A Method of Predicting the Chances of Successor Failure for Individual Students in Large introductory Engineering Physics Classes

Highly Correlative Discriminant Indicators Are Used to Determine a Student's Chances for Success in an Australian First-Year Engineering Physics Course

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ABSTRACT: It would be exceptionally beneficial to know which students were going to pass and which students were going to fail a subject prior to beginning the class. However, due to the dynamic nature of the teaching method, where instructor-to-student helps and student-to-student help is crucial, it is nearly impossible to predict the final distribution of marks in a subject. This is especially true for small classes when the instructor can assess the students continually and individually, and respond to their various problems. It is also true for subjects taught in the third and fourth years of an engineering student’s university education, due to smaller student class sizes and a more cohesive student grouping. However, in introductory subjects, such as Engineering Physics, where the student class size ranges from 170 to 350 students, there is little chance for the instructor to assess the students individually or continually. Also, instead of the students being a cohesive group of students, as they are in later years of their education, they come from extremely diverse educational, economic and cultural backgrounds. The large population sizes and heterogeneous mixture of these introductory subjects, in concert with the exhaustive testing of the students’ capabilities both from their Tertiary Entrance Scores and their introductory university achievement tests, allow highly correlative predictive indicators to be applied that give students a probabilistic assessment of their chances to successfully complete their introductory Engineering Physics subject. In this way, a student knows very clearly where he stands in the class, and the effort they must put forward to complete successfully in the class. In addition, their progressive assessment throughout the course of the subject can be used by the student as a positive feedback mechanism concerning their progress through the subject. The results of the analysis show that students can be advised as to their chances of failing or passing to a high probability, but obviously not with absolute certainty. However, some students that have exceedingly high scores or exceedingly low scores in their high school and university testing can be given almost total assurance that they will pass or fail the subject respectively.

INTRODUCTION

At the University of Newcastle, there are two separate sequences of two semester-based engineering physics subjects that are offered by the Department of Physics to students that are enrolled in courses leading to degrees in engineering or the Physical Sciences. The less rigorous of these two sequences includes PHYS 111 and PHYS 112, which are required for all engineering students that are not enrolled in either Electrical Engineering or Computer Engineering. The engineering degrees serviced by this sequence are Mechanical Engineering, Chemical Engineering, industrial Engineering, Civil Engineering, Materials Engineering, Environmental Engineering and Surveying. PHYS 111 is also required separately by several other degree programs located in the faculty of Sciences and Mathematics. This subject is by far the largest of the introductory engineering physics courses, incorporating between 300-400 students each year. In comparison, the PHYS 113 and PHYS 114 sequence, the more rigorous of the two engineering physics sequences, is required only for the Electrical Engineering, Computer Engineering and Physics students. Due to the greater selectivity and rigour of the PHYS 113 and PHYS 114 sequence, it has traditionally contained a much smaller cohort of students, ranging from 150-200 students each year.

Due to the large numbers of students that are required to be enrolled in these two sequences (greater than 500 students each year), and to the substantial amount that are unsuccessful in their first attempt to pass the classes (35%-40%), it has become important to objectively and quantitatively discern the probability that an individual student has of passing the course during their initial attempt. For instance, if it were found that a student had a high probability of passing the course in their respective sequence during their first attempt, they would be instructed in that regard, and may direct their efforts into other courses in which they may be lacking. On the other hand, if a student was found to have a low probability of passing the course, then they would be advised to that effect, and be directed toward available help sessions and tutors, or toward remedial instruction that would better prepare them for these introductory engineering physics sequences.

Traditionally, the Department has adopted the policy that two key indicators would be consulted to determine the probability of a prospective student’s success in either of the two sequences. These two indicators were the student’s scores on their Higher School Certificate (HSC) Tertiary Entrance Examination, and their beginning-of-the-year Physics Attainment Test. If their scores on both of these two tests were sufficiently high, then they were informed that they should have few problems in passing the subjects. On the other
were both sufficiently low, then they were advised that their chances of passing on their first attempt were low, and were directed toward additional assistance. However, this method of ascertaining a student’s chances for success was highly subjective, and did not attempt to address the vast majority of students that had average scores on either, or both, of the tests. Additionally, the Attainment ‘rest had been in use in the Department of Physics for twelve years, with only slight modifications, whereas the physics courses themselves had undergone significant upgrading over the past decade.

In order to determine the validity of the two tests toward projecting student performance in the engineering physics sequences, it was agreed to accumulate data on the students taking all of the introductory engineering physics subjects, and to statistically analyze that data. The project was begun at the beginning of the academic year in 1994, and has proceeded to the current time, having analyzed six semester-based subjects, comprising over 1250 student results. After accomplishing its initial objectives of determining the validity of the two discriminant pre-enrolment tests, the mission of the analysis was expanded to determine if other variables, or groups of variables, were also useful in determining a student’s probability of success.

The overall variable investigated in the analysis are listed below:

1) Attainment Test Score  
2) Progressive Assessment Test 1 (given 5 weeks into the semester)  
3) Progressive Assessment Test 2 (given 10 weeks into the semester)  
4) Tutorial Attendance  
5) Final Examination  
6) Course of Study  
7) Faculty of Course Origin  
8) Student’s Last Name  
9) Student’s Initials  
10) Student’s Cumulative Lab Score  
11) Student’s Individual Lab Scores  
12) Student’s Tertiary Entrance Examination Score (Scholastic Aptitude Test Score)  
13) Student’s Overall Course Grade (out of 100)  
14) Student’s Year of original Entry into the University  
15) Student’s Laboratory Instructor  
16) Student’s Tutorial Instructor  
17) Student’s Sex

EXPECTED RESULTS

Although the analysis was originally initiated only to determine the soundness of the two indicators we were using to qualify the students, it was quickly realized that a total analysis of all the available data could be undertaken with nominally the same effort. The expanded analysis would serve two purposes. It would easily determine the validity of the two predominant discriminant indicators, and it would also determine if there were other undiscovered variables that maybe affecting a student’s performance in the course. From the data that was available to be analyzed, the following outcomes were originally hypothesized:

1) When analyzing the singular correlations between Scholastic Aptitude Test Score, Attainment Test Score and final grade, the Attainment Test Score would have a much stronger correlation with final grade than the Scholastic Aptitude Test Score. This had been the case with a similar, but more specific analysis done four years earlier.

2) The women students would have higher preliminary scores, and would perform better in all aspects of the course than their male counterparts. This hypothesis also extended to attendance in tutorials and performance on laboratory assignments.

3) The Progressive Assessment Tests would be good forward-directed discriminant indicators concerning how students would perform on the final examination, and overall in their respective courses.

4) Students that had both a high score on their Scholastic Aptitude Test and their Attainment Test would perform very well in any of the introductory engineering physics subjects, and would have close to a 100% success rate as a group.

5) Students that had high attendance at their tutorials would also do well on other aspects of their assessment, including their laboratory reports and their Progressive Assessment Tests.

6) Students whose courses were resident within the Faculty of Engineering would have a higher overall performance, in both course sequences, than their counterparts in the Faculty of Science and Mathematics.

7) Students which were au-oiled in Environmental Engineering would perform better than students enrolled in any other
engineeering degree program due to their Scholastic Aptitude Test Score being the highest required by any of the engineering or science degree programs.

8) There would be no correlation, or a negligible correlation, between tutorial instructor, laboratory instructor, a student's last name, a student's initials, and the student's over-all performance in their respective subjects.

9) Students undertaking a double degree option would perform better than students undertaking a single degree program.

For some of the original hypotheses there was obviously a higher level of confidence than for others, but it was expected that the confidence levels generated by the correlation analysis would reflect this varying degree of certainty.

ACTUAL RESULTS OF THE ANALYSIS

As can be seen from reviewing the graphs below, some of our hypotheses were strongly verified, and others were not supported by the analysis at all. There are seven points to make about the results of the analysis, and how they affected our original hypotheses.

Attainment Test:
In the less advanced Physics 111 course, the value of the Attainment Test score as an indicator for success was strongly correlated for students seeking a Science-based degree, but negligibly correlated for students seeking an Engineering degree. This trend continued in the analysis performed on the more advanced PHYS 113 course. In both courses, the Attainment Test seemed to be a poor indicator concerning an engineering student's overall performance in the class, but was a strong indicator in deciding if a science student could succeed in either of the two courses.

HSC Scholastic Aptitude Test Score
Unlike the Attainment Test, an engineering student's Scholastic Aptitude Test Score is a very strong indicator of how the student will perform in a variety of areas. This correlation was evident in the analysis of both the courses, but much stronger for the PHYS 111 and PHYS 112 sequence, than it was for the PHYS 113 and PHYS 114 sequence. Of the two traditional discriminant indicators that were used prior to this analysis being done, it soon became apparent that the Student's Scholastic Aptitude Test Score was the more robust of the two.

Progressive Assessment Tests
The students' marks on the second Progressive Assessment Test correlated much more strongly to their final exam, and to their final grade, than did their performance on their first Progressive Assessment Test. In both course sequences, there was a positive correlation between a student's results on their Progressive Assessment Tests and all other aspects of the course. A student's results on these two tests, taken together with their Scholastic Aptitude Test Scores (if they are an engineering student) or their Attainment Test Score (if they are a Science student) allows a prediction to be made of how they will perform on the final exam, with a high level of confidence associated with that prediction.

Final Exam
The best way for a student to perform well on the final examination was for them to do well on the two mid-semester examinations. Although there was some correlation between doing well on laboratories, and attending tutorial sessions, these correlations paled into insignificance when compared to the strong correlations found between performing well on the Progressive Assessment Tests and a student's performance on the final exam. This was the case irrespective of gender, degree or faculty of origin.
Attendance in Tutorials
Attendance in tutorials was not strongly correlative with any one aspect of either of the two course sequences, but was mildly correlative to just about every aspect of the course. The only correlation that was significant was that those students with perfect, or near-perfect, attendance in the tutorials, virtually never failed their respective subjects. However, the reasons for this could be many. For instance, it might be that good students more naturally felt responsible to go to tutorials, and would have done well in their subjects irrespective. Or, on the other hand, it may mean that good tutorial attendance makes good students, that go on to do well in their subjects.

Degree Program
There were strong differences between the students from the various different degrees that were enrolled in the same subject. Prior to entering either of the two course sequences, there were large differences between the Scholastic Aptitude Test scores that were required for entry into each of the different degree programs. And, correspondingly, there were also differences between the Attainment Test results received by students from each of these degree programs. In some cases, these marked differences in Scholastic Aptitude Test scores and Attainment Test scores did predispose some groups of students toward a higher success rate than other groups of students. This was the case for the Electrical Engineers and the Environmental Engineers. They had much higher requirements placed on them as an incoming group of students, and subsequently performed better overall as a group than any other sub-set of the students attending either of the two course sequences.

Lab Scores and Tutors
There did not seem to be any substantial correlation at all between laboratory instructor or tutor, and a student’s performance in either the laboratory, the tutorial, or their overall performance in either course sequence.

Gender and Course Performance
Women entering all of the degree programs requiring introductory engineering physics subjects had higher Scholastic Aptitude Test scores and higher Attainment Test scores than their male counterparts as a group. Therefore, it was not surprising that they performed better than their male counterparts in almost all aspects of the assessment criteria in both course sequences. However, in one crucial aspect of the assessment, they performed markedly weaker. That aspect was the final exam, and as a result, women overall performed worse than men in the subjects as a whole. This is entirely the result of the final exam comprising 60% of the overall course assessment criteria, and due to nothing else.

CONCLUSIONS
The primary conclusion that follows from this discriminant analysis is that different subgroups of each of the two courses have to be dealt with differently when attempting to predict if a student will succeed or fail. The chances of an engineering student passing or failing either of the course sequences depends on their degree program, their gender and their Scholastic Aptitude Test score. If they are an Electrical Engineer, and female, and have a high Scholastic Aptitude Test score, then they should have a strong chance of doing well in any of the subjects. If, in addition, they scored well on the Attainment Test and attended all of their tutorials, their chances of succeeding would rise even further. On the other hand, if they are a male, and an Industrial Engineering student, and have a low Scholastic Aptitude Test score, then their chances of succeeding in their course sequence would be low. If they additionally scored low on the Attainment Test, and decided not to attend their tutorials or laboratories, then they would have little chance of successfully completing the course.
Another positive outcome of the analysis was that it was realized that the Attainment Test was no longer a strong discriminant indicator, and would have to be rewritten. Both course sequences had changed markedly over the past several years, and the Attainment Test hadn’t. It is currently in the process of being modified to represent the new syllabi that the course sequences currently present to the students. In rewriting the test, other knowledge tests, similar to the Scholastic Aptitude Test given to high school students, are being chosen to create a discriminant test that will do more to measure a student’s IQ in Physics, rather than their understanding of broad Physics principles.

One conclusion of this analysis that confirmed a long-held belief was that women students (both in engineering and in the sciences) are better prepared to perform well in the courses, and are more consistent and persistent performers than their male counterparts. As a group, they scored higher in laboratories, Progressive Assessment Tests and attendance in tutorials than did their male counterparts. However, in both course sequences, over the course of two years, they have continued to perform worse than men on the final examination.

The reasons for this are not entirely obvious, although there are several hypotheses that have been developed to explain this phenomenon. One suggestion was that the questions may be subconsciously directed toward men’s experiences, rather than being neutral. This could have a basis in truth due to the fact that all of the questions on the final exam are developed by lecturers in the Department of Physics, which is comprised entirely on men. A second suggestion that was put forward was that there was either a conscious or subconscious bias toward women students when marking the exams, which also are only marked by lecturers in the Department of Physics. A third suggestion was that the women in the course, having dorm well in every other aspect of the course, may not dedicate enough time toward studying for the final exam, as compared to men, that had not done as well up to that point. And, a fourth suggestion was that women do not operate as well as men in fixed-time, high stress environments. This last suggestion can be discounted due to the fact that the women involved in these courses all scored higher as a group than did their male counterparts in their Scholastic Aptitude Tests, which also were very high stress, fixed-time environments.

REFERENCES


Biographical Information

Scott Grenquist is a tenured professor in the Department of Physics at the University of Newcastle in Australia. He received his Bachelor of Arts in Modern Languages (Japanese) from the University of Notre Dame in 1982, his Bachelor of Science in Mechanical Engineering in 1984, and his Master of Science in Electrical and Computer Engineering in 1986. He is currently completing a Ph.D. in Science Education at the National Centre for Science and Mathematics Education at Curtin University of Technology in Australia. He has been an Executive Committee member of the Australasian Association for Engineering Education for the past seven years, and has been extremely active in introducing Engineering Technology programs into Australian Higher Education.