PREDICTION OF ENGINEERING STUDENT PROGRESSION FROM ENTRANCE DATA

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ABSTRACT

Most Western economies are suffering from problems in attracting students to study Science, Engineering and Technology courses at university level. Concurrently, engineering programmes tend to have higher dropout rates than courses in humanities, business or health sciences. They also typically have a higher unit cost per student. Many reasons have been suggested in the literature why the retention rates are lower in such programmes. However little data exists in the Irish context for what information is useful in identifying which factors are predictive of retention and to what degree they influence retention probability. What information is available, typically considers single factors (e.g. mathematical attainment, overall grades, English attainment etc), but does not consider any interaction effects.

The work reported in this paper examines entrance data for approximately 22,000 students in Trinity College over a 10 year period. Those variables which are predictive of retention are identified – both for engineers and for students generally. It is shown that appropriate use of this information provides significant extra discrimination (over either random selection or any single factor model) in identifying those students most likely to encounter progression difficulties.

KEYWORDS: EDUCATION, RETENTION, STUDENT PERFORMANCE

INTRODUCTION

National and European debate consistently recognises the need for Europe to produce greater numbers of highly-skilled graduates in engineering and technology fields in order to improve our competitiveness in the global economy. Despite the importance of this being frequently stressed in policy discussions and the media, both applicant and graduate numbers in these fields are not increasing quickly enough to keep up with demand from industry and academia [1].

Targets have been set both by individual countries and on a Europe-wide level, and in many cases these are not being met. A task force established to examine the issue in Ireland reported that a 6-7 per cent annual increase in supply would be required, but noted that this would prove “very difficult in the current climate of falling numbers of entrants to third-level courses in engineering and IT” [2].

Part of the difficulty in recruiting students may be due to the fact that engineering has been said to be “hampered by a reputation that deters many students, especially the ones with a broad range of interests (including women)”

[1]. The reality is that an engineering education can be a good basis for a broad range of careers, but is not consistently perceived in this way.

This paper describes a study of entrant students at Trinity College Dublin, and how student data available at the time of entry can be used to predict the success of students in their first year of studies.

Some previous work has been reported in the literature, both internationally [3], [4] and nationally [5], [6], [7]. In the national context however, the nature and extent of the investigations carried out are unprecedented in the literature. Moran and Crowley's seminal work [7] examined 924 students across a range of academic faculties, but for only 1 entrance cohort, of whom 110 were engineering students. Furthermore there have been substantial changes to the high school examination and university entrance mechanisms in the intervening period (their data is from 1976). Somers studied the engineering entrants in Trinity College in 1988 with a total sample size of 107 and also a single entrance cohort.

1 ENGINEERING ENROLMENT

1.1 Enrolment trends

Enrolment trends in many European countries show static or declining numbers of people entering engineering dropped programmes. In Ireland, the numbers of new entrant students selecting engineering as their first choice by 40% between 2000 and 2012 [8].

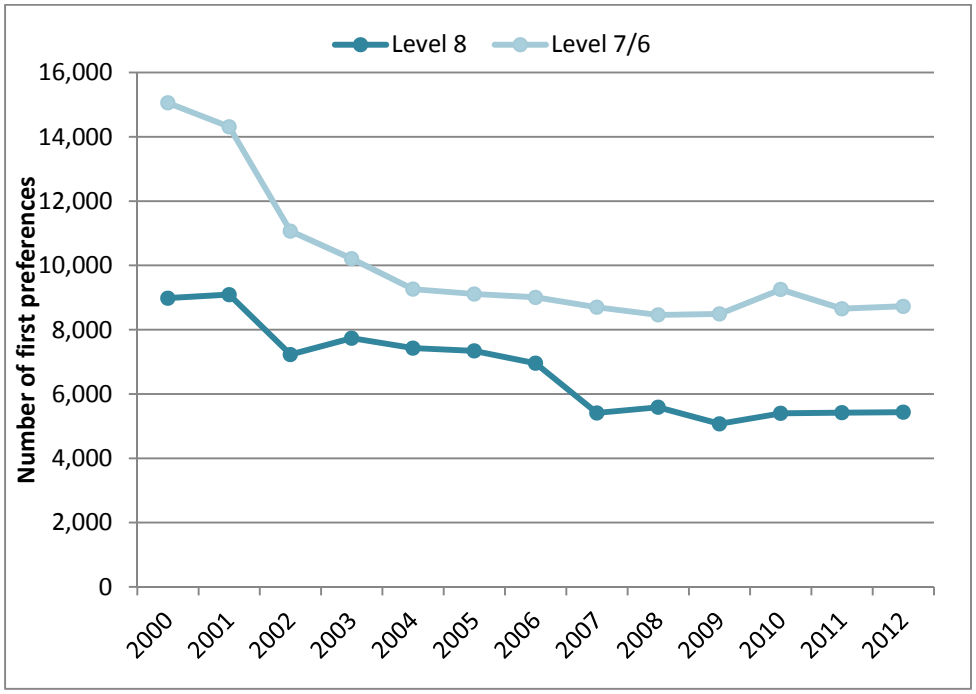

Fig. 1. Trends in number of students selecting engineering programmes as their first choice in Ireland

In order to consider increasing the number of engineering students it is essential to examine the measures that may be excluding potential entrants. This

paper presents some of the results of the ATTRACT project, which has examined the formal barriers standing in the way of entry to engineering. Issues relating to prior student achievement both in engineering-relevant subjects and other areas are examined to assess whether or not alternative procedures could be used to admit more, but still highly-qualified, students.

1.2 Engineering entry requirements

Students who enter third-level through traditional routes are admitted on the basis of their CAO points, i.e. a calculation based on results in a student's six best subjects in the Leaving Certificate exams. In addition to the points requirement, most engineering programmes specify further subject-specific requirements. An overwhelming majority (81 per cent) of accredited Level 8 engineering programmes require entrants to possess a minimum grade of C3 in higher-level maths. A science subject is specified as a requirement by approximately 9 per cent of programmes.

The maths requirement alone has the effect of greatly restricting the numbers of school-leavers who are eligible for entry to engineering programmes. The low numbers of students taking higher-level maths for the Leaving Certificate has been a frequent topic of debate in recent years, and as the situation stands only 16 per cent of Leaving Certificate students take the higher-level paper, while only 12 per cent achieve a C3 or above. This automatically means that only 12 per cent of school-leaving students meet the basic eligibility requirements for the majority of engineering degree programmes.

It is common practice in many other European countries for Physics and/or Chemistry to be set as additional subject requirements for entry, given the relevance of these subjects to engineering study. If either or both of these subjects were to be required by Irish universities, the pool of eligible applicants would likely shrink still further.

Given this circumstance it is extremely useful to examine the performance of students at university in relation to their prior achievement in these and a much broader range of areas in order to determine what impact such factors really have on their subsequent success. This provides a practical way of testing the effectiveness of those set requirements. The purpose of this paper is to explore this question and to reveal the factors which can be proven to impact on student performance.

2 DATA

The study reported here set out to test what correlation, if any, can be found between available data on new entrants to the university and subsequent progression at the end of first year. The subject of the study is approximately 22,000 students entering Trinity College Dublin over a ten-year period (2000 – 2009), with a particular focus on the engineering entrants over this time period, some 1,835 students.

The factors analysed were as follows:

- Fact of having taken a given subject in high school or not (binary)
- Mark achieved in each subject in high school (range: 0 – 100)

- Degree programme chosen (binary; 1 of 2 programmes available)
- Gender (binary)
- CAO points –see below (0 – 600)
- Residential status; whether student lives in family home or not (binary)

The response variable considered was whether a student successfully progressed through their first year examinations. Students at Trinity College who fail to pass these end-of-year examinations may take a 'supplemental' examination before the start of the new academic year. Those passing this examination are allowed to proceed, while those failing it are required to repeat the entire year (all modules) – with a limit on the number of attempts allowed to repeat a year, after exceeding which students are forcibly excluded from the university (i.e. involuntary dropout).

Some subtleties arise in the entry mechanism which are worthy of clarification. Leaving Certificate students have a largely free choice in the number of subjects (there are approximately 80 subjects available), the level (a choice of two and in some cases three – a higher, ordinary (i.e. lower), and in the case of Mathematics, Irish and English, a 'foundation' level). Entry to university is based on supply and demand, occasionally augmented by certain minimum requirements specified by the university. Where supply exceeds demand, entry is decided by calculating a 'points score' – a process managed by a centralised unit called the Central Applications Office (CAO). Points are awarded based on the percentage achieved and the level of the examination. The minimum passing grade is 40% for which a score of 45 is awarded and the maximum score is 100 – for subjects taken at the higher level (5 and 60 respectively for subjects taken at the lower level). Students can aggregate the marks from any six subjects (giving a maximum score of 600 points). Most students will take 7 subjects, but occasionally students may elect to take 8, 9 or more subjects.

3 ANALYSIS

A logistic regression was performed on the data with the input variables listed above, and the response variable as a binary value representing (un-) successful progression to the next academic year. The presence of a binary indicator variable for each secondary-school subject allows us to distinguish between those who have taken a subject and failed to achieve a passing grade (thus returning a zero score) and those who have not taken the subject. An outcome of this classification process is that all subjects will have some 'critical score' – i.e. an achievement level above which a benefit (in terms of increased probability of passing the examinations) is conferred and below which the opposite is the case.

4 RESULTS

4.1 Engineering Specific Results

The results of the logistic regression are shown in *Fig. 2* below.

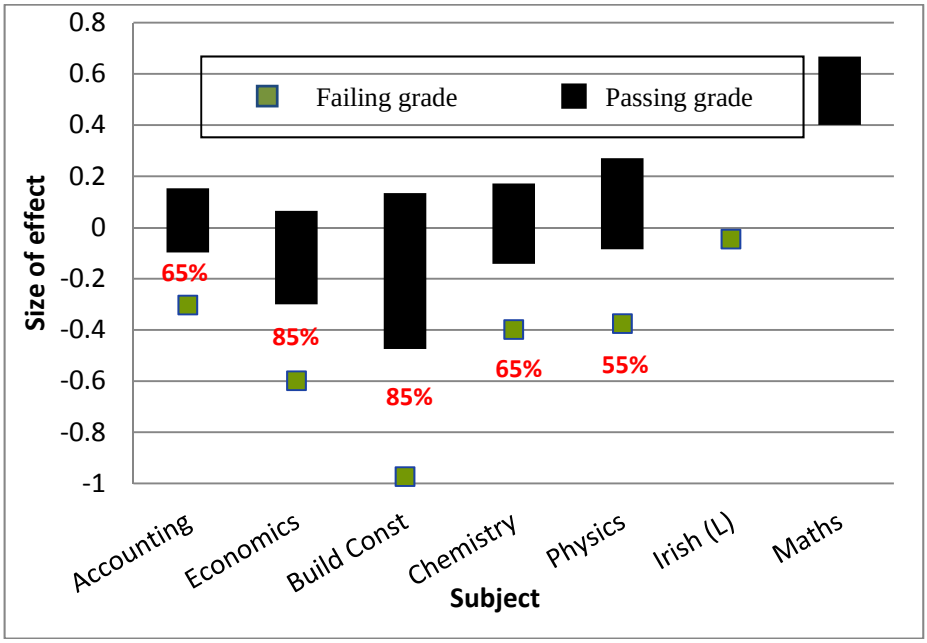

***Fig. 2*. Effect Size for Secondary School Subjects**

In addition to the effects shown, there is a small effect regarding student course preference. Students receiving a lower course preference (than their first choice) incur a negative effect from -0.017 for first preference to -0.171 for tenth preference (lowest possible). All effects are statistically significant at the 1% level or higher. Several interesting observations may be made from the data:

- Mathematics achievement confers the single biggest advantage to students – echoing results found in [5] and [7]. It should be noted that students are required to have a minimum of 55% in higher mathematics (score 60)
- Building construction has a significant effect. However this effect is only positive over a grade of 85%. Furthermore, only a small percentage of all students (2.5%) study this subject.
- Simply studying Irish at the lower level incurs a small penalty, irrespective of examination score.

Fig. 3 shows a receiver operating characteristic based on the logistic model. True positive rate (students who are correctly predicted, above a given probability threshold, to fail to progress) is plotted versus false positive rate (those who are predicted to fail to progress but in fact succeed). The line of zero discrimination, i.e. random selection, is shown in red. Considering the overall CAO score is less predictive than using the identified factors above – the difference being significant at low false positive rates, albeit less significant at higher rates. This is relevant for planning any targeted intervention – the ability to correctly identify students likely to fail to progress using limited resources while limiting incorrectly identified students to an acceptable level.

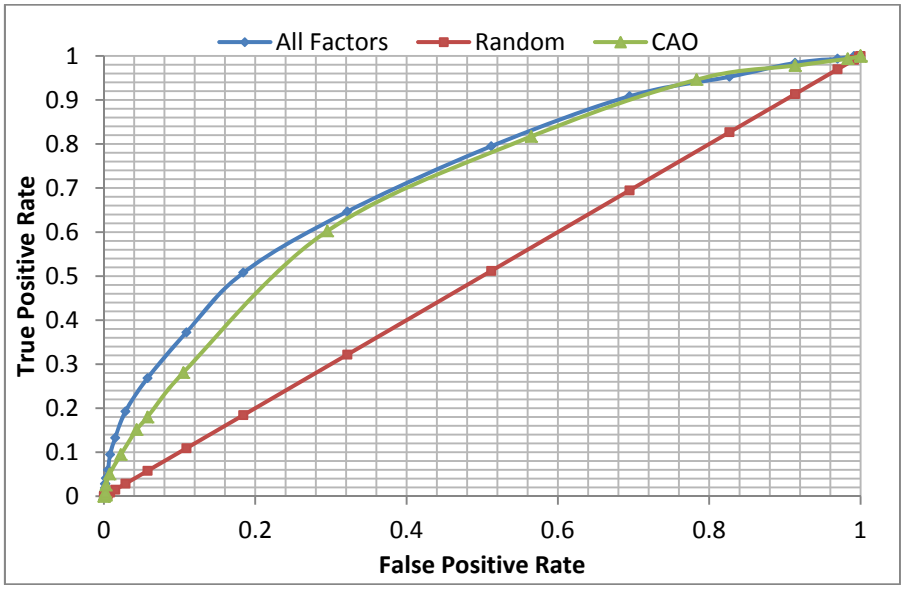

Fig. 3. **Receiver Operating Characteristic**

4.2 Results for entire student cohort

When the data for the entire student cohort is considered (~20,000 students over 10 years), some interesting detail emerges. Most of the subjects that are predictive for just the engineers have similar relevance for the entire student body, while some additional subhects emerge as important. Mathematics remains the subject with the largest positive contribution of any individual subject – irrespective of the grade achieved – suggesting that those taking the subject at the higher level (~55% of the student body here, but only ~16% of the national student body) have a mindset or attributes suited to third level. Intriguingly, the subject with the most predictive power (i.e. largest range of effect size) for engineering; build construction, has similar predictive power for the student body as a whole (and indeed arts and humanities students when considered as a separate subgroup) – despite only 1.5% of the entrance cohort taking this subject.

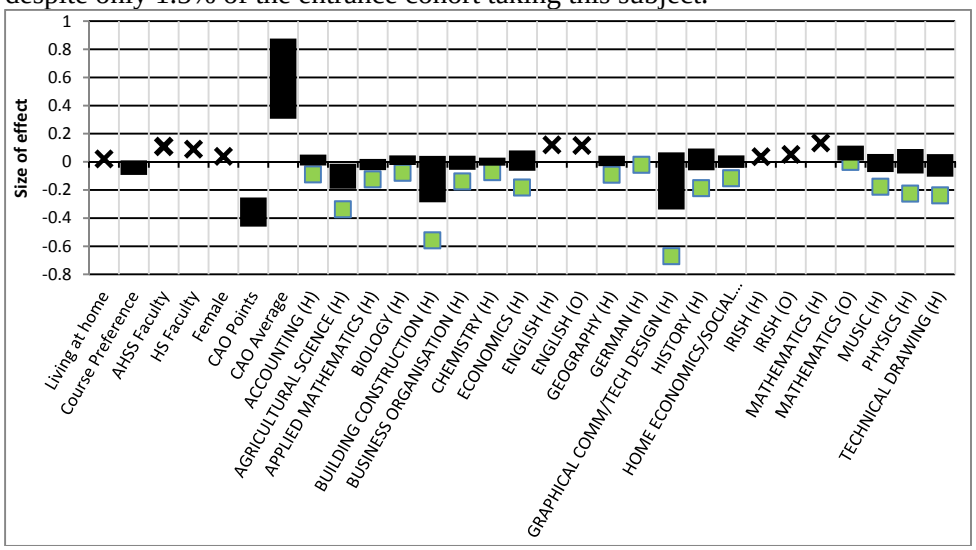

Fig. 4. **Effect Size for individual subjects, entire student body**

Other relatively minor effects are noted for female students, and those living at home. However, perhaps the most interesting factor emerging from the study of the entire group (and replicated within the sub-groups for each particular faculty) is the opposing effects of the students CAO score with their average CAO points per subject. The former has a negative effect, while the latter has a positive effect – indicating that there is valuable information in the 'extra' subjects not counted for CAO points purposes – suggesting that 'targetting' of certain subjects by some students for the purposes of points maximisation is widespread (and indeed entirely rational from the students perspective).

4.3 Subject choice and student performance

It would appear from the data discussed above that many students are concentrating their efforts on particular subjects in their individual portfolio. While this may be an entirely rational choice by the students in many respects, it has potentially very serious consequences for the numbers of students eligible and interested in entering engineering programmes – and by extension for the economic health of the country. Taking one particular example – students may weigh up the risks and benefits of taking higher level mathematics. The benefits include the possibility that they may achieve a good grade (and associated CAO points) and that they retain the option to enter courses (such as engineering) where higher maths is a requirement. The risks include not being able to enter third level if they fail, and being required to devote more time to the subject at the expense of other subjects. The evidence suggests that they are probably correct – students (in this study) on average get a smaller percentage of their CAO points from higher mathematics than from most other subjects.

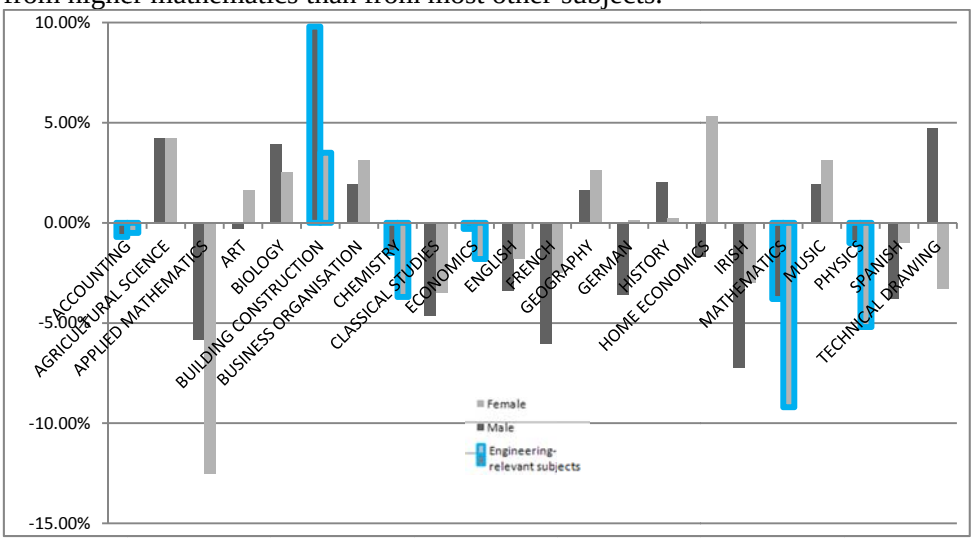

Fig. 5. **Relative difficulty of subjects at Leaving Certificate**

Furthermore, a very high percentage (given the low number who opt for high level) fail the examination [9]. Also highlighted in the above graph are the other subjects which have predictive power in engineering – notably all, with the exception of building construction (taken by 1.5% of students) are 'more difficult' than average.

5 CONCLUSIONS

A detailed analysis of a large body of students has been undertaken. Specific factors relevant to student progression have been identified, in both the overall cohort and looking specifically at the engineering sub-group. It has been demonstrated that student performance in certain subjects at the leaving certificate level has a predictive power above and beyond the overall performance data used to decide entry.

This information is specifically relevant for admission and retention as it suggests that it may be possible to identify those most or least likely to progress within the system. A goal (amongst others) of any entrance mechanism must surely be to identify those students most likely to succeed and to favour their entry. This information could be used as an alternative/parallel entry mechanism to the current CAO system, or as the basis of an argument for change. It also has application in terms of targeting scarce resources in terms of student support – successful discrimination of those more likely to fail would enable support initiatives to be directed more accurately at those most in need.

Evidence is presented which supports anecdotal 'wisdom' about students targeting certain subjects and their reasons for doing so. Worryingly for those in the engineering education sector, it would appear that students (particularly female students) perform worse in those subjects most predictive of successful progression in engineering programs. More positively, it would appear that this may be amenable to change – recent newspaper reports [10] suggest that the re-introduction of bonus points for higher mathematics has seen a 20% increase in the number of students taking the subject at this level. It remains to be seen however whether this effect persists, or has a generally positive impact on STEM studies – or simply acts as leverage to increase the threshold points level on high demand courses such as law and medicine.

6 ACKNOWLEDGEMENTS

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