but, as yet, there is no evidence to suggest that by eliminating choice on the paper, we have reduced the mean mark or the pass rate for this cohort.

A decrease in both mean marks and pass rates is evident for the first-year building services students – but only in the first semester exam, with the second semester exam showing no significant deviation from previous years. As mentioned above, this increased early failure rate is likely to be due to other factors, such as difficulties adapting to third-level. However, another important factor is that ten fewer students sat the second semester exam than the first semester one; such students would not have been included in the compilation of pass rates for end-of-year exams in previous years, but did affect the pass rate in first semester, possibly making it artificially low. Further analysis of this trend will be conducted in the future, when more data is available. We plan to conduct a follow-up of the maths grades of the first-year students in later years in order to further ascertain potential benefits of this approach.

References

Carr, M. and Ní Fhloinn, E. (2007) "Increasing Learning by Decreasing Choice: What do Students Think?" In *Proc. ALM 14 – International Conference on Adults Learning Mathematics, Limerick, Ireland, June 2007.* To appear.