Differences in Grade Outcomes Between ICT Engineering and Computer Science Degrees

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Abstract— **This full-paper relates to research on the effectiveness of GPA thresholding as a predictor of eventual grade performance in engineering study. Rather than rely on High School grades as a predictor of eventual success in tertiary (ICT-related) engineering, we have adopted a more open-entry model, but require a high performance from the students over their compulsory first year courses in order to progress in engineering study. In this paper we examine whether this is a satisfactory predictor of eventual student success (based on grade performance), or is it that issues such as High-School to University transition unduly negatively influence these grades and lead to a decision not to allow an otherwise capable student to progress. To examine this, we compare student GPAs and graduation rates between a four year Bachelor of Engineering and a three year Bachelor of Science degree which share similar courses. The hypothesis to test is whether students who have been excluded from continuing with Engineering study are in fact capable of passing the advanced level technical courses.**

Keywords- integrated tutorials, student retention, holistic pedagogy in engineering

I. Introduction

Globally, professional technical qualifications such as engineering degrees often restrict entry by some set of criteria, normally dominated by High School grades - either holistically or in specific subjects. However, such a reliance on High School performance can easily exclude those from lower socio-economic backgrounds, who had a negative experience in their final year of High School or who have otherwise suffered some disadvantage (perhaps on the basis of race or gender) [1].

At Victoria University of Wellington (VUW), for a variety of reasons including a lack of trust in the new NCEA High School National grading criteria [2], we have opted for a more open entry approach, and instead placed the onus on students to perform well in their required first year engineering courses. We have defined the critical threshold as an above average, B grade. In the New Zealand grading system, a C- achievement (that represents a numerical grade range of 50-54%) is the minimum passing grade. Thereafter grades increase every 5%, so a B grade corresponds to a grade between 75 and 79% - an above average pass. For a typical Gaussian shaped grade distribution, we would holistically expect 50% of university *passing* students to score below this B grade. However, we hypothesize that Engineering is attracting the better students and therefore more than 50% *should* be able to attain this B threshold. Historically we have excluded approximately 55% of our entry cohort from progressing under this criterion [3]. Our goal is to reduce this to 40% but without a decrease in academic quality. Grade inflation is an obvious mechanism if we were only concerned about overall student numbers, but of course this does sacrifice quality and graduate outcomes, and so instead we have adopted a number of novel assistive practices and major curriculum changes [3].

However the outstanding questions are:

- Is this above average, B GPA threshold the appropriate level, or perhaps could it be lower?
- Is a GPA threshold required at all? Should we instead allow any students that pass the courses (C- grade or better) to continue in Engineering study?

These are difficult questions to resolve as obviously we cannot create a control group and progress them through a different pathway. However, we are able to study a subset of students who were excluded from continuing in their engineering study but who enrolled in similar technical courses in their subsequent BSc. To further understand this relationship, sections II and III present our academic programme, noting the similarities between the four year Bachelor of Engineering (BE) and the three year Bachelor of Science (BSc) degrees.

II. The First Year Structure

The Engineering degree at VUW focusses on the ICT/High-Tech areas of engineering rather than the more traditional civil/structural/chemical (etc.) disciplines. With research interests in mechatronics, communications, signal processing, electronics, artificial intelligence, computer graphics, cybersecurity and programming languages, we offer two primary paths for the four year Bachelor of Engineering (BE) degree – an ECEN (Electronics and Computer Systems Engineering) "hardware" path, and a SWEN (Software Engineering) "software" path. Despite our best efforts, we could not agree on a common first year given that the hardware faculty staff strongly believes that good mathematics (especially calculus) and physics are essential, with software staff debating the usefulness of these subject in their programme at all, preferring instead discrete mathematics, statistics, and more programming. Consequently we have two first year programmes, with 5 courses in common:

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Common to all engineering

COMP102: Introduction to Computer Program Design

This course introduces the fundamentals of programming in a high-level language (Java), using an object oriented approach to programme design.

COMP103: Intro to Data Structures and Algorithms

This course builds on COMP102, focusing on the techniques for designing, building and analyzing computer programs that deal with large collections of data. It provides an understanding of the principles of data abstraction, algorithm design and analysis.

ENGR101: Engineering Technology

This course provides a general introduction to the fundamental technical concepts needed to understand the design and engineering of electronic, mechatronic, networked and software systems. Experience is gained in basic engineering practice with assembly and testing of basic hardware, software and networked systems.

ENGR110: Engineering Modelling and Design

This course introduces the role of modelling in the engineering design process. Different modelling techniques are presented and techniques for evaluating each that can aid design decisions are demonstrated.

ENGR121: Engineering Mathematics Foundations

This course is an introduction to the range of mathematical techniques employed by engineers, including functions and calculus, linear algebra and vector geometry, probability and statistics. There is an emphasis on applications and modelling.

Hardware First Year (additional) Curriculum

ENGR122: Engineering Mathematics with Calculus

This course presents further mathematical techniques employed by electronic and computer systems engineers with emphasis on methods of calculus, differential equations and linear algebra. There is an emphasis on engineering applications and use of software.

ENGR141: Engineering Science (chemistry and physics)

This course deals with scientific topics relevant to engineering. Topics include forms and use of energy, basic electric circuits, introductory atomic theory, exploitation of chemical energy and chemical hazards.

ENGR142: Engineering Physics for Electronics and Computer Systems

This course presents the physics theory and practice relevant to electronics and computer systems engineering. Topics covered include electrostatics (charge, force, field, potential), magnetic field and force, DC and AC circuits, and electromagnetic induction.

Software First Year (additional) Curriculum

CYBR171: Cybersecurity Fundamentals

This course examines how cybersecurity affects individuals and society and aims to develop understanding that the concept of cybersecurity goes beyond technology to include people, information and processes. The course uses a range of security tools but does not involve programming.

ENGR123: Engineering Mathematics with Logic and Stats

This course develops the mathematical techniques employed by network and software engineers including methods of combinatorics, logic, probability and decision theory.

+ Choice of an introductory physics course including first year computer graphics.

So, perhaps somewhat regrettably, we are forcing the student to at least make the hardware/software decision at the beginning of their first year. As mentioned, the students' GPA from these required courses are used to determine whether they are permitted to continue in an engineering degree or instead to convert to a BSc. We label this criterion as attaining "Part I" of our degree (Part II is passing subsequent compulsory, higher level courses).

However, this decision is not entirely a binary selection based solely on a GPA resolved to some arbitrary precision of significant digits. The Dean of Engineering makes the final decision, and for borderline students, there is some flexibility. For example a software student who has excelled at the programming courses but has only just passed the mathematics course might be allowed to proceed, and conversely a hardware student with excellent mathematics and physics but poor programming might also be allowed to proceed. There can also be a "decision pending" result enabled by the structure of our second year.

III. The Subsequent Years

At VUW, for a multitude of reasons, including course rationality and resource utilization, technical courses are open to both BSc and BE students (and in fact students from other degrees as well if they have the prerequisites). The primary difference between the Engineering and Science degrees (other than the final fourth year (that is exclusive to the BE) are the professional engineering courses, work experience and guidance, project management, and professional practice. For reasons related primarily to student maturity, other than the work experience and guidance, these courses begin at the third year. Therefore, other than preparation for work experience, science and engineering students can take identical courses. Whilst we do have a course at second year titled, ENGR201: Engineering in Context (which "addresses the research, analysis, critical and creative thinking skills embodied in written and oral communication which professional engineers are expected to display in the workplace"), entry into this course is open to anyone who has passed ENGR101, 110 and any three other courses from the list in section II.

What this means in practice is that a student who has been excluded from continuing with their Bachelor of Engineering enrolment (i.e. have failed their Part I), can effectively have an almost identical set of second year courses. The "Decision Pending" result then can, for these borderline students, delay the exclusion decision until the end of the students' second year of study, with the implication that they only have to catch up on the work experience preparation courses. We have been cautious in our utilization of this ternary level of decision making as we think it is generally unfair to either provide false hope for students who we believe are not going to achieve the required academic quality, or to otherwise delay the work experience of students who might.

By third year however, compulsory engineering courses such as ENGR301 (Project Management), ENGR302 (Group (Engineering) Project), ENGR391 (Practical work experience – 400 hours) are restricted to BE students only. The remainder of the technical courses – both hardware and software – are accessible to students from any degree (providing prerequisites are met). This then gives us the ability to track student performance in the advanced technical courses of three student cohorts: those who achieved the GPA criterion (attained Part I) and are confirmed BE students; those who were excluded from the BE but are taking the same technical courses under a BSc umbrella, and (for second year at least) those who fell into the ternary classification of "Decision Pending" – and whom might arguably be extremely motivated to do well.

IV. High School Grades As A Prediction of Success

It is relevant to state that we have very carefully considered whether our mostly open-entry model into our engineering degree is the best approach. As mentioned, many universities do restrict entry on the basis of High School grades. To investigate this, we have undertaken an extensive exercise to determine whether such a prediction is reasonable for the electronics/ICT forms of engineering that our university offers [2].

This study used both manual correlation efforts and data mining software (Weka) in an effort to predict eventual success in our ICT/Electronics engineering degrees. We considered a large range of High School grades (the New Zealand NCEA assessment divides each subject into numerous modules, all of which are individually assessed – so for example, Chemistry at the final year of High School would be presented as individually assessed modules in titration, redox, organic, aqueous systems etc., there being no overarching assessment of the subject in its entirety. This does give us a fine granularity of subject assessment with which to form a predictor, but as outlined in [4] this also means students have additional transitional problems when they come to university and examinations cover an entire course, not specific components.

The manual correlation efforts peaked at a correlation score of 0.722 for hardware (ECEN) students and their High School Mathematics and Physics grades. For the software students, the best manual correlation achieved was 0.513 (surprisingly related to their scores in High School English!).

We ran the data mining software over a wide range of scenarios, including both binary and ternary predictions (i.e. a "Decision pending" category as well as a prediction of success and failure). However, we were unable to create any form of predictor that (had we used it to determine a degree entry criterion) would not have resulted in the exclusion of a significant number of students who eventually did graduate with an engineering degree.

Indeed, such entry-level predictors strongly favor students from higher socio-economic backgrounds and are at variance with our efforts to increase equity participation, particularly indigenous Maori and Pacific Nation students.

After a careful consideration of the results (failings) of these predictors, and the impact it would have especially on our equity students, we elected to allow the mostly open entry into our engineering degree, and allow the students to demonstrate their ability over the first year of our programme. The results of this discussed in section V.

V. Stages Of Student Attrition

As discussed in section III, if we compare the first three years of a Bachelor of Engineering programme, with the three years of a Bachelor of Science, there is a commonality of technical courses. The first stage of our analysis then, is to examine what happens to students who are prevented from continuing in their engineering study after first year.

The difficulty of course, is that it is very difficult to individually survey such students in order to fully understand the motivation for leaving the BE degree and where they then go to. Prior research definitely indicates that there non-academic issues are very significant influencers [4]. We do not have a required exit interview, and so to track the different student pathways we have to individually examine each student's academic records to determine which degree (if any)they are progressing in. As the data indicates, a non-trivial number just disappear from the university system and we are not resourced to further track and interview such students.

We expect three stages of student attrition:

(1) Students who have not attained Part I after their first year of study and elect to transfer to a different degree

(2) Students who for a variety of personal or health reasons leave the degree at various points, but not necessarily related to academic issues.

(3) Students who are offered permanent job placements following their engineering work experience placements, and elect to transfer out of the four year BE, and graduate instead with a three year BSc and immediately engage in employment.

We have noticed, particularly in the last 5 years, that the local and national economy has exploded with ICT start-ups and the expansion of large software firms. Indeed such has been the demand for software engineering graduates, that the New Zealand Government funded the creation of three ICT Graduate Schools throughout the country, (of which our University successfully bid for one) in order to help meet this demand [5]. Due to the strong overlap of courses between the BE and BSc, it is reasonably straight-forward for a student who has completed three years of the BE to credit these courses and graduate with a BSc instead. As presented in below, this particularly impacts the graduation rates of our software SWEN students, less so our hardware ECEN students.

We would expect that attrition due to point 2 would be reasonably small, and evenly distributed amongst the different majors and degrees.

VI. Student Success Rates

We begin by considering the percentage of students who pass our Part I. As described in [3] and summarized in Table I, this results in a historical attrition of approximately half of the initially enrolled BE students. As discussed in [6], we are optimistic that various intervention programmes might reduce this attrition rate by 5 or 6% this year. The right-most column of Table I indicates the comparative success of women students (our data unfortunately only permits a binary gender classification). With some variances, women comprise between 8 and 14% of our entry cohort, and generally have a superior rate of attaining Part I compared to their male counterparts.

TABLE I. Percentage Of Students Who Attain Part I

Cohort entry year	Part I success rate (%)	Part I women success rate (%)
2007	29	20
2008	42	57
2009	44	60
2010	45	31
2011	44	40
2012	46	58
2013	42	73
2014	44	48
2015	44	69
2016	41	38
2017	50 (predicted)	

We are aware that a significant number of students enroll in Engineering for the wrong purposes. Many are actually seeking a trade (i.e. electrician or PCB technician) and would be far better suited to enrolment in a polytechnic. Indeed we do endeavor to identify such students early in their programme and inform them of such alternative engineering pathways. Some are academically not capable of engineering work, and some have not developed the study habits and skills to succeed in tertiary study.

When we compare these attrition figures to other open entry, professional degrees, they are not unexpected and arguments such as ensuring graduate quality are often used as a justification [7]. However, what if for many students, the below-average results were more of an indication of transitioning issues than actual academic ability? Certainly given changes in our High School grading system (the NCEA grading system discussed in Section IV and in more detail in [8]) the transition is more challenging than it has been in the past, both in terms of academic expectations and teaching, learning and assessment styles.

We consider the graduation rate over all degrees at our university, for students who initially enrolled in Engineering. Table II reveals that approximately only one in four of the initially enrolled students are graduating with a Bachelor of Engineering degree. However, a similar number graduate with a Bachelor of Science degree in a related discipline. So 60% of our initially enrolled engineering students do complete a VUW degree, and about 50% in an ICT discipline. So clearly some failed Part I students are capable of at least satisfactory performance in the advanced courses.

TABLE II. Percentage of students Graduating at VUW – figures for Women Only are presented in parentheses

Cohort entry year	Graduate BE (%)	Graduate BSc (%)	Graduate other degree
2007	19 (20)	24 (10)	14 (30)
2008	27 (43)	19 (14)	12 (14)
2009	24 (40)	24 (20)	14 (30)
2010	25 (23)	22 (15)	10 (23)
2011	23 (30)	27 (40)	6 (10)
2012	22 (32)	21 (16)	4 (5)
2013	16 (27)	20 (20)	2 (0)

Note that 2014 students would (best case) be graduating BE in 2017, and 2017 graduation data was not available at the time of paper submission.

Interestingly, broken down by gender (the figures in parentheses in Table II) we see in general a far higher rate of BE degree completion by women students and a lower overall rate of non-degree completion. We consider this issue further later in the paper.

Our equity figures for Maori and Pasifika completion are difficult to comparatively analyze due to the low numbers of such students enrolling. Generally only 5-10% of our enrolling students self-identify as Maori, and with an attrition figure similar to our overall student cohort, then we are dealing with small numbers with a correspondingly large statistical variation. This figure is worse for Pasifika students who generally only comprise 1-5% of our entry cohort. However, an inspection of the (widely varying figures) does not indicate a trend that seems to be at a significant variance to our main student cohort.

TABLE III. SWEN (Software) Graduation Rates

Cohort entry year	% of initial enrolments	Graduate BE (%)	Graduate BSc (%)	Graduate Other Degree (%)
2007	44	15	32	13
2008	30	21	17	14
2009	43	13	32	15
2010	51	23	23	7
2011	39	19	37	7
2012	55	27	26	1
2013	58	13	25	1
average		19	27	8

TABLE IV. ECEN (HARDWARE) GRADUATION RATES

Cohort entry year	% of initial enrolments	Graduate BE (%)	Graduate BSc (%)	Graduate Other Degree (%)
2007	35	22	16	14
2008	54	32	17	13
2009	40	35	14	12
2010	32	29	14	14
2011	35	32	8	3
2012	30	14	14	6
2013	32	22	10	4
average		27	13	9

Had we excluded these students in the form of a high-barrier entrance criterion, then yes, our graduation rates would be higher, but at the expense of also preventing some students from disadvantaged backgrounds from potentially succeeding.

It is also informative to break-down the results of Table II to consider the different majors. Table III presents the results for the software SWEN students, Table IV for the hardware ECEN students.

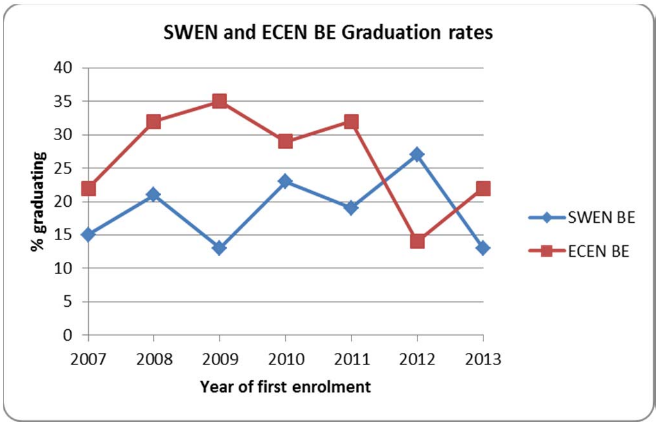

Fig. 1. Comparison of graduation rates (expressed as a percentage of initially enrolling students) of students who initially enrolled in a Bachelor of Engineering and graduated with a Bachelor of Engineering

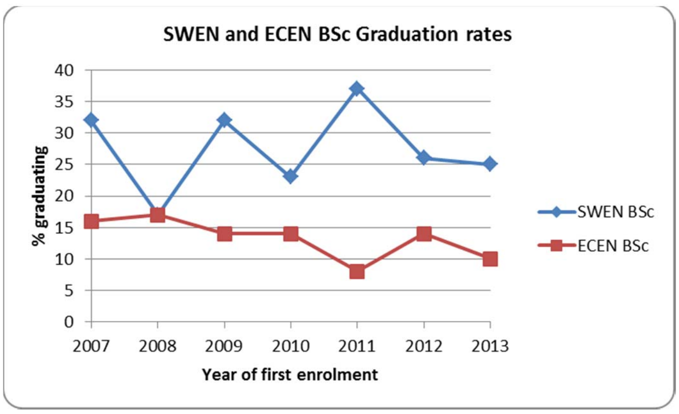

Fig. 2. Comparison of overall graduation rates (expressed as a percentage of initially enrolling students) of students who initially enrolled in a Bachelor of Engineering but graduated Bachelor of Science

As illustrated in Fig. 1, in general, ECEN (hardware) students are more likely to graduate with a BE than their software SWEN counterparts (who in turn are more likely to graduate with a BSc as illustrated in Fig. 2). Approximately the same proportion move to another (different) area of study and subsequently graduate.

Repeating this exercise considering only those students who passed Part I, yields Tables V and VI. These results show a far greater variance. The maximum SWEN rate of attaining Part I has peaked at 52%, considerably higher than the ECEN maximum of 43%. Our analysis reveals the essential differences are in the gradings for the calculus and physics courses required of an ECEN student but not for SWEN.

Of significant interest is that once past Part I, a student who originally identified as ECEN is significantly far more likely to graduate with an Engineering degree (admittedly not necessarily in the actual ECEN major) than a SWEN student – an average of 70% c.f. 45% respectively and presented in Fig. 3. The attrition due to employment offers at the end of a SWEN student's third year is responsible for much of this, as evidenced by the two-fold increase in SWEN students graduating with a BSc (compared to an ECEN student). Referring back to the previous discussion of female vs. male SWEN completion rates, an interesting question (for which we have no data) is whether male students are preferentially receiving job offers and whether this is a contributor to the higher rate of BE degree completion amongst women students.

TABLE V. BE GRADUATION RATES OF SWEN STUDENTS WHO ATTAINED PART I

Cohort entry year	% achieved Part I	Graduate BE (%)
2007	34	44
2008	31	67
2009	38	35
2010	50	46
2011	47	40
2012	52	52
2013	45	30
average	42	45

TABLE VI. BE GRADUATION RATES OF ECEN (HARDWARE) STUDENTS WHO ATTAINED PART I

Cohort entry year	% achieved Part I	Graduate BE (%)
2007	30	73
2008	42	77
2009	43	81
2010	34	83
2011	42	75
2012	39	35
2013	35	65
average	38	70

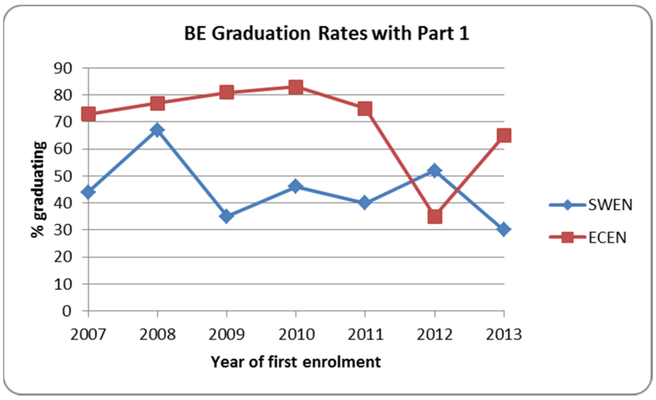

Fig. 3. Comparison of overall graduation rates in the Bachelor of Engineering (expressed as a percentage of initially enrolling students) of students who successfully passed Part I.

VI. Student Quality With and Without Part I

The results so far indicate two interesting trends:

- Less than 50% of students who originally enroll in a BE, gain a sufficient GPA in their first year courses to be allowed to continue
- Only 50% of these remaining students will go on to graduate with a BE
  - 70% of ECEN students
  - 45% of SWEN students

There is little we can do to prevent the SWEN losses between years three and four other than to restrict the ability for the cross-crediting of course achievement between the BE and BSc, but we strongly feel that this would not be advantageous to our students, many of whom might abandon the goal of degree completion altogether. Let us now consider how those engineering excluded students perform. Table VII presents the GPA in years two and three of students who did not finish Part I. Table VIII illustrates the equivalent results from students who did finish Part I and graduated with a degree other than a Bachelor of Engineering. We compare these against Table IX which are the GPA of students who did graduate BE (and therefore obviously obtained Part I).

TABLE VII. GPA of Non-BE Graduates Who Did **NOT** Finish Part I

Cohort entry year	% of entry cohort	GPA
2007	26	3.1
2008	23	3.4
2009	24	3.0
2010	17	3.7
2011	17	3.3
2012	9	3.5
2013	12	4.0
average		3.4
Std. dev		0.3

From Table VII we see that on average, students who were excluded from continuing with a BE degree attained a GPA of 3.4 (2007-2013), equivalent to a C+/B- grade – clear passes, but quite low quality.

TABLE VIII. GPA of Non-BE Graduates Who Achieved Part I

Cohort entry year	% of entry cohort	GPA
2007	14	4.5
2008	8	3.6
2009	13	5.2
2010	16	4.6
2011	16	3.9
2012	15	5.5
2013	10	4.6
average		4.6
Std. dev		0.7

From Table VIII and Fig. 4, for students who graduated, (but NOT with a BE, it is clear that the students who have attained Part I score on average at least one grade point higher than the students who did not, and in fact at an average 4.6 GPA, this is only marginally below the B level GPA of 5.0.

TABLE IX. GPA of BE Graduates

Cohort entry year	% of entry cohort	GPA
2007	19	5.8
2008	27	5.5
2009	24	4.9
2010	25	5.8
2011	23	5.0
2012	22	5.5
2013	16	5.7
average		5.4
Std. dev		0.4

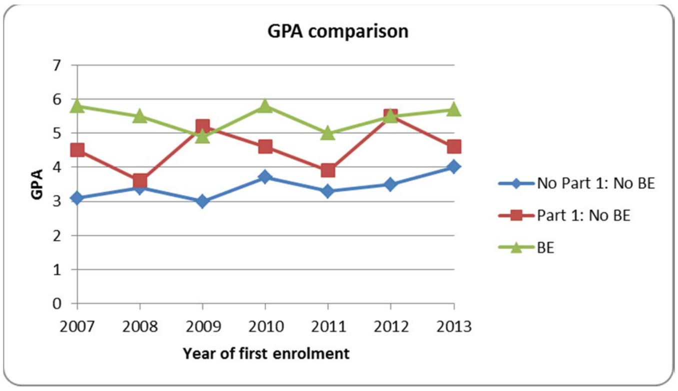

Fig. 4. Comparison of overall GPA scores for students who (blue) graduated with a degree other than a Bachelor of Egineering and who did NOT pass Part I; (red) students who passed Part I but for various reasons graduated with a degree other than a Bachelor of Engineering; (green) students who graduated with a Bachelor of Engineering (who obviously have passed Part I).

There is no doubt from a consideration of Table IX that the BE students are performing at a grade point higher than their colleagues who passed Part I but elected to graduate with a different degree. This GPA difference is plotted in Fig. 4. So perhaps it is not just the job offers that have resulted in this attrition – maybe the students found the subsequent years of study too difficult and this influenced their decision to leave the BE programme? Without an exit interview, we are unable to definitively answer this question.

V. CONCLUSIONS

It is clear that for some of the students that we prevent from continuing with the BE programme on the basis of a failed Part I, that they are capable of handling the advanced level courses and graduating with some related degree. A significant number however, leave the technical area completely and elect a different discipline (often Information Systems).

Of those students who continue with technical studies, there are approximately two grade categories between those who did not achieve their Part I, and those who did and continue with the BE. Therefore, a reasonable conclusion is that if we were to abolish the Part I, then we would potentially have an influx of students in our engineering fourth year operating (on average) at two grade points lower than our current student intake (remembering that a BSc is only three years and such student generally are not able to enroll in our fourth year courses.). By inference, this would also mean that we might have a significant group of students graduating with our BE degree who are (again on average) two grade points lower in ability than our current graduation cohort.

Currently our University enjoys an exceptional relationship with industry. Our employment rate for our BE graduates is effectively 100%, and the quality of our graduating students is one of the main reasons for this. On the basis of this analysis, the Dean of the Faculty has decided not to abolish the Part I criteria, nor to lower the B GPA threshold. Until such time as financial motivators from the University management dictate that increased student numbers are essential, the quality of our graduating cohort is of more importance.

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