The Validity of High School Performance as a Predictor of University Undergraduate Engineering Performance

D. Lowe, A.J. Johnston, T. Wilkinson
The University of Sydney
Sydney, 2006, Australia
E-mail: {david.lowe, archie.johnston, tim.wilkinson}@sydney.edu.au

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INTRODUCTION

A critical issue for most undergraduate University programs is the process by which students are selected for admission. Whilst often moderated by broader objectives, such as emphasising merit-based admission, encouraging diversity, or recognising previous socio-economic disadvantages, ideally any selection process ought to be able to identify those students who are most likely to be successful in, and suited to, the program to which they are applying. There is an enormous body of work about admissions processes, and yet despite this the effectiveness of these processes is still the subject of much debate. In this paper we explore the relationship between current measures of high school performance and students' performance within their University undergraduate engineering degree programs.

1 BACKGROUND

The question of the relevance of high school academic performance to university admissions remains a subject of active debate [1]. Within an Australian context, most Universities utilise a centrally determined ATAR (Australian Tertiary Admissions Rank – a performance indicator calculated as a weighted mix of both continuous assessment and examination results) as a key mechanism for ranking students, though this is often adjusted through student performance in specific subjects relevant to the discipline, submission of portfolios or personal statements, or evidence of socio-economic disadvantage. Similar mechanisms are used in many other countries.

A number of studies have explored the extent to which these measures can predict subsequent student University performance. Wurf and Croft-Piggin [2] consider not just ATAR but a range of other measures. Lowe and Johnston [3] studied the correlation between students' undergraduate performance and their responses to a range of broader questions regarding their motivation and aptitude prior to commencing their University studies. Knipe [4] also considered whether ATAR could be used to predict the likelihood of *completing* degree programs.

If Engineering programs are considered, then there is a range of existing admissions approaches that focus on aspects that are of particularly relevant to the discipline. These often have a strong emphasis on evaluating specific technical knowledge, such as the Graduate Aptitude Test in Engineering (GATE) test used by many Universities in India. Whilst this approach is focused on graduate admission, and therefore able to utilise knowledge gained in undergraduate programs, it does provide evidence of the extent to which technical knowledge dominates [5]. Other institutions (such as NUS in Singapore) have developed tests that assess the students' broader affinity with Engineering and general aptitude - but these correlations appear uncertain. Scott and Yates [6] explored connections to the graduates who were deemed to be 'highly successful' by their employers, though this was in terms of personal traits rather than clear academic performance measures.

Within the above context it is aimed to utilise data available to explore the correlation between the undergraduate engineering course performance of students and a range of secondary school academic performance measures, including performance in particular subjects as well as the students' overall ATAR.

2 RESEARCH APPROACH

The University of Sydney (USyd) has been offering engineering degree programs for over 150 years, and currently has in excess of 3,500 enrolled engineering undergraduates across a wide range of engineering disciplines. This provides a rich pool of data that can be mined to explore student performance. All students who studied undergraduate Engineering at the University of Sydney between 2006 and 2014 have been identified (comparing high schools results prior to 2006 is problematic due to system changes). From this pool of 4319 students those who gained entry to their USyd course based on the New South Wales Higher School certificate were selected. For each of these students their results were identified for every University subject attempted within their degree program as well as their high school subject results and the subsequent ATAR. Students' gender, the course preference[1], the enrolled degree program and the data was then anonymised.

Finally, a series of critical questions were identified regarding possible relationships between different elements of high school performance and engineering undergraduate degree performance. The data was then interrogated to identify salient trends.

3 QUESTIONS

As outlined above, a rich set of data capturing students' secondary school performance as well as their subsequent performance within the Engineering undergraduate degree was identified. Using this data it is possible to explore a range of key questions.

3.1 To what extent is ATAR a reliable predictor of performance in the first year of students' undergraduate engineering degree program?

The first question relates to the extent to which the ATAR (the Australian Tertiary Admission Rank) correlates with undergraduate engineering performance. The ATAR is a percentile score that ranges between 0 and 99.95, and represents a student's

[1] In NSW, students apply to University degree courses through a central body (the Universities Admission Centre – UAC). They are able to specify multiple course preferences, and will then gain an offer to their highest preference course for which they have met the criteria as specified by the relevant University.

notional position within their school cohort. It is used across most Australian states as a primary criterion for University admission.

In terms of performance in the undergraduate degree there are numerous measures that could be used: various combinations of subject marks and/or grades; proportion of subjects successfully completed; rate of progress through the degree; or comparison of subject results to the rest of the cohort. The students' WAM (Weighted Average Mark, where each mark is weighted by the associated subject load) was considered. Figure 1 shows a scatter graph comparing the ATAR to the WAM achieved in the first year of the engineering degree program for every one of the 4,319 students enrolled since 2006.

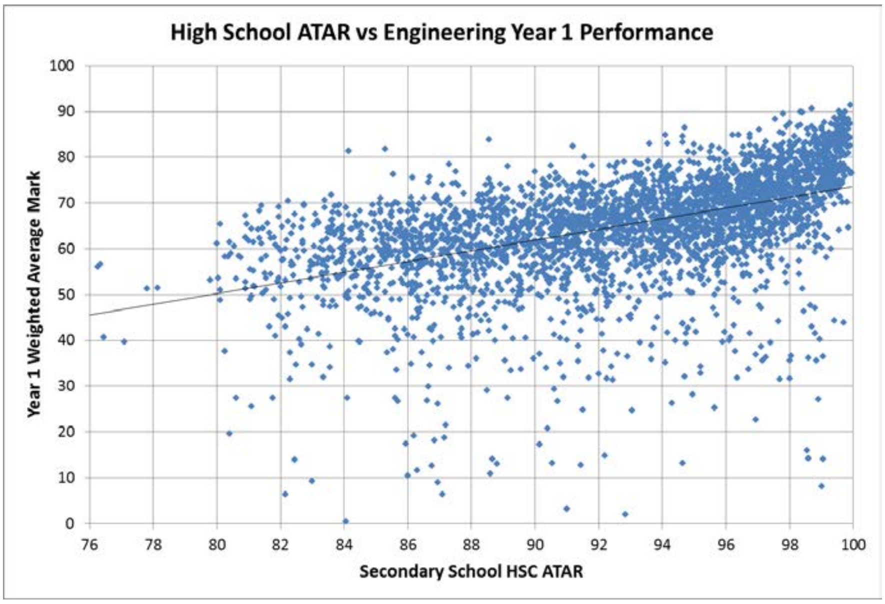

Figure 1: ATAR vs WAM for First Year Engineering Students

There is a clear correlation (r=0.505) that is particularly significant for students entering the degree course with relatively high ATARs. There is however, also a wide spread of performance around the correlation line. For example, considering some arbitrary thresholds, 21.4% of high-performing (ATAR≥94) incoming students had a lower first year performance (WAM<65). In comparison, 37.1% of lower-performing (ATAR<94) incoming students had a higher first-year performance (WAM≥65).

3.2 Does the correlation between ATAR and WAM change as the student progresses through the course?

The above analysis indicates that there is a significant correlation between ATAR and WAM in the first year of the course. It is worth exploring whether this continues into performance in later years of the degree program. Figure 2 shows the average WAM in each year of the program graphed against different incoming ATAR bands. As can be seen the actual level of performance varies (generally being lowest in the second year of the degree and highest in the fourth year) but the general relationship with ATAR remains relatively similar. It is worth noting however that the correlation does drop progressively during the degree (Y1 r=0.505; Y2 r=0.433; Y3 r=0.327; Y4 r=0.292). This trend would be consistent with at least some students with lower ATARs progressively overcoming earlier detrimental learning issues, and some students with higher ATARs having problems or distractions or losing motivation during their degree). `

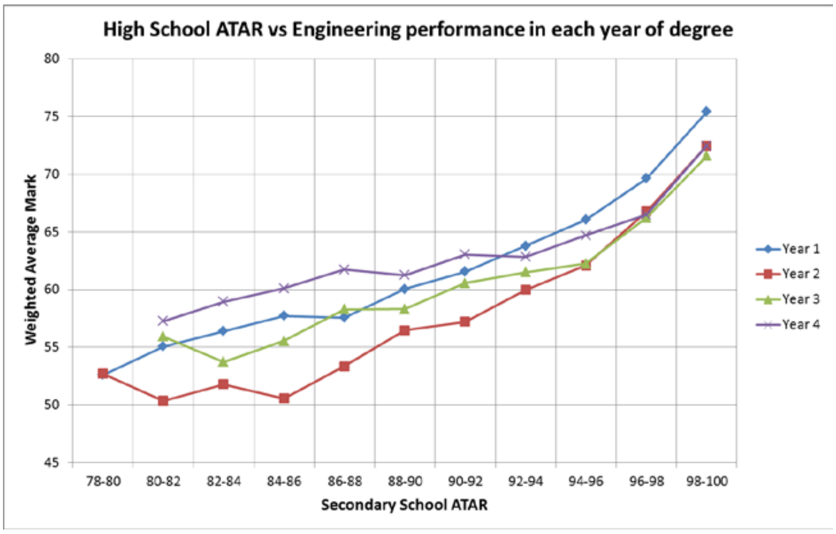

Figure 2: Student performance by year of course

3.3 Are specific HSC subjects better predictors of performance?

The ATAR is an indicator that is designed for general use across all University programs. As such it may not adequately take into account the specific assumed knowledge relevant to engineering, or adequately identify those students who are inherently more adept at engineering. This issue can be explored by analysing the correlation between individual high school subjects (undertaken by the student) and subsequent performance within the first year of their engineering degree. The results of this comparison are shown in Table 1, ordered from highest correlation to lowest.

Table 1: Correlation between HSC subjects and WAM in first year of the engineering degree

HSC Subject	***Mark Correlation***	***Band Correlation***
Physics	0.505	0.469
Chemistry	0.481	0.435
Engineering Studies	0.481	0.426
Mathematics Extension 2	0.432	0.377
Mathematics Extension 1	0.421	0.386
Mathematics	0.399	0.329
Software Design & Development	0.394	0.346
Biology	0.381	0.303
Economics	0.341	0.368
English Extension 1	0.285	0.235
General Mathematics	0.218	0.328
Music 2	0.201	0.279
English Standard	0.178	0.161
Design And Technology	0.095	0.101
Music 1	0.021	-0.030
All 2U and higher Maths (Mean of 2U, E1, E2)	0.432	0.405
All Science (Mean of Physics, Chemistry, Biology)	0.484	0.448

It should be noted that the correlation with both the reported subject mark as well as the band that the mark has fallen (results in most subjects is reported within a range of band 1 to band 6, though in the higher level “extension” subjects the bands are E1 to E4). As can be seen from these results there is a strong first year correlation with performance in high school maths and sciences, though this correlation is no higher than that for the base ATAR.

This relationship can be investigated further by comparing the performance of students who achieved higher marks in the maths and science (i.e. a band E3 or higher in extension maths subjects, and a band 4 or higher in Physics, Chemistry or Biology) with those who achieved a lower mark. These results are compared in Figure 3. There is clear evidence that students who have achieved higher results in Maths and Sciences will, *on average,* perform better. For example, if two students are compared with the same ATAR then a student with higher Maths performance will, on average, achieve a first-year WAM which is approximately 4.5 points higher. Conversely, a student without high Mathematics results will, *on average*, perform similarly in first year to another student with high Mathematics results but an ATAR which is typically 3 to 4 points lower. A similar pattern also holds true for Science subjects.

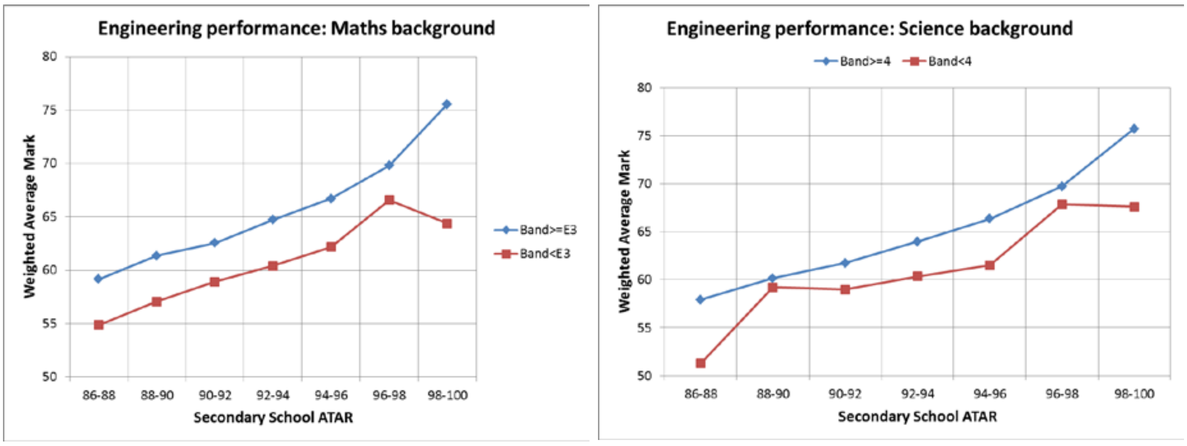

Figure 3: Student performance for varying results in Secondary School (a) Mathematics and (b) Science (Biology, Chemistry, and Physics)

It is worth noting that creating a weighted sum of ATAR, Maths and Science results it is possible to generate a hybrid score. By adjusting the weights of these components the highest correlation that can be achieved between the score and the first year performance is r=0.544 (compared to r=0.505 for the base ATAR).

3.4 Are selected HSC subjects (maths? science?) better predictors of performance in technical areas than in broader education areas?

Whilst the above results indicate that the base ATAR might be a relatively effective predictor of performance, and that individual subjects only moderate this to a minimal extent, it is also worth exploring whether ATAR, Maths performance or Science performance is a better indicator of likely performance in different types of university subjects. Specifically, the performance throughout the degree in units broadly classified as: mathematics; disciplinary/technical; and general engineering. The results of this comparison are shown in Table 2.

Table 2: Correlation between HSC subjects and performance in specific sets of engineering units

HSC Results	***Engineering degree results***	***Correlation***
ATAR	First year technical units	0.433
All 2U and higher Maths	First year technical units	0.338
All Science units	First year technical units	0.441
ATAR	All technical units	0.414
All 2U and higher Maths	All technical units	0.329
All Science units	All technical units	0.414
ATAR	Maths units	0.550
All 2U and higher Maths	Maths units	0.524
All Science units	Maths units	0.503
ATAR	General engineering	0.430
All 2U and higher Maths	General engineering	0.348
All Science units	General engineering	0.443

Generally, these trends reaffirm the validity of the ATAR as a basis for predicting likely performance across all areas. Surprisingly the performance in undergraduate degree mathematics is more highly correlation with ATAR than with the secondary school mathematics units. Conversely, the broader general engineering subjects (which incorporate aspects such as teamwork, communication, and IT skills) are more highly correlated to performance in high school science subjects than to the general ATAR, though the difference is relatively small.

3.5 Is there a gender difference?

It is also possible to determine whether there is a significant difference in the ATAR/degree performance relationship between female and male students. Figure 4 shows the results for both groups in both first year and fourth year of their studies. The comparison indicates that there is not a significant difference.

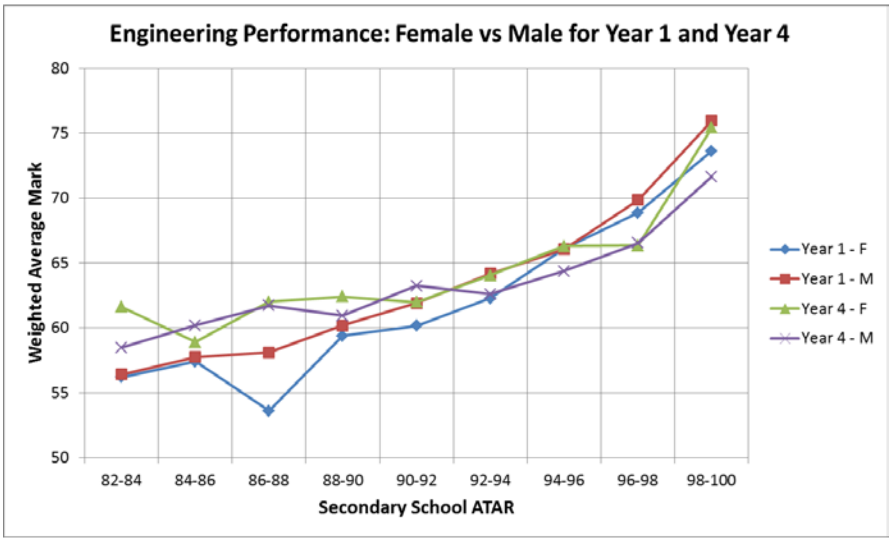

Figure 4: Comparison of student performance by gender

3.6 What is the impact of the preference number?

Another potential factor that might affect student performance during their degree studies is their motivation and motivation might, in turn, be affected by whether or not the student was admitted to their first preference of the discipline of study. Figure 5 provides a comparison of students performance for those who gained admission to the highest preference they specified vs those who only gained admission to their 2nd or 3rd preference. At higher ATAR levels there is not a noticeable difference – possibly because the higher ATAR has provided access to a broader range of courses and so even if they missed out on higher preferences the result is still likely to be acceptable. Conversely there is at least some evidence that at lower ATARs the preference may become a factor. Clearly, this warrants more detailed exploration – possibly by considering whether the missed preferences were in cognate or non-cognate areas.

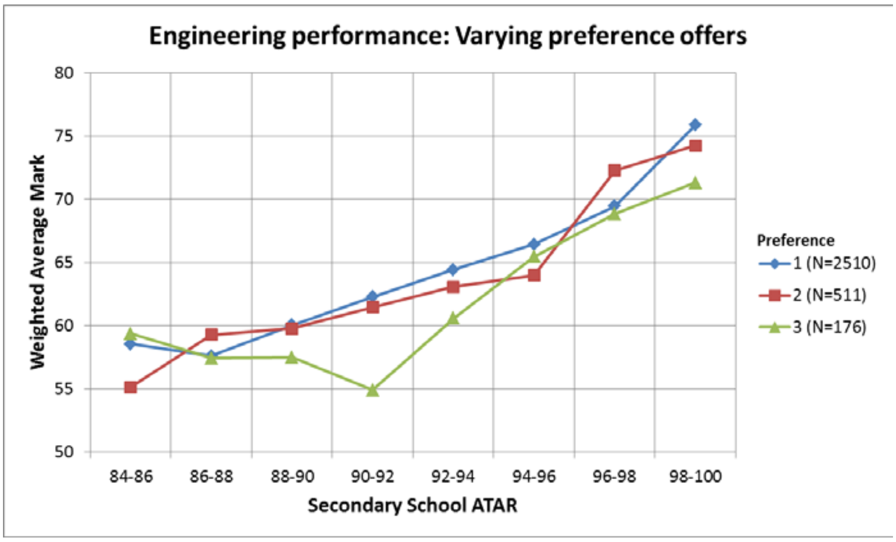

Figure 5: Comparison of students whose offer was for different course preferences

3.7 Is there a difference between single and combined degree students?

Finally, the effect of whether the student is studying a single engineering degree or a combined degree is considered that links the engineering degree with a second degree such as commerce, law, science, arts, etc. (approximately 40% of USyd undergraduate engineers are admitted to these combined degrees – generally with higher ATARs).

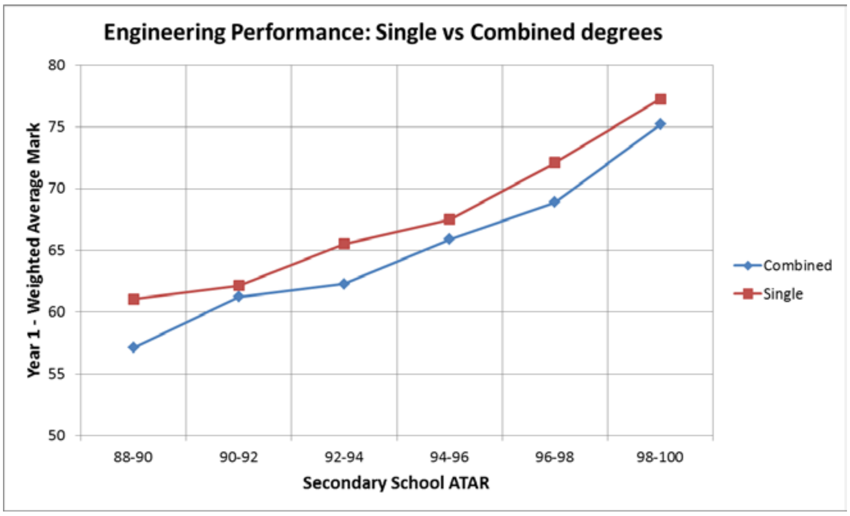

Figure 6: Comparison of Single vs Combined degree students

The results demonstrate a good example of Simpsons Paradox. Taken collectively, the average mark of combined degree students is notably higher than that for single degree students (67.6 compared to 63.5 in first year, with the difference diminishing in later years but remaining higher for combined degree students). Paradoxically however, it can be seen that in Figure 6, for every ATAR band shown the single degree students performed better than the combined degree students! Essentially this is because the combined degree students tend to be heavily weighted towards higher ATARs. This phenomenon highlights the care that needs to be taken in interpreting performance data: i.e. taken overall, combined degree students out-perform the single degree students however when ATAR is factored out then the single degree students actually have slightly better performance outcomes.

4 SUMMARY AND ACKNOWLEDGMENTS

This paper has used a preliminary analysis of a large data set to explore a range of questions related to the relationship between high school performance and the associated connection to performance within engineering undergraduate degrees. This exploration has supported the validity of the use of the general ATAR as a basis for making offers of places to students. It has however also highlighted that the ATAR is only a broad indicator and that there are other measures that may also be valuable. This is significant insofar as it provides valuable input into the ongoing efforts to refine the processes through which offers are made to applicants.

In addition to the above observations it is also important to note that this preliminary analysis has highlighted numerous areas that warrant much more detailed analysis. Examples include: exploration of different measure of undergraduate performance (e.g. average marks vs proportion of subjects successfully passed); predictors of level of improvement rather than raw performance; relationship to the breadth of courses to which students had originally applied; etc. These questions will be explored as part of ongoing work in this area.

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