Analysis of First-year Student performance in an Engineering Program

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During the last ten years, the typical criteria for entry to an engineering course at a university in NSW, Australia, has been based on the University Admission Index (UAI). It was an index derived largely from the achievements of a student in examinations at the end of their secondary school education. The UAI provided a measure of overall academic achievement that assisted institutions to rank applicants for tertiary selection. In 2010, the UAI in NSW was replaced by the Australian Tertiary Admission Rank (ATAR). A student who is able to rank well enough, will be able to enter an engineering course of their choice without any further testing of cognitive ability. Students who are unable to achieve the desired ranking will need to find alternative methods of entry. The question of just where this ranking cut-off lies could be regarded as a subjective measure; is it possible that universities are denying entry to students that have potential to become successful engineers? In this paper, an analysis of the performance of a group of students that have completed their first-year of study in electrical engineering at the University of Wollongong during the years 2000-2010 is undertaken. Student groupings are created based on their background knowledge and their performances investigated. The result is a collection of results that illustrate the likelihood of a student achieving an acceptable result at the end of their first year of study.

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An Analysis of First-year Student Performance in an Engineering Program[1]

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Abstract
During the last ten years, the typical criteria for entry to an engineering course at a university in NSW, Australia, has been based on the University Admission Index (UAI). It was an index derived largely from the achievements of a student in examinations at the end of their secondary school education. The UAI provided a measure of overall academic achievement that assisted institutions to rank applicants for tertiary selection. In 2010, the UAI in NSW was replaced by the Australian Tertiary Admission Rank (ATAR). A student who is able to rank well enough, will be able to enter an engineering course of their choice without any further testing of cognitive ability. Students who are unable to achieve the desired ranking will need to find alternative methods of entry. The question of just where this ranking cut-off lies could be regarded as a subjective measure; is it possible that universities are denying entry to students that have potential to become successful engineers? In this paper, an analysis of the performance of a group of students that have completed their first-year of study in electrical engineering at the University of Wollongong during the years 2000-2010 is undertaken. Student groupings are created based on their background knowledge and their performances investigated. The result is a collection of results that illustrate the likelihood of a student achieving an acceptable result at the end of their first year of study.

Keywords: predicting performance, comparative performance, engineering education, entrance criteria

1. Introduction

The most widely used criteria to determine entry to an engineering program at an Australian university is a ranking scheme based on a student's performance in state run exams held at the completion of their secondary school education. The ranking methodology varies slightly from state to state. In NSW, the UAI ranking scheme has been used from 2000 to 2009. Recently, there has been a trend towards using the Australian Tertiary Admission Rank (ATAR) since it provides a more uniform entrance criterion. The two schemes do not differ greatly. Indeed, the general philosophy is to provide a metric that can be used to compare an individual's performance against all other candidates.

Exactly what the results of these 'end-of-school' examinations indicate has been questioned previously. Ellyard [2] proposes that these exams are not useful as predictors for success in tertiary education. Ellyard suggests that alternative schemes such as direct application, similar to a job application process, could be an option. Many universities, such as the University of Wollongong, have an 'early entry' scheme that enables students to apply for entry prior to the completion of their state-wide exams. In this situation, students are interviewed and assessed on their school assessment results and other academic and non-academic achievements to determine if they are suitable to study engineering. They can be given direct or conditional entry, bypassing the usual ranking criteria.

However, the major issue of the suitability of using a ranking scheme, such as the UAI or ATAR, remains a subjective method. The degree of objectiveness in using this particular metric is relatively untested.

Whilst most educators would agree that a high ranking would be a good indicator of potential success, the point at which this metric can no longer be relied upon is unclear. Are there additional indicators that may improve the confidence with which the metric is applied? A university under pressure to fulfil the quota of student intake may struggle with the estimation of the cut-off to be applied and allow students with lower than usual rankings into a course. In some cases, this may be based on a review of the student's background, choice of subjects and individual interests.

The work reported in this paper attempts to reconcile the factors that may contribute to the success or otherwise of students entering into a university engineering program. Is it possible to know how a student will perform

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based on the entrance criteria used to admit them to a degree program? If it is possible, with what degree of certainty can the models be applied and what is a suitable metric? If it is possible to identify 'at risk' students (i.e. those who may struggle in a first-year program) and provide them with remedial activities, then the retention rates of this group might be improved. Are tailored programs required for such students?

2. Related Research

There is a reasonable body of work that has attempted to link cognitive skills, entrance criteria and other factors, to student performance in the first year of a course at university. Instead of a statistical approach, Johnston [4] conducted a survey of academic staff at a Scottish university to try to understand why it was that first year student retention rates were poor. The results of this survey suggested that non-academic reasons were the more likely cause of failure. The range of non-academic issues that were believed to contribute to this problem were also found to be very diverse. The outcomes of this research included a series of strategies to improve retention rates that included: a minimum attendance policy; greater institutional support; increased academic support, and; a focus on course selection. In the context of the research work reported in the current research, such strategies are of significance. If students who belong to a group with a high risk of failure can be identified, rather than place these students in the same program as those likely to be successful, the option for an alternative program can be justified.

In their paper investigating factors that influence graduation rates, Zhang et al. [7] leverage cross institutional data from 1987 to 2002. They present a 'multiple logistic regression model' exploring the 'relationships between graduation and demographic and academic characteristics'. Zhang et al. [7] investigate factors that influence time to graduation. The statistics available to this research are quite extensive. Data are available from a total of approximately 87,000 engineering students, spanning several disciplines. If an analogy is made between the high school grade point average (GPA) reported in [7] and the UAI, then the results that their research reveals are closely matched to the work reported in the research reported in this paper.

Zhang et al. conclude that 'High school GPA and math SAT scores were positively correlated with graduation rates for all universities for which this data was available'. In Australia, there is no uniform 'scholastic aptitude test' (SAT) available to universities in the subject of mathematics. The closest entity to the SAT would be individual scores from the various courses available to high school students in mathematics. Accordingly, it is not easy to directly compare results that Zhang et al. obtained with those presented in the current research.

The current research indicates that there is some level of correlation between the student UAI ranking and their achievements at the end of their first year of study; although it could not be called high. In the research conducted for the current paper, the correlation between high school mathematical results and WAM was not high.

In the body of work reported by Giesey and Manhire [3], an analysis is performed to determine the time taken to complete a BSEE program at Ohio University. The work identifies several reasons why some students take longer than the prescribed four years. One key finding is that 'higher admission standards would improve time-to-degree but the lower enrolments would have repercussions for both the engineering department and the profession'. It is not in the best interests of universities and the engineering profession to raise the entrance requirements to such a high level that the number of engineers that graduate in minimum time increases. It is important, however, to recognise that some students will require extra support in the early years of their program in order to complete a degree successfully in the minimum time. Just what this support might involve was not the focus of the research.

An Australian project that attempts to link university entrance ranking scores and an early-course diagnostic test with one semester performance is reported in Barry and Chapman [1]. The authors' aim was to find a better predictor of student performance than the tertiary entrance ranking score, or TER. The TER was the metric used prior to the UAI and ATAR ranking methods. The focus was on mathematical skills for students undertaking either science or engineering courses. Their work concluded that the use of diagnostic tests are a better predictor of performance than the TER. A key outcome in their research is that the correlation of university performance against TER performance is not high, which supports the finding of the research conducted for this current paper. Indeed this outcome is also supported by Lee et al. [5], a similar paper reflecting the UK experience.

A slightly different observation was tested in a paper by Todd [6]. The question asked by the research was 'Given that the grades at A-level are used heavily as a tool for selection, do they remain a reliable indicator of ability?' The outcomes addressed in the research for this paper did not seek to correlate absolute performance at the end of first year with the student achievements prior to the start of their program. Todd concluded that students graduating from secondary education in recent times do so with far less abilities than those with equivalent grades from 15 years ago. This trend was not explored in the research for this paper. However, in contrast to Todd's work, the findings of the current research suggest that the performance at secondary school level remains a good indicator of overall ability.

A highly relevant and intriguing body of work is presented by Russell et. al [8]. The authors report on an interview scheme used by another Australian university to "identify students who are both able and motivated, but may not meet the required academic admission criteria based on their high school exam results". Their work is highly relevant since the basic entrance criteria is the UAI. Two of the research questions addressed in their work are; do the interview results measure something different to student ability (reflected in the student UAI) and do the results correlate with student progression? The latter question is perhaps of more specific importance to the current research. The interview results are correlated with student performance in mathematics courses and engineering project work. They conclude that the interview scores do not differ significantly from UAI as an indicator of student performance in the mathematics courses. The correlation between academic ability, as determined by the interview process, and performance in mathematics was weak. Such a conclusion is supported by the current research.

3. Data Collection

The data used for the current research was obtained from the records of students enrolled in a degree program in the School of Electrical, Computer and Telecommunications Engineering at the University of Wollongong, Australia during the period 2000 to 2010, inclusive. Altogether, the records of 635 students were available to assist with the analyses. This does not represent the entire cohort admitted to the degree programs during this period. Rather, it represents the cohort of which a UAI ranking, as a minimum, was available.

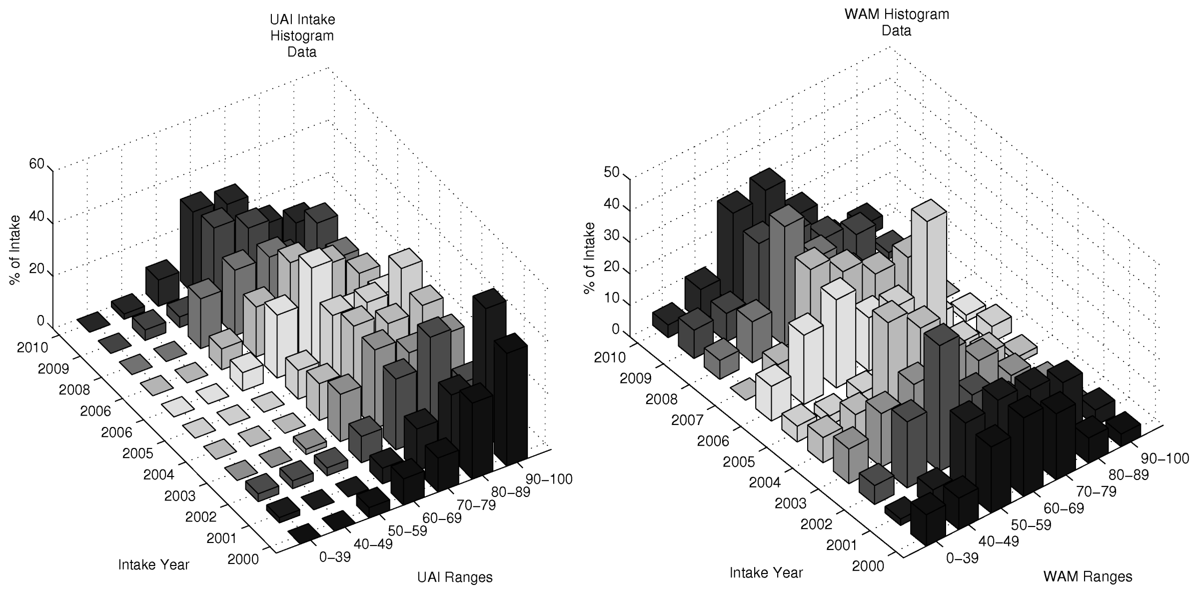
The information obtained from these records included their main secondary school result, the UAI, as well as results from their performance in individual subjects in their secondary school studies. In particular, the accomplishments of the students in the various physics and mathematics courses was observed. The hypothesis to be tested is that students with a high level of performance in mathematics and physics would be successful in their studies of engineering. The performance in these subjects forms the basis of one alternative entrance pathway to courses at the University.

Each year of study at an electrical engineering course consists of 48 credit points of subject load. Each subject has a credit point weighting commensurate with the degree of difficulty and the level of work required to complete the subject, given its content structure. A typical first-year program will require a student to complete a 12 credit point program in each of four topic areas: mathematics, physics, computer science and electrical engineering.

At the completion of the first year of study, an average grade is calculated for each student. This average is referred to as a weighted average mark, or WAM. The term 'weighted' is introduced because as the student progresses through the course, subjects at higher levels contribute more to the average mark. In this study, the WAM is simply the average of all of the subjects that the student has attempted in their first year of study.

3.1 Overview of Performance

The aim of the research reported in this paper is to understand what links (if any) exist between entrance criteria for University and performance at the completion of a first-year program of study. As an introduction to this research, consider Figures 1a and 1b. These two figures illustrate 10-years of data that corresponds to the student UAI score (used as the main entrance criteria) and average scores at the end of a first-year program of study, constructed as a histogram.



(a) (b)

Figure 1: A Set of Data Histograms: (a) UAI Intake Data; (b) WAM Data.

From Figure 1 it is evident that the average UAI of a student entering the University in 2010 is less than what it was in the year 2000. It is also evident that the average WAM score appeared to be in steady decline until 2009 and 2010 where it has improved to be similar to that in the early years of data collection. This is loosely correlated to the improvement in UAI intake scores in the same years.

4. Modelling Methods

The notion that overall performance at the end of a student's secondary school education should be closely linked to their performance at university seems logical. If one is able to exclude external factors that might affect performance, then there should be good linkage between the two sets of results. By determining the Pearson correlation coefficient between the student's UAI and their WAM, the strength of this relationship can be quantified. Other objective measures of achievement, such as the final result of a secondary school mathematics course, may also correlate with student performance.

Since there are several different sets of data available, the calculation of the correlation between variables was undertaken using different cohorts of students and combinations of their results. In total, ten different groups of students were identified and investigated. These groups are defined by the courses taken by students in their final year of secondary school. The groups are students:

i. with UAI only (UO) (no results for any other subjects)
ii. who undertook basic mathematics (M)
iii. who undertook basic mathematics (M) with physics (P) (MP)
iv. who undertook basic (M) and extension-1 (E1) mathematics (ME1)
v. who undertook basic (M) and extension-1 (E1) mathematics with physics (P) (ME1P)
vi. who undertook extension-1 (E1) and -2 (E2) mathematics (E1E2)
vii. who undertook extension-1 (E1) and -2 (E2) mathematics with physics (P) (E1E2P)
viii. who undertook any mathematics course (AM)
ix. who undertook any mathematics course with physics (AMP)

Unlisted is the group of students with a UAI. This is the entire cohort.

4.1 Simple Correlation

With the groupings as defined, the correlation between WAM and secondary school performance is investigated. Table 1 presents a summary of the correlation coefficients of the various groups of students, their individual subjects and the WAM.

Table 1: Summary of Correlation Coefficients

Group	UAI	M	P	E1	E2
	Individual Subjects				
UO	0.64	–	–	–	–
M	0.18	0.36	–	–	–
MP	0.44	0.4	0.54	–	–
ME1	0.61	0.51	–	0.46	–
ME1P	0.67	–	0.56	0.56	–
E1E2	0.69	–	–	0.53	0.53
E1E2P	0.73	–	0.68	0.55	0.51
AM	0.62	–	–	–	–
AMP	0.66	–	–	–	–
All	0.64	–	–	–	–

Referring to Table 1, consider the row of the group ME1. This term refers to students that have studied basic and extension-1 mathematics in their final year at secondary school. The number in the 'UAI' column indicates that the correlation coefficient between the UAI of this group and their WAM is 0.61. Similarly, the number in the 'M' column tells us that the coefficient is 0.51 between this cohorts' score in basic mathematics and their WAM. From Table 1, one can determine that the results of students who have studied extension-1 and -2 mathematics have the highest correlation with their WAM. However, the value of 0.73 is not a convincing one. Furthermore, the size of this cohort is relatively small; 24 students in total.

4.2 Relative Performance

Another comparative technique is to look at the performance of each student with respect to the cohort that each student belongs to as well as the overall intake of students. The hypothesis here is that if a student belongs to the ME1P cohort, for example, then it may be possible to gauge how this student will perform in first year, based on their UAI relative to the ME1P cohort. Visualising the data is more complex because the analyses results are multi-dimensional. In order to simplify the comparisons, two key metrics will be set and relative performance around these metrics determined. The two key metrics are a UAI of 83 and WAM of 55%. These two set-points effectively breaks each cohort into additional categories; those with a UAI above or below 83 and those with a WAM of greater than or less than 55% at the end of first year. These set-points are somewhat arbitrary. By way of an example, consider the MP cohort. There are 129 students that belong to this group. Of this group, there are 113 students that were admitted who had a UAI less than 83. Of these 113 students, there were 54 students that were able to achieve a WAM of 55% or better at the end of their first year of study. This categorisation method provides a mechanism for comparing groups with similar backgrounds (i.e. subjects studied in the final year of secondary school) and achievements. Extending the example in the previous paragraph, one might conclude (based solely on the data analysed for this research), that a student who enters university and who has studied mathematics and physics in their final year of secondary school and achieved a UAI of 75 has a slightly less than even chance of completing their first year of university with a WAM greater than 55%.

Figure 2 illustrates the categorisation of the entire set of students used in this study.

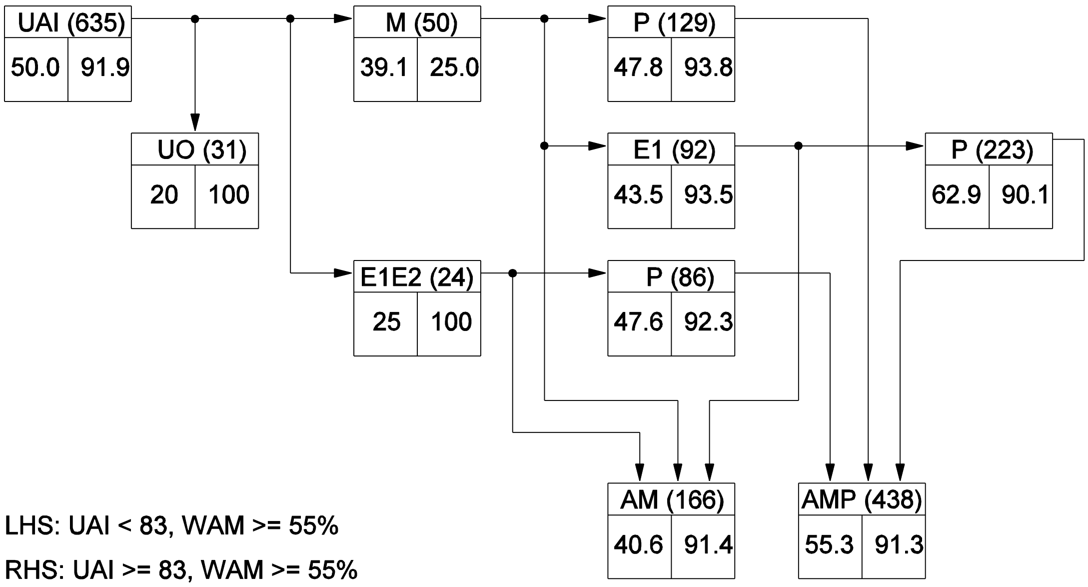


Figure 2: Categorised Comparative Results

There is much information contained within Figure 2. Each box contains several numbers. In the top part of the box, the cohort and number of students in that cohort is identified. As an example, consider the top row of boxes. The left most box is the entire group of students for which UAI data has been recorded. The next box is the M cohort, of which there are 50 students and the final box is the MP cohort of which there are 129 students.

The comparative data is in the lower part of each category. The left-hand side (LHS) identifies the percentage of students within the cohort that have been admitted with a UAI less than 83 that have achieved a WAM of 55% or better at the end of their first year of study. The right-hand side (RHS) identifies the percentage of students within the cohort that have been admitted with a UAI greater than or equal to 83 that have achieved a WAM of 55% or better at the end of their first year of study. As an example, the right-most box in the top row identifies the MP cohort. There are 129 students that belong in this group. Of the students in this group that were admitted with a UAI less than 83, 47.8% were able to achieve a WAM of 55% or better. If their UAI was 83 or better, then 93.8% were able to achieve a WAM of 55% or better.

5. Discussion of Results

Using the term modelling in the previous section would seem to be somewhat misleading. Perhaps use of the term ‘categorisation’ is more suitable. The results that are illustrated in Figure 2 give a valuable insight to the type of student one would want to attract to an engineering degree. If entrance to a course in electrical computer or telecommunications engineering were restricted to students who obtained a UAI of 83 or better, and they have studied physics as part of their final year at secondary school, then they are almost universally twice as likely to complete their first year at university with a WAM better than 55% than a student with a UAI less than 83.

There is only one group of students that consistently perform at a level one could deem acceptable; the ME1P group. These students seem to be able to have a 62.9% likelihood of completing their first year of studies with a reasonable WAM regardless of their UAI. What is hidden in this set of data, however, is the minimum UAI in this cohort. It would be most unlikely that a group of ME1P students with very poor UAIs would achieve the same success rates. This statement really sums up the difficulties in predicting student performance. How is ‘unlikely’ quantified?

5.1 Focus on ME1P Group

Since the ME1P group appear to be the most likely student group to succeed, it is interesting to determine the point at which the lower UAI ranked students become less likely to achieve a satisfactory WAM. Table 2 shows the performance of students from this group as their entrance score is lowered. It also presents the percentage of the ME1P cohort that belong to the group below the threshold.

Table 2: ME1P Cohort Comparative Performances

UAI Threshold	UAI < Threshold, WAM ≥ 55%	Cohort < Threshold
83.0	62.9	59.2
82.0	62.2	57.0
81.0	61.3	55.6
80.0	58.6	52.0
79.0	56.4	49.3
78.0	53.1	43.0
77.0	50.6	38.1
76.0	50.0	34.1
75.0	46.5	31.8
74.0	43.1	26.0

It is clear that a student with a UAI less than 76 who has studied extension-1 mathematics and physics has only a 50% chance of attaining a WAM of greater than or equal to 55% at the end of their first year of study. This is only a statistical observation and by no means a guaranteed result for students in this cohort. As the UAI score is lowered, the number of students in the cohort is reduced. The smaller sample set means that the confidence in the accuracy of the result is also reduced.

5.2 Final Comments

There is data missing in this study that is highly desirable, but probably impossible to obtain. This data belongs to the group of students with a relatively high UAI who did not undertake mathematics or physics courses as part of their senior, secondary schooling . Such students rarely take up the idea of studying engineering.

What the research data presented here also provides is evidence that if universities are going to accept students with what could be regarded as a poor entrance score, then unless these students are treated differently, the likelihood that they will perform poorly in the early coursework at university is quite high. This research does not preclude how students will perform in the remainder of their course. These 'at risk' students can be identified upon entrance to the university and their programs can be tailored accordingly.

6. Further Research

To gain more insight into student performance in the early stages of their degree program, it would be a interesting exercise to determine links between performance in individual courses at university and the subjects studied as part of their final year at secondary school. Such relationships could be used to customise the coursework for 'at-risk' students. Pragmatically, it makes more sense to focus on a student's foundation knowledge during the early years by giving them more time to develop the skill set to deal with the more complex concepts in the specialisation part of their course. There is a higher probability that this cohort will take more than the minimum time to complete their course anyway.

The extension to this work is to track student progress through the entire course. The simplest way to do this would be to track the student WAM throughout their entire degree. Again, instead of trying to model just how this trend will be realised, insight could be obtained about how students might move from say a group that have an average of 50-55% in year 1 to a group that have an average of say 55-60% in year two.

7. Conclusions

This paper has presented a fresh way of analysing student performance in the first year of a university engineering program. The research has been able to link achievements in their final year of secondary school to the early stage of their degree program.

Analyses clearly indicate that there is an increased probability of failure in these early university years for students who do not have the cognitive maturity upon entrance to the university. The paper also shows that students who have a background in advanced mathematics and physics will be more likely to outperform those who don't. It was not possible to find a well correlated link between performance in mathematics and physics in the High School exams (HSC). However, there would appear to be evidence to indicate that overall cognitive ability, as indexed by the UAI, is an excellent indicator of the likelihood of success at the end of a first-year engineering program.

Another key outcome of the current research is that by categorising the historical data, it is possible to clearly identify 'at-risk' students. That is, it is possible to identify a cohort of students who have a high probability of performing poorly in their first year of an undergraduate engineering course. Whether or not remedial actions are taken is a matter of university policy. Regardless, this research can form the basis for justification of resource allocation to this group.

Figure and Tables

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Biography

Dr Philip Ciufo graduated from the University of Wollongong with a Bachelor of Engineering (Electrical) in 1992, Master of Engineering (Electrical) in 1994 and PhD (Electrical Engineering) in 2002. He is currently a Senior Lecturer at the University of Wollongong in the School of Electrical, Computer and Telecommunications Engineering. He is also a member of the Endeavour Energy Power Quality and Reliability Centre. His areas of research include power quality, power systems modelling, renewable energy integration, sustainable engineering and intelligent distribution (smart) grids. Dr Ciufo also has a research interest in undergraduate student performance and the various influences that determine what makes a good engineer.