Increasing Learning by Decreasing Choice: What Do Students Think?

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Abstract: In first-year engineering mathematics programmes in Dublin Institute of Technology, students were commonly required to attempt five out of eight questions in their end-of-year examination. As these questions are based on well-defined areas, this allows students to entirely omit certain topics and still perform impressively. This approach causes serious problems in later years, as students lack the basic knowledge required to attempt more advanced mathematics. A common example of this is differential equations: many students skip integration in first year, only to discover this is a pre-requisite for second and third year material. This observation is borne out by the fact that the most common problem for which engineering students sought help in the Students' Maths Learning Centre last year was basic integration, with 56% of those coming from second or third year.

One way to address this problem would be by reducing (or even eliminating) choice questions on mathematics papers in first-year: if the material covered is necessary groundwork for later years, it should not be possible for students to omit it entirely. In this study, the results of an anonymous survey completed by students to determine their opinions of reduced choice in early years are presented.

1. Introduction

Dublin Institute of Technology (DIT) offers a wide range of engineering programmes, at both Ordinary Degree (OD) and Honours Degree (HD) level. The OD programmes take three years to complete, and students are required to have a minimum of a grade D3 in Ordinary Level Leaving Cert Maths for entry into the programme (that is, a pass grade in the final mathematics exam at the end of secondary school in Ireland). The HD programmes take four years to complete, and students must have achieved a minimum of a grade C3 in Higher Level Leaving Cert Maths. It is possible for students who obtain high grades in their final examinations in the OD programmes to enter into third year of the HD programmes, and so leave with a HD qualification within five years of beginning their studies. As a result, within the Faculty of Engineering, there are students with a wide range of mathematical abilities.

In first-year engineering programmes, the standard format of many end-of-year maths exams to date has been to require the student to answer five questions out of eight. As these questions are based on well-defined areas, it has been possible for students to entirely omit certain topics, and still receive very high grades in mathematics. This practice has led to serious difficulties for some students in later years of their programmes, as they lack the basic mathematical knowledge required to learn more advanced topics.

One of the most common examples of this is in the case of differential equations: many students avoid integration completely in first year, but then find that this is a pre-requisite for second and third year material. As well as noting this anecdotally in the classroom situation, this observation can be borne out by the fact that the most common topic for which engineering students sought help from the Students' Maths Learning Centre last year was basic integration, with 56% of the queries coming from second or third year students (Ní Fhloinn, 2007).

One approach to dealing with this problem is to reduce, or even eliminate, choice from maths exams, particularly in the early years of engineering programmes. To ascertain if students felt this would be a beneficial approach overall, an anonymous survey was prepared for WebCT and students from the Faculty of Engineering were encouraged to complete this survey. Obviously, the option to remove or reduce choice within exam papers would short-term involve a greater amount of work for students, and so it was of interest to us to observe whether there would be a marked shift in the maturity of the students' attitudes as they made the transition from school students to young adult learners of mathematics, in their acknowledgement that the harder route may in the end be the more beneficial one. In this paper, we discuss the results of the survey, and look in detail at the differences between the responses of the group as a whole, compared with those of students in the older years.

2. Structure of Survey

The survey was divided into ten questions, dealing with differentiation, integration, matrices and statistics. Students were questioned as to whether they had ever omitted questions on any of these topics, and then if they had struggled with other subjects as a result of avoiding these topics in earlier years. Finally, they were asked if they felt that there should be no choice on maths papers, and if so, for what years; or if they believed that certain topics should always be compulsory. Students were also given the opportunity to add any extra comments they had on the overall topic of choice in maths exams.

A total of 276 students from the Faculty of Engineering completed the survey. Table 1 below shows the breakdown of the years and degree types for the students who responded to the survey.

Table 1. Breakdown of year and degree type for the 272 students from the Faculty of Engineering who completed the anonymous survey on WebCT.

Year and Degree Type	Number of Student Responses
1st year, Honours Degree	79
2nd year, Honours Degree	57
3rd year, Honours Degree	54
4th year, Honours Degree	50
1st year, Ordinary Degree	1
2nd year, Ordinary Degree	2
3rd year, Ordinary Degree	33
Total	**276**

As can be seen from the table, far fewer Ordinary Degree students completed the survey; however, 35% of the 3rd Honours Degree students and 46% of the 4th year Honours Degree students were former Ordinary Degree students, and we were particularly anxious to obtain the opinions of these students, as they have studied on both degree types. In addition, it is of value to see if students' opinions change as they go through the later years of the programmes.

3. Survey Results

In this section, we will give details of the results of the survey, and will begin by looking at the overall response for the questions dealing with the avoidance of certain topics for maths exams.

3.1 Avoidance of Topics

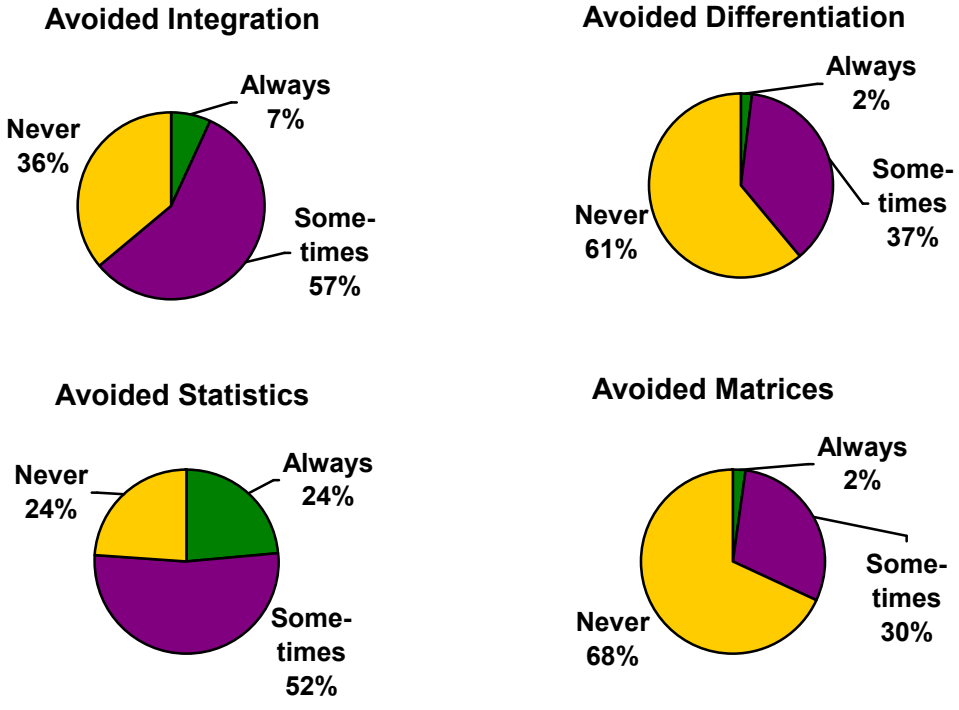
The first four questions in the survey asked students: "Have you ever avoided questions on integration/differentiation/statistics/matrices by choosing other questions on the paper?" From previous observations while correcting exams, it was expected that far more students would have avoided integration and statistics than the other two topics, and this proved to be true, as can be seen in Table 2 below.

Table 2. Students' responses to the question "Have you ever avoided questions on integration/differentiation/statistics/matrices by choosing other questions on the paper?"

	Avoid Integration	Avoid Differentiation	Avoid Statistics	Avoid Matrices
Always	19	5	65	6
Sometimes	157	102	144	82
Never	100	169	66	188

Figure 1 shows a series of pie charts, detailing the information shown in Table 2, but displaying the results as a percentage of the overall responses, for ease of comparison between the different topics.

Figure 1. Pie charts displaying students' responses to the question "Have you ever avoided questions on integration/differentiation/statistics/matrices by choosing other questions on the paper?" shown as a percentage of the overall responses.



It is clear from the pie charts that 64% of students overall avoided integration to some degree; 39% of students avoided differentiation; 77% avoided statistics and 32% avoided matrices. If we consider instead only the responses from students in 3rd or 4th year, there are no significant deviations from the percentages displayed below.

3.2 Struggling because of Avoidance of Topics

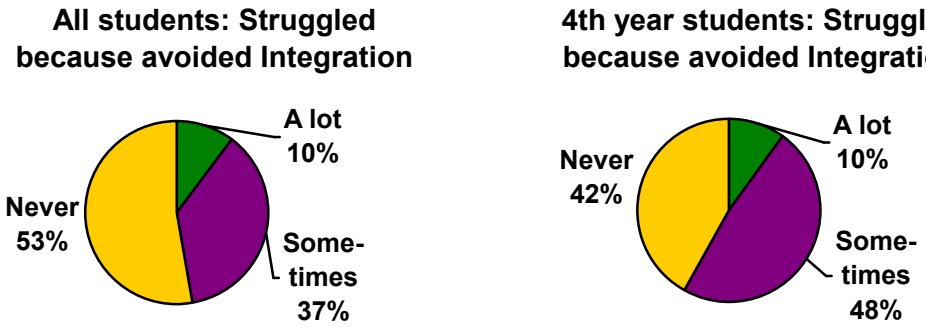
The next series of questions asked students if they felt that they have struggled in other subjects because they have avoided questions on integration/differentiation/statistics/matrices in earlier years. In these questions, we expected that there would be an appreciable difference between the overall responses and those of students in their final year, and this proved to be the case. Table 3 below shows the overall responses from all students.

Table 3. Students' responses to the question "I have struggled in other subjects because I have avoided questions on integration/differentiation/statistics/matrices on the maths paper in earlier years."

	Struggled because avoided Integration	Struggled because avoided Differentiation	Struggled because avoided Statistics	Struggled because avoided Matrices
A lot	28	13	12	7
Sometimes	102	75	74	41
Never	146	187	190	228

We now compare the overall responses for each topic with those of the 4th year students, to see how far-reaching the effect of avoiding certain topics can become as students progress through their programme. Figure 2 below compares the overall response for students who struggled because they avoided integration with the response of the final year students.

Figure 2. Pie charts displaying students' responses to the question "I have struggled in other subjects because I have avoided questions on integration on the maths paper in earlier years" shown as a percentage of the overall responses, first for all students, then only for 4th years.



It is very striking to observe that, from all the students who responded, 47% struggled to some degree because of avoiding integration, with this percentage rising to 58% of students at the end of their degree programme. As one 4th year student observed:

"I feel I have struggled all the way through college without understanding the general basics of integration, and I know many of my classmates have been in the same situation, and I'm sure it will continue unless something is done."

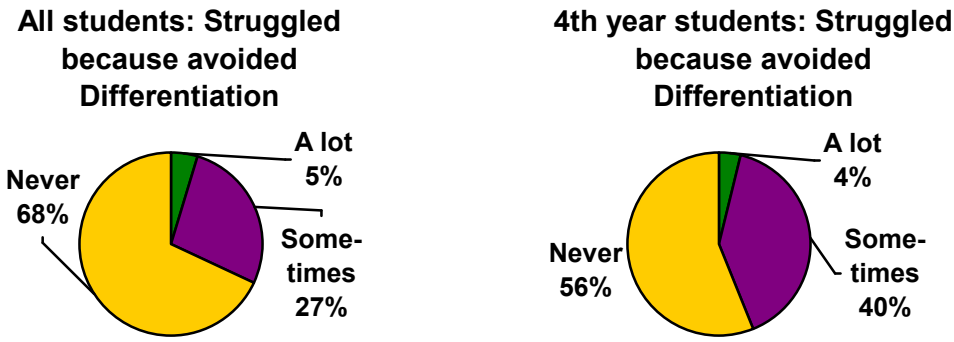
Another 4th year student stated that

"More focus should be placed on integration as every person I know has a weakness in this area, including myself!"

These comments show that students are themselves only too aware of the complications caused for them by not having a good grounding in a topic such as integration.

If we move on to the case of differentiation, which 39% of students admitted to avoiding, we see, from Figure 3, that 32% of students struggled as a result: almost all those who omitted the topic. This is a highly important observation, as it indicates that students who skip questions on differentiation are extremely likely to have problems as a direct result.

Figure 3. Pie charts displaying students' responses to the question "I have struggled in other subjects because I have avoided questions on differentiation on maths papers in earlier years" shown as a percentage of the overall responses, first for all students, then only for 4th years.



Looking at the final year students in isolation, 44% of them felt they struggled because of avoiding differentiation, again showing that the full impact of this approach of skipping questions is not felt until later years. This sentiment is expressed in the following comment from a student:

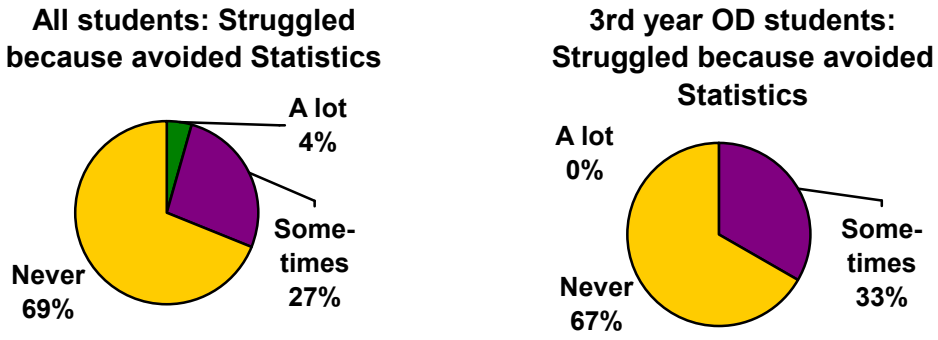
"I think differentiation is sometimes skipped in the Leaving Cert and this can make college difficult. I think that it should be compulsory because in first year you can just pass on matrices…this doesn't help the student in later years when lecturers assume you know how to do it."

Such high numbers of students admitting difficulties in later years due to the avoidance of this topic early on again emphasises the importance of calculus for those pursuing programmes in engineering.

Moving on to the case of statistics, a topic in which a huge three quarters of students have avoided questions as some stage, we see in Figure 4 that only 31% of students feel that they struggled in other subjects as a result. This is a far lower relative percentage than for other topics, when it is taken into account the number of students who omit the topic versus the number who experience problems afterwards. Interestingly, this was the only topic where a closer examination of the responses of the 4th year students indicated a *lower* percentage of difficulties than this overall figure of 31%. However, when we looked instead at the responses of the 3rd year Ordinary Degree students, as shown as Figure 4, we see that this figure is slightly higher than the overall. The vast majority of the 3rd year OD students who responded

to the survey are in Mechanical Engineering, in which students need a good knowledge of statistics for courses such as quality control. Therefore, these students would be more likely to experience problems than those in other types of engineering programmes.

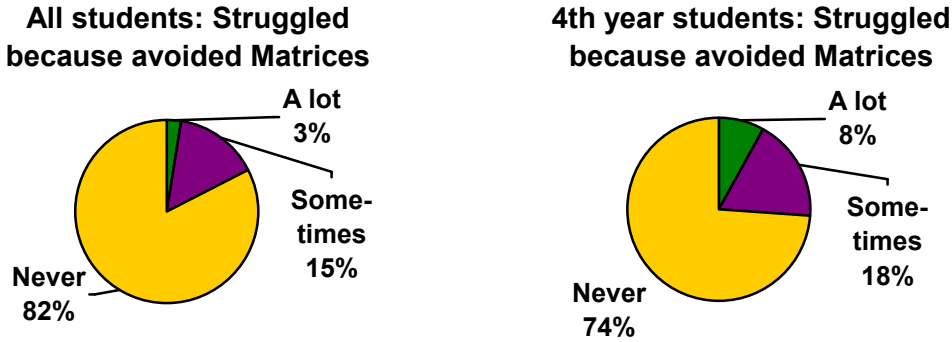
Figure 4. Pie charts displaying students' responses to the question "I have struggled in other subjects because I have avoided questions on statistics on the maths paper in earlier years" shown as a percentage of the overall responses, first for all students, then only for 3rd year Ordinary Degree students.



This observation is further borne out by some of the students' comments, which range from *"I don't see the need for Structural Engineers to do statistics",* to *"in Mechanical Engineering, statistics is strongly required",* or *"I struggled with statistics, however I have not found as much use for this topic in other subjects".*

Finally, looking at the responses for matrices, as expected, not as many students experienced difficulties having omitted them. Traditionally, matrices questions are very popular in exams, and only 32% of students said they had ever avoided them, so it is not overly surprising that only 18% had difficulties later on as a result, as shown in Figure 5. This figure does increase in 26% for the 4th year students in isolation, which is still a significant portion of the final years students.

Figure 5. Pie charts displaying students' responses to the question "I have struggled in other subjects because I have avoided questions on matrices on the maths paper in earlier years" shown as a percentage of the overall responses, first for all students, then only for 4th years.

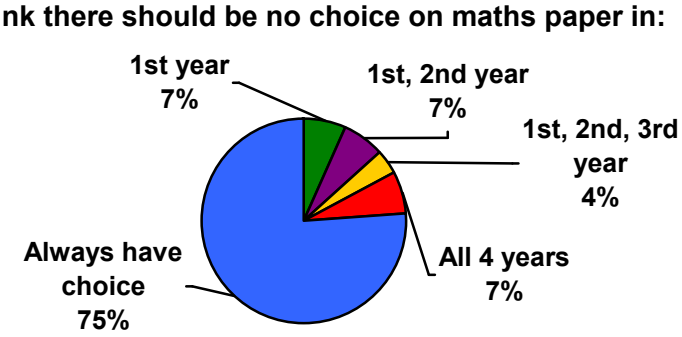


3.3 Opinions on Choice

The final set of questions that students were asked concerned their opinions on whether there should be no choice in maths exams in every year, or in the early year, and which topics (if any) should be compulsory questions. These questions provoked

the liveliest debate in the students' comments, with remarks ranging from *"Introducing choice into exams defeats the purpose of exams entirely"* to the heartfelt plea: *"Choice is good. It relieves stress. Keep it please!"* Figure 6 below shows their responses to the question of whether choice should be removed from maths exams.

Figure 6. Pie chart displaying students' responses to the question "I think there should be no choice on maths papers in 1st year/1st, 2nd years/1st, 2nd, 3rd years/all 4 years/always have choice" shown as a percentage of the overall responses for all students.



Although 75% of students believe there should always be choice on the maths paper, a substantially higher proportion than we had expected believe that choice should be removed in order to improve their overall comprehension of their engineering programme. One student observed:

> *"A paper with no choice is more beneficial in the long run as you are forced to understand the entire content of the maths course. It also means that everyone has the same questions and judging the entire classes' progress is easier this way."*

Several other students voiced similar opinions to this comment.

One very interesting (and, for us, unexpected!) result was that, when 4th year students' responses were isolated for this question, 82% of them were in favour of always having choice in the exam. We had expected that far more of these students would opt for no choice in earlier years at least, particularly in light of the problems they have experienced as a result of avoiding certain topics early on. The 3rd year HD students in isolation gave a more expected response with only 67% in favour of always having a choice, but the final year students seemed more resistant to this idea.

Quite a few students, who did not feel that choice should be abolished, felt instead that a sensible approach would be to *"have more continuous assessment exams on differentiation and integration and then a choice in the final exam."* Several possible advantages were extolled for this, including:

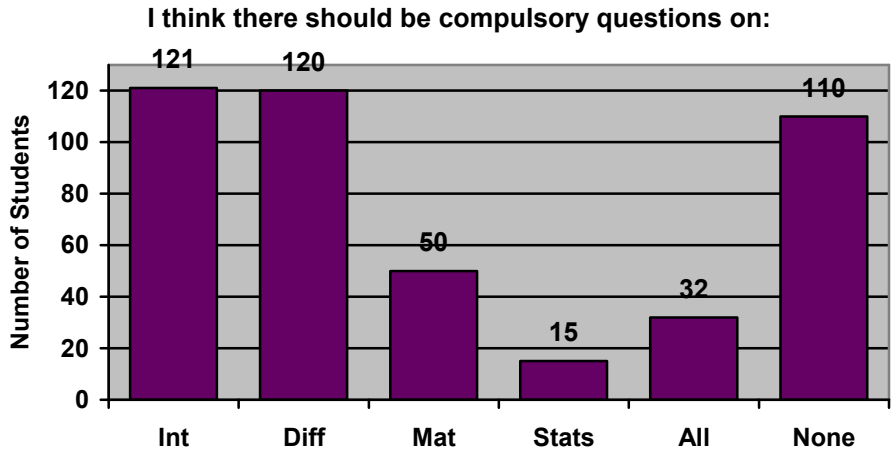
> *"Variety puts less stress on a student, which makes for a better exam, while continuous assessment spread over the semester…forces the student to study regularly, and…they can see where they went wrong, hopefully learning from it and being more comfortable going into the final exam."*

All of these students felt that it was important that there be no choice in the continuous assessments exams, however. Other students advocated reduced choice in the final exam:

> *"Although I do think that there should be a choice on the paper in case you have a mind block, I think there is too much of a choice. Maybe 5 questions out of 6 would work."*

Finally, students were asked for their response to the statement "I think there should be compulsory questions on integration/differentiation/matrices/statistics/all questions/no questions". The full results are shown in Figure 7 below.

Figure 7. Bar chart displaying students' responses to the question "I think there should be compulsory questions on integration/differentiation/matrices/statistics/all questions/no questions".



In this case, a massive 60% of students felt that there should be compulsory questions on at least some topics, with the highest numbers in favour of questions on integration and differentiation. This percentage did not change appreciably when students from later years were studied in isolation. They recognised the importance of compulsory questions, stating:

> *"If questions are not compulsory, it is possible to never do a certain type of question and therefore never learn it no matter how important it is."*

Others felt quite strongly that:

> *"All questions should be compulsory in first year so as to be sure all students at least know the basics of each question."*

Therefore, students seemed to be more in favour of certain questions being compulsory, rather than having no choice on the paper.

4. Other Comments by Students

In addition to the remarks included thus far, some students commented on other aspects of their mathematics education, and we have gathered together some of the most common or interesting ones in this section. A number of students called for a reduction in class sizes for maths, with no more than thirty students per class, with observations such as:

> *"This gives more individual time with the lecturer which is not possible in a large group. It is easier to ask questions in a smaller group if you have a problem than in a class of 200 students"*

One student mentioned that it is particularly difficult for students who have completed the OD programme and progress to 3rd year in the HD programme, as they suddenly find themselves in very large classes and find it harder to cope.

Several students singled out specific members of the lecturing staff for being *"immediately able to stimulate an interest in the subject, which has made it so much*

easier!" and found that *"the effort being put into maths now in the college as a whole is brilliant",* and that "*the maths course in this college is run really well and there is always someone to help you".* There was also praise for the existence of the Maths Learning Centre: *"only for the maths learning centre, I would not have got by".*

They also identified tutorials as being of enormous help, and many suggested that more, or longer, tutorials would be of benefit to students as *"tutorials are more effective at routing out problems early on*." Many students mentioned the benefits of being able to cover material at a slower pace in tutorials, or having the opportunity to work through questions themselves.

One student, who was firmly in favour of removing choice from all maths exams, stipulated however that:

> *" an open book exam of sorts is the way to go; by this, I mean the formulae should be allowed; it is unlikely that engineers in business do not check these before using them so I don't see the need to try and learn them off."*

Another student addressed the common problem of "maths anxiety":

> *"Maths can seem much more complicated than it actually is – if the lecturer is good, they will be able to "dumb down" the parts that seem complicated and so I believe more people will try the "hard" questions. In my experience, people (including myself) sometimes are afraid of maths, as it seems like they will never understand it. If it was made less "scary", more people will answer the maths questions that have a low answer rate."*

Overall, students seemed to be fairly positive about their experience of maths at third-level.

5. Conclusion

The overall consensus from the engineering students who completed this survey was that they recognised the need for compulsory questions on certain topics, primarily calculus, in order to avoid problems in later years of their programme. A quarter of the students also felt that choice should be removed from maths papers in at least some of the end-of-year examinations, a figure that is far higher than we had expected, and one which displays a considerable maturity on the part of these young adults, given that this does mean additional work in the short-term. Another point that arose was in relation to statistics, with students from certain strains of engineering feeling that it was less relevant to them; an argument can be made for designing more targeted maths programmes for each strain of engineering, although it is also important that students grasp the value of a good general background in mathematics, to allow them to be more flexible in the workplace and prepare them for possible future roles in managerial positions.

References

Ní Fhloinn, E. (2007) *Making Maths More Meaningful: Successful Support Structures for Struggling Students.* In Proc. of ALM 13 – Intl. Conf. on Adults Learning Mathematics, Belfast, N. Ireland. To appear.