Are Introductory Courses Suitable Pathways for Success in the BE(Hons)

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***Abstract*—We investigate the ability of introductory physics and mathematics courses to provide a successful pathway into the Engineering program at Victoria University of Wellington. We find that an increasing number of students require these courses, however neither course appears to adequately prepare students for the completion of an engineering degree. The introductory physics course in particular, does not adequately prepare student to pass subsequent physics courses. We examine both the delivery and curricula of these courses against literature 'best practice' models. Finally we make a series of recommended changes be made to either university entry requirements or to these courses to offer allow students a reasonable pathway into the BE(Hons) degree.**

Keywords—engineering; first-year; introductory; mathematics; physics; entry requirements;

I. Introduction

This paper details an examination of our two introductory courses and how successful they have been as pathways for students in the Bachelor of Engineering with Honours (BE(Hons)) degree. In doing so it considers the entry policy to the BE(Hons) for these students, the suitability of the courses themselves to act as pre-requisites for subsequent core courses and the outcomes for students taking these courses. A number of studies have been published examining the student success in specific courses as part of this program [1][2][3]. Little work has been done comparing the performance of students who are forced to take introductory courses to the rest of the cohort. Both the number and percentage of students attempting the BE(Hons) using these introductory courses has increased over recent years (enrolment numbers are presented in section III). Anecdotally these students have been observed to struggle academically throughout their degree, suggesting that they are unprepared for studying engineering at Victoria University of Wellington (VUW). This paper presents the requirements of the BE(Hons) degree at VUW alongside recent enrolment trends, then examines the curricula, course performance and a critical review of our two introductory courses: PHYS122 and MATH132.

II. Background

The School of Engineering and Computer Science (SECS) at VUW, New Zealand (NZ) offers a four year BE(Hons) degree in three majors: Software Engineering (SWEN), Network Engineering (NWEN) and Electronic and Computer Systems (ECEN). VUW is a publically funded university and has offered the BE(Hons) since 2007. Our undergraduate program is predominantly comprised of domestic NZ students who typically enter the program after completion of high school and the National Certificate of Educational Achievement (NCEA) [4]. The authors note that students' NCEA experience can discourage uptake of STEM courses, particularly for indigenous students [4][5].

To be automatically accepted into programs offered at VUW, students must achieve University Entrance (UE) and achieve a Guaranteed Entry Score (GES) of at least 150 points based on their NCEA level 3 scores. An explanation of NCEA, UE and GES is included in the S.I. Students with less than 150 points can still be considered if they meet the UE requirement. While prerequisites are in place for some specific courses within the degree, SECS maintains no restrictions, or prerequisites on entry to the BE(Hons) other than those required by VUW. Demands for increased student numbers by the university has allowed for students who have a GES of lower than the university's threshold of 150 to gain entry to engineering.

Rather than place quality control at the entry point as some other universities do [7], quality control over students in SECS is done through the use of a required B average (>70%) across core courses in first year. A comparison between New Zealand grades and US grades is provided in the S.I. This requirement is referred to as Part 1 of the BE(Hons) degree. Failure to obtain the B average and pass Part 1 effectively removes a student from the engineering degree. Part 1 consists of the following selection of courses which all students must take. This includes several common core courses described elsewhere [8]. In addition to the common core courses, ECEN students then have the following Part 1 courses: ENGR122 (Engineering Mathematics with Calculus), PHYS114 (Physics 1A) and ENGR142 (Engineering Physics for Electronics and Computer Systems). SWEN and NWEN students instead have the following additional Part 1 courses ENGR123 (Engineering Mathematics with Logic and Statistics) and PHYS122 (Introduction to Physics for Scientists and Engineers).

Currently, a student is able to enrol in the VUW BE(Hons) with a mixture of subjects from the NCEA curriculum that contains few subjects that prepare students for engineering. It

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is possible to enrol in the BE(Hons) with no math, physics or digital technology (Computer Programming) background. The actual number of students who enter with no related NCEA credits is small, but not zero. More common are students with poor NCEA results in specific related subjects, such as, physics, math or digital technology or are missing key standards (assessment topics) in one or more of these subjects. Alternatively, as NCEA allows for piecemeal assessment of a subject, a student may also only have small areas of achievement in a subject (such as calculus), rather than a coherent body of knowledge connecting that subject [6].

All engineering students with less than 16 NCEA level 3 mathematics credits are forced to pass an introductory mathematics course, MATH132, prior to enrolling into the first of the core engineering mathematics courses, ENGR121, shown in Fig 1. MATH132 is offered over the summer trimester, allowing students to take the course prior to their first year of university, or during their first trimester of university study. A passing grade in MATH132 is deemed sufficient to allow students to enrol in the first core mathematics course required for the BE(Hons) qualification.

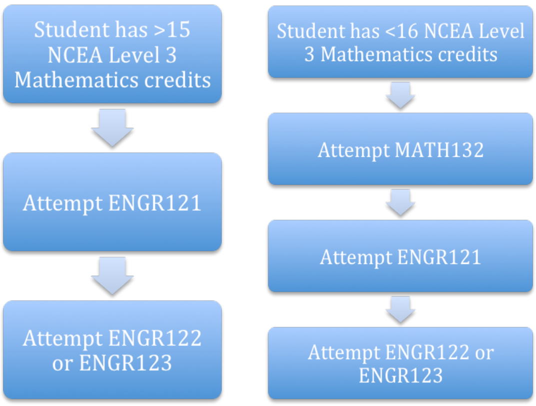

Fig. 1. Example of Mathematics pathways for BE(Hons) students with varying levels of mathematics ability.

Non-ECEN BE(Hons) students must only pass PHYS122 in order to achieve their qualification. Well-prepared students gain entry directly to PHYS114 and ENGR142 whilst other students must first pass PHYS122 before being allowed to enrol in either of PHYS114 or ENGR142 as shown in Fig 2. ECEN majors without 18 credits of NCEA Level 3 physics and the NCEA Level 3 mathematics standards for integration and differentiation, are required to pass PHYS122 prior to enrolling in their core physics courses (PHYS114 and ENGR142 or PHYS115), all of which must be passed in order to achieve the qualification.

As a consequence of university 'relative open entry' and specific entry requirements for core courses, a significant percentage of our first-year cohort are required to take introductory courses. This also means that many of these students do not take all the core courses required for Part 1 in their first year. Tables I and II indicate that between 10 and 20% of all new BE(Hons) students require MATH132 and up to 40% of BE(Hons) ECEN students require PHYS122. The fraction of our ECEN cohort requiring PHYS122 is increasing over time (shown in Table II), whereas the fraction of students attempting MATH132 appears to be declining (Table I).

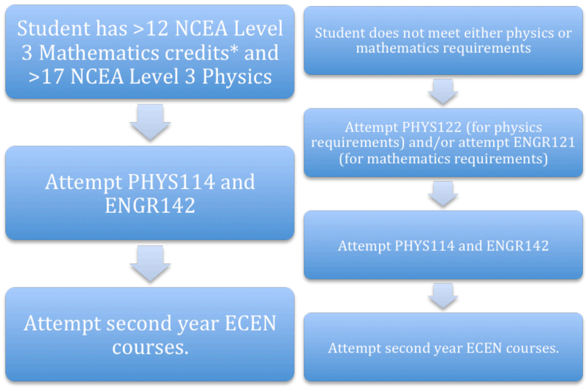

Fig. 2. Physics pathways for BE(Hons) ECEN student with varying levels of mathematics and physics ability.

TABLE I. COHORT PERCENTAGE AND RAW NUMBER OF ALL BE(HONS) STUDENTS ENROLLED IN MATH132 BY YEAR.

Year	*BE(Hons) students in MATH132*	*Cohort %*
2009	21	18%
2010	30	26%
2011	23	21%
2012	40	24%
2013	35	23%
2014	45	26%
2015	27	17%
2016	22	10%

These introductory courses are not part of pre-degree bridging programs, or specific bridging courses as such. SECS is currently unable to offer a specifically targeted engineering bridging program or courses. VUW's full bridging program was withdrawn by the university in 2012 due to changes in government funding that removed the government subsidy for bridging programs. The university was unwilling to fund delivery of bridging programs on its own. Practically however PHYS122 and MATH132 represent a recommended pathway into the BE(Hons) program for underprepared students, and thus serve a bridging role. Dedicated bridging pathways exist at other New Zealand universities but experience similar funding pressures despite improving student outcomes [5].

TABLE II. COHORT PERCENTAGE AND RAW NUMBER OF ALL BE(HONS) ECEN STUDENTS ENROLLED IN PHYS122 BY YEAR.

Year	*BE(Hons) students in PHYS122*	*Cohort %*
2010	7	18%
2011	4	11%
2012	10	20%
2013	13	27%
2014	20	34%
2015	19	43%
2016	13	37%

III. BE(HONS) ENROLMENTS

Table III shows the number of students enrolled in the various majors of the BE(Hons) from the period of 2007 through to 2016. Over this period cohort numbers have increased dramatically, with almost all growth coming from enrolments in SWEN. Over this same period NWEN and ECEN enrolments have stayed mostly static leading to a reduction in their percentage composition of the cohort over time. As such any course that predominantly affects SWEN students will likely impact the majority of our student population. Of the two courses we discuss in this paper, PHYS122 is required for all SWEN students (unless they elect to take the harder physics course, PHYS114).

TABLE III. BE(HONS) STUDENT ENROLMENTS SPLIT BY MAJOR. STUDENTS ARE GROUPED BY THE MAJOR THEY INITIALLY ENROLLED IN DURING THEIR FIRST TRIMESTER COURSE(S).

Year	*Enrolments*	*SWEN*	*ECEN[a]*	*NWEN*
2007	107	44%	35%	21%
2008	98	30%	54%	16%
2009	114	46%	39%	16%
2010	115	51%	33%	16%
2011	109	39%	35%	26%
2012	169	55%	30%	15%
2013	154	58%	32%	10%
2014	176	56%	33%	11%
2015	159	60%	28%	12%
2016	213	73%	16%	10%

a. Includes non-ECEN hardware majors *for the 2007-2010 period.*

IV. PHYS 122 RESULTS

PHYS122 is an introductory physics course for BE(Hons) students and is a core course required for SWEN and NWEN students counting towards the calculation of these students B average for their Part 1. It also comprises these students' only compulsory physics course. It covers a variety of topics including motion, trigonometry, light, waves and basic circuits. A passing grade in PHYS122 also gives students entry into the core physics courses necessary for the ECEN major. As such, it acts as a gateway course for weak physics or mathematics students into the ECEN major. We next examine the curriculum and delivery of PHYS122 in the context of modern educational literature, and contrast this with examples of 'best practice' from other introductory physics courses.

A. PHYS122 Curriculum

There are no mathematics or physics entry requirements to PHYS122, only UE is required. PHYS122 expects 13 hours of student work per week of the 12 week course. This is broken down (weekly) into 3 hours of lectures, 3 hours of labs (reduced to 2 hours in 2015), 3 hours of assignment work and 4 hours for personal review of course content. In order to pass the course a student must meet the mandatory course requirements of: sitting the mid-term test, completing all 10 lab activities and scoring at least 40% in the final exam plus achieving an overall grade of 50% or better.

PHYS122 course learning objectives (CLOs) are stated as:

1. Identify and use the concepts of the course to discuss physics related questions and solve problems
2. Develop basic physics laboratory skills
3. Clearly represent and communicate ideas in physics using appropriate language and symbols
4. Use critical thinking to apply knowledge and understanding to new situations

Assessment is divided into four components: ten assignments (worth 15% overall with each contributing 1.5% of the students' final grade), ten laboratory sessions (worth 30% overall with each contributing 3% of the students final grade), a 1 hour in-term test (worth 15% of the final grade) and a 3 hour final exam worth 40% of the final grade. Some courses allow students to make up poor assessment items later – however this option is not available to students in PHYS122. The course content for the 2010-2016 period includes: basic mathematics, forces and motion, energy, oscillations, waves, electric forces and charges, DC circuits and AC circuits.

Weekly assignments in PHYS122 are assessed entirely based on a student's reflection upon being provided the correct answers. To quote the course outline: "*You compare your problem-solving strategies, explanations and answers with mine, highlight corrections, then write your reflective comments…we scrutinize them and …[award] a mark out of 3. No detailed feedback – you do that by mindfully comparing your answers with mine.*"

This marking scheme awards 1 mark for handing an assignment in, 1 for correct or self-corrected work and the final mark for perceptive reflective comments. The exact nature of a perceptive reflective comment is not made clear.

Unsurprisingly, with only 4 possible marks available for each assignment (and a zero marking only being obtainable by submitting nothing) the average mark for submitted assignments starts at 80% for assignment 1 and descends to approximately 60% by assignment 10. During this period the rate of non-submission of assignments rises from 20% for the first assignment to just above 50% for assignment 9 and over 80% for assignment 10. Laboratory grades are similarly high with averages ranging from 71 to 93% for all 10 labs. Laboratory sessions are highly supervised and require students to submit their work during the lab period. The labs are designed to reinforce lecture material and typically include students working on experiments, taking measurements and interpreting data. Students struggling with material or calculations receive one-to-one guidance from the tutor. The practical result of these assessment items is that an average student will achieve above 70% on all their internal assessment items over the course of the trimester, and consequently will feel confident of their mastery of the material because of this. Unfortunately this appears to be an erroneous assumption on the part of most students as their grade for these formative assessments are poor predictors of a student's performance on summative assessments.

The first summative assessment students encounter in PHYS122 is the mid-term test, given after 6 weeks of lectures and laboratories. The 15% in-term test has 50 marks split into a Part A and Part B worth 39 marks and 11 marks respectively. Part A questions are multi-choice worth up to 3 marks each. Questions are marked following the following criteria: correct answer and good explanation (3 marks), wrong choice but good physics (2 marks), correct choice and poor or no explanation (1 mark), wrong choice and wrong physics (0 marks).

This requirement for explanation is stated only once at the start of the course, other than this each question appears as a standard multi-choice test requiring only circling the correct answer. Part B comprises a series of long answer questions. No practice tests or model solutions are provided to students as the same test is used each year. An example of a typical Part A question is shown in Fig 3. Questions such as that presented in Fig 3. give students minimal ability to demonstrate their physics understanding, instead requiring rote memorization of a particular fact. Several of the answers were discussed in class in detail requiring students to simply then recall which specific method Aristarchus was responsible for. Conversations with the academic staff responsible for the course suggest that the test is intended to be tricky and generate a low average grade in order to encourage students to work harder in preparation for the final exam. Performance in this mid-term test is typically poor, as indicated in Table VI.

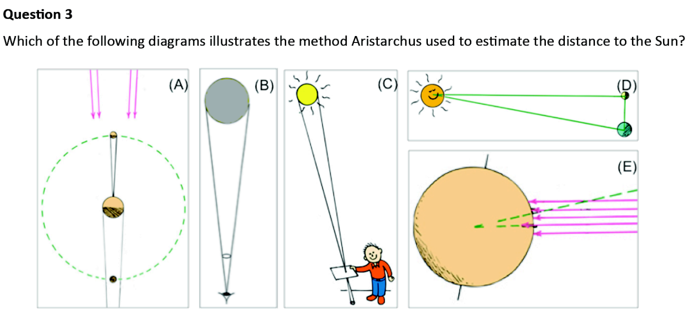

Fig. 3. An example of a multichoice question requiring explanation from the PHYS122 mid-term test. The correct answer is D, as Aristarchus determined the relative sizes of the distance between the Earth and the moon and the and the Sun by measuring the angle between the Sun and moon as 87 degrees during a half moon.

TABLE IV. PHYS122 MID-TERM TEST SCORE AND MID-TERM TEST FAILURE PERCENTAGE BY YEAR.

Year	*Mean Mark*	*% of students that score below 50%*
2012	51%	46%
2013	50%	46%
2014	48%	51%
2015	43%	65%
2016[d.]	52%	44%

The final examination for PHYS122 is three hours and is worth 40% of a student's final grade. Students must also gain at least 40% of the possible marks in the exam in order to meet mandatory course requirements. Unlike the mid-term tests, students have access to both previous exams and model answers from previous exams with which to revise. Whilst not having access to raw data from exam marks (as these are marked and scaled internally) we can estimate that in order to maintain the PHYS122 pass rate, the average score in the exam must be between 60 and 70%. Given the average student performance, an average student would enter the exam with 43.5% of the overall grade for PHYS122, and if they achieved only 40% in the exam (as they are required to) then they should expect a grade of approximately 60% (corresponding to a C or C+ grade for the course overall.) The data presented in Table IV suggests that average students either do better than this in the final exam or have their marks scaled up to ensure a more than 80% pass rate and an average grade of a B-.

B. PHYS122 student performance data

PHYS122 has had reasonable pass rates between 80 and 90%, except in its first year. PHYS122 awards a mean grade of between a C+ and a B- for all BE(Hons) students, only slightly below the students' required B average. However, the percentage of students who achieve a B grade or better in the course has varied wildly in the past, from as low as 33% to as high as 68%. Given that the content and delivery of the course have varied little over this time, this is some reason for concern as this level of grade variation is not observed in other courses. A further issue is highlighted when we examine the subset of PHYS122 students that intend to complete an ECEN major. Table V shows the performance of these students that have passed PHYS122 in subsequent physics courses. After taking PHYS122 ECEN majors must pass both PHYS114 and either PHYS115 or ENGR142. The former of these covers the basics of motion and waves and the latter cover electricity, magnetism and optics. Due to the historically poor performance of BE(Hons) students in PHYS115, an alternative course was created in 2015 (ENGR142). One of the aims of this course was to cover the same material in a manner more suited to the needs of BE(Hons) students.

TABLE V. PHYS122 PASS RATE AND AVERAGE GRADE FOR BE(HONS) STUDENTS OVER ALL YEARS IN WHICH PHYS122 HAS BEEN OFFERED.

Year	*BE(Hons) students*	*Pass %*	*Average GPA[b]*	*% >B-*
2010	6	50%	2.5	33%
2011	53	85%	3.62	38%
2012	84	79%	4.57	60%
2013	74	82%	4.61	65%
2014	97	88%	4.57	68%
2015	126	87%	3.57	34%
2016	169	89%	4.21	47%

b. Mean GPA calculated from all BE(Hons) student grades awarded that year. Students must achieve a GPA of 5 or better (a B grade) to progress in the BE(Hons) degree.

Table V indicates that, from all the BE(Hons) students who have passed PHYS122, only 43% and 45% of them go on to pass their subsequent physics course (PHYS114 and ENGR142 respectively). It should be noted that the pass rate of 45% for PHYS122 students attempting ENGR142, whilst far from ideal, is a marked improvement of the 29% pass rate exhibited previously by PHYS115. For all BE(Hons) students taking PHYS114, the pass rate is between 67 and 89%, suggesting that PHYS122 is not adequately preparing students. The comparable pass rate for ENGR142 is between 64-65% which suggests, despite the improvement this course has seen over PHYS115, that PHYS122 students are poorly prepared to pass this course as well.

The majority of PHYS122 students do not pass their subsequent physics courses. Of the PHYS122 students that attempt subsequent physics courses, between 25 and 35% have passed with a grade below a B (Table VI). This has a significant impact on the ECEN Part 1 completion rate. Grades attained from PHYS114, PHYS115 and ENGR142 all count towards a student's B average, and with the majority of students getting below a B in these courses their only hope is to offset these low grades by doing well in their other courses. Simply put, only 37% of ECEN students that take PHYS122 ever go on to achieve Part 1 of their BE(Hons) degrees.

Finally, it is reasonable to assume that for a course such as PHYS122 which acts as a prerequisite to another course (such as PHYS114 or ENGR142), that a student's grade in subsequent courses should be correlated to their performance in the first course. Such a phenomena has been observed weakly in other BE(Hons) courses in mathematics and computer science [5]. Subsequent course performance data is presented in Table VI. When attempting to correlate PHYS122 grades with those in subsequent physics courses we find little to no correlation. A linear correlation between PHYS122 and PHYS114 has a gradient (m) of 0.14 (r-squared=0.017). Similar correlations relating PHYS122 to PHYS115 (m=0.36, r-squared=0.216) and ENGR142 (m=0.34, r-squared=0.103) are stronger, but still very weak. In all cases PHYS122 students gain substantially lower grades in their subsequent courses than they did in PHYS122. The lack of correlation, combined with poor pass rates implies that passing PHYS122 is not sufficient preparation for students to succeed in their subsequent physics courses.

TABLE VI. PERFORMANCE OF BE(HONS) STUDENTS WHO HAVE PASSED PHYS122 IN SUBSEQUENT PHYSICS COURSES.

Result	*PHYS114*	*PHYS115*	*ENGR142*
Failed	25 (57%)	20 (71%)	11 (55%)
Passed with a grade lower then a B	11 (25%)	7 (25%)	7 (35%)
Passed with a B or higher grade B	8 (18%)	1 (4%)	2 (10%)
Total	**44**	**28**	**20**

C. Comparison of PHYS122 to 'best practice'

Modern physics education literature has numerous examples of 'best practice' for teaching introductory physics courses to students from a variety of backgrounds [9][10][11][12]. One prevalent theme in many of the publications is the reliance on data-validated teaching frameworks such as 'Active Learning' (AL) which utilize tools such as 'Peer Instruction' and 'Just-In-Time' teaching. In short, such approaches seek to use lecture time to focus on the upper echelons of Bloom's (revised) Taxonomy [13], rather than the lower levels that are often simply require rote memorization of facts.

Such an approach has been demonstrated to be effective across a variety of class sizes [9] (up to several hundred students when combined with smaller group tutorials or workshops) and, perhaps most importantly, shows the most efficacy for minority groups of students (such as women or indigenous peoples) [11]. These approaches often yield greater student engagement, attendance and ultimately pass rates, however several publications note that the increased mental load on students can also result in them preferring more passive learning styles. It is also noteworthy that, when performed badly, AL approaches may also show no improvement over traditional teaching styles [14]. With these qualifications noted however, AL has also been shown to a consistent method of improving student conceptual understanding and opinion of physics as a subject for study. Typically improvements are measured using a standard questionnaire of basic physics questions; usually the Force Concept Inventory (FCI), Force and Motion Concept Evaluation, Conceptual Survey of Electricity and Magnetism (CSEM) and Brief Electricity and Magnetism Assessment [15]. Given that PHYS122 is the only physics course many engineering students will take, it is the authors' opinion that improved conceptual understanding and a change in the opinion of the field of physics should be perhaps the main goal for this course

Unfortunately we find that many of the techniques used in PHYS122 can be categorized as passive teaching techniques masquerading as active learning, specifically class-wide discussions involving a minority of students, and classroom response systems used primarily for testing memory recall. Weekly formative assessments (assignments) are ideally suited to provide students regular feedback on their learning, however the nature of the assignments themselves leads to many students simply not attempting them. Nowhere is this clearer than in the drop in assignment submission immediately following the first summative assessment – the mid-term test.

The lack of both practice questions for the test and any form of recording of lectures mean that any student that falls ill or simply fails to keep up with the lecturer during a lecture has little recourse to re-learn the missed material. The reflective nature of the assignments, while admirable in its intention to enable students to identify weaknesses in their understanding, is flawed for several reasons. The first is that the pace of the course affords students insufficient time to go back and fill in identified gaps in their understanding. The second is that the lack of critical feedback on assignments from an expert erroneously gives many students the impression that they are well prepared for summative assessment items based on their performance on formative assessment items. Nowhere are the differences between these two types of assessment discussed with the students.

Finally, the suggested course textbook used is Conceptual Physics 12th Edition by Hewitt and Pearon, 2015. Whilst this is an excellent textbook, it is not designed to help student develop engineering-style problem solving skills and is largely disconnected from the rest of the course. In particular, the textbook emphasis qualitative concept development, rather than the quantitative problem solving skills students require to perform well in their summative assessments.

D. PHYS122 Graduate Data

Perhaps the strongest piece of evidence against the effectiveness of PHYS122 is the number of PHYS122 students that subsequently graduate with a BE(Hons). Table VIII details these data. Table VII indicates a slightly reduced chance for SWEN or NWEN students to graduate if they take PHYS122 (the background BE(Hons) graduation rate for SWEN and NWEN students is approximately 19% of the first year cohort). These are statistically significant changes (at 95% confidence) even though the numbers of graduates are small. This is partially expected as the only SWEN and NWEN students who do not have to do PHYS122 are those who successfully pass the core ECEN physics course, PHYS114, and thus will be strong academic performers from high school due to the entry requirements of these courses. Importantly however, only one ECEN student who has passed PHYS122 has ever graduated with a BE(Hons) in ECEN from the 2009 to 2013 cohort. The authors note that some other ECEN students (4 in total) have graduated with alternative computer science degrees.

TABLE VII. PHYS122 STUDENT GRADUATE NUMBERS.

Major	***Enrolments (2010 – 2013)***	***Number of Graduates***	***%***
SWEN	155	20	13%
ECEN	29	1[c.]	3%
NWEN	40	5	13%
Other	21	2	10%
TOTAL	245	28	11%

[c.] This student achieved an A+ in PHYS122.

E. PHYS122 Summary and Recommendations

When all of these factors are considered, it becomes clear that PHYS122 is not producing students with the skills necessary to succeed in an ECEN BE(Hons) degree, and yet it is the entry pathway recommended by SECS for weakly prepared students. It is the authors' opinion however, that these are all fixable issues with some well-designed experiments and reliance on modern educational literature. Firstly a standardised physics concept test, such as the FCI, should be administered to the class at the beginning and end of trimester to gauge progress [15]. Secondly the content should be reduced and more time spent using AL to improve students understanding of basic physics concepts, with only a secondary goal being physics problem solving [9]. Specifically the scientific method as applied in the context of physics and engineering. This contextualization is crucial in ensuring BE(Hons) students engage with the material in a meaningful way as has been observed in other courses [3].

PHYS122 students must also be given some opportunity to interact and familiarize themselves with the format of summative assessment prior to the mid-term test. Formative assignments should be restricted so that both reflective marks and summative marks are given to allow students to better gauge their abilities. An excellent tool here would be an online self-evaluation quiz tool. The mid-term test should be re-written to specifically evaluate student's understanding of concepts and not simply the ability to recall facts. Other engineering courses have a 'core', 'completion', 'challenge' structure that guides students to higher levels of Bloom's revised taxonomy [13] throughout assessment items. The adoption of this in PHYS122 is likely to also see student engagement and understanding gains as measured by the FCI.

Finally, acknowledgement needs to be made that PHYS122 is serving two very different populations of students: SWEN/NWEN students and ECEN students. Whilst we expect the above changes would be sufficient to improve grades for the former, the latter requires formulation of additional practice items and lecture material to adequately prepare ECEN students for ENGR142 and PHYS114.

V. MATH132

MATH132 is the introductory mathematics course for BE(Hons) students that do not meet the mathematics entry requirements for the core mathematics courses. It covers topics including basic algebra, calculus, set theory and trigonometry over its 12 week duration.

A. MATH132 Curriculum

MATH132 has no entry requirements excepting university entrance and expects 10 hours of student work per week over the 12 week course. This is broken down (weekly) into 3 hours of lectures and a weekly assignment and 1 hour tutorial with all other time free for reading and review. In order to pass the course a student must meet the mandatory course requirements of: sitting both in-term tests and achieving an overall grade of 50% or better.

MATH132 course learning objectives (CLOs) are:

1. Perform symbolic manipulation of algebraic and arithmetic expressions and solve simple equations
2. Be familiar with elementary function and their properties, and have a grasp of the basic ideas in differential and integral calculus
3. Demonstrate these skills in assignments, tests and exams
4. Have some understanding of the reasons that mathematics has evolved in the way it has: in other words you should not only be able to apply mathematical rules, but you should understand why those rules exist.

Assessment is divided into 4 sections: eight assignments (worth 10% overall with each contributing 1.2% of the students final grade), two 1 hour in-term tests (worth 15% of the final grade) and a 3 hour final exam worth 60% of the final grade. Better performance in the final exam can replace test marks if it is to the student's benefit.

Weekly assignments in MATH132 are assessed entirely summatively with marks based on a student's ability to correctly answer questions similar to those worked through during the tutorials (to which full worked solutions are provided). Answers to assignments and tests are provided immediately after their completion and numerous practice tests and exams exist which are provided to the students.

Student performance in assignments is an excellent indicator of how they will perform in both mid-term tests and the final exam, in stark contract to what is observed in PHYS122. Often test and exam questions are previously asked assignment questions with relatively minor changes. Both test and exam contain a range of calculation-based questions ranging from simple mastery questions to harder questions (akin to the 'Challenge' questions set in other engineering courses).

MATH132 is clearly not akin to a modern 'best practice' course for teaching the fundamentals of mathematics [16]. However, it acknowledges that its purpose is to simply provide students the basic building blocks of mathematical manipulation and understanding and, whilst covering a variety of topics, provides ample opportunity for practice and regular expert feedback on student work. Whilst lectures do not (to the authors' knowledge) implement any AL strategies, the quality and quantity of tutorials and assignments allows students to identify and rectify gaps in their knowledge in a safe, small classroom environment.

B. MATH132 student performance data

Table VIII shows that MATH132 has a highly variable pass rate, ranging from 52% to 91% for BE(Hons) students with a mean grade of a B- or C+, similar to PHYS122. Also similarly to PHYS122, the percentage of MATH132 students that achieve a B grade or better is typically below 45% (excepting 2013). The difference however is that MATH132 is not included in the average grade calculations for Part 1, and hence students are free to simply pass the course and continue with their degrees. Importantly, with the success of ENGR121 [3], fewer students require MATH132 each year, with 2016 reporting the lowest ever percentage of 10% of the BE(Hons) cohort enrolled in MATH132.

TABLE VIII. MATH132 PASS RATE AND AVERAGE GRADE FOR BE(HONS) STUDENTS.

Year	*BE(Hons) students*	*Pass %*	*Average GPA[d]*	*% >B-*
2009	26	81%	4.00	42%
2010	23	52%	2.85	35%
2011	15	80%	3.8	40%
2012	32	59%	3.00	31%
2013	31	87%	5.03	65%
2014	32	91%	4.43	50%
2015	36	58%	3.88	31%
2016	24	63%	4.53	42%

d. Mean GPA calculated from all BE(Hons) student grades awarded that year..

Table IX suggests that despite relatively poor student performance in MATH132, a passing grade in it does indicate a student is somewhat prepared for their subsequent mathematics course. More than 59% of students that pass MATH132 also pass their subsequent mathematics course and stand a reasonable chance at achieving a grade of a B or better in it. The background failure rates for MATH161 and ENGR121 are 26% and 10% respectively. Interestingly, despite the difference in teaching style between MATH161 (a standard mathematics courses) and ENGR121 (an engineering mathematics course) [3] there appears no significant differences in success rates. This may be due to the small ENGR121 sample size.

TABLE IX. PERFORMANCE OF BE(HONS) STUDENTS WHO HAVE PASSED MATH132 IN SUBSEQUENT MATHEMATICS COURSES.

Result	*MATH161*	*ENGR121*
Failed	41 (39%)	9 (41%)
Passed with a grade lower then a B	39 (37%)	8 (36%)
Passed with a B or higher grade B	26 (25%)	5 (23%)
Total	**106**	**22**

Correlations between MATH132 grades and grades in subsequent mathematics courses are stronger than was observed for PHYS122. Linearly correlating MATH132 and MATH161 grades yields a gradient of 0.56 (r-squared = 0.365), and of 0.41 (r-squared = 0.233) between MATH132 and ENGR121. Whilst both correlations are still weak, data suggests that students that achieve good grades in MATH132 stand a reasonable chance of passing either MATH161 or ENGR121.

C. MATH132 Graduate Data

Table X displays the number of MATH132 students that have subsequently graduated with a BE(Hons) degree. Only weakly prepared students are advised into MATH132 and, as a consequence, even students who complete MATH132 have a significantly lower chance of graduating than students that do not attempt this course. This ~10% graduation rate appears relatively consistent across BE(Hons) majors, contrasting again with the markedly poorer ECEN graduation rate observed for PHYS122. The stronger correlation between MATH132 grades and grades in subsequent mathematics courses, when compared to PHYS122, suggests that MATH132 is better preparing students for their follow-on courses.

TABLE X. MATH132 STUDENTS WHO HAVE SUBSEQUENTLY GRADUATED SEPARATED BY MAJOR.

Major	*Enrolments (2010 – 2013)*	*Number of Graduates*	*%*
SWEN	74	6	8%
ECEN	21	2[e.]	10%
NWEN	20	2	10%
Other	7	1	14%
TOTAL	122	11	9%

[e.] One of these ECEN students graduated with a SWEN major.

D. MATH132 Summary and Recommendations

It is the authors' opinion that the poor graduation rates of MATH132 students are not primarily due to weaknesses in the course itself. Evidence from both student performance and grade correlation suggest that MATH132 is also not preparing the majority of students that pass it for subsequent study. However this is likely mostly a factor of the cohort attracted to MATH132 that create its high failure rate and low graduation rate in the BE(Hons). This is not to suggest that changes made to MATH132 in line with modern pedagogy could not improve these rates, but as BE(Hons) student enrolments in it decline, we perceive this as far less of a significant issue than PHYS122.

VI. Conclusion

The policy of 'relative open entry' in the Victoria University engineering program, which maintains few entry requirements, allows students to enrol who often fail because they do not have the required academic background and aptitude to succeed in the core courses. There is a discourse around entry requirements that is both subtle and pervasive in undermining meaningful enrolment practices by placing 'opportunity' as a valid reason for allowing entry to students. The fact that we do not have an adequate understanding of what students need to know to be successful in terms of academic preparation for first year Engineering is a systemic failure built into an education system that wants growth. SECS has not undertaken an adequate curriculum and teaching review of its courses to analyze where within the curriculum students are failing. SECS can be viewed as giving an equal opportunity to participate to everybody and thus benefitting those that may have been disadvantaged if excluded on a basis of entry through educational achievement standards, however this opportunity does not mean equal opportunity for success to all participants.

We find that success in subsequent required BE(Hons) core courses has not been achieved satisfactorily for this group of students. This paper has shown that the introductory courses are not adequately preparing students for subsequent courses in the same field. We show that students entering the BE(Hons) in SWEN or NWEN without NCEA mathematics have a lower average grade in subsequent mathematics courses than their peers, and are significantly less likely to graduate with BE(Hons) degree. We show that a student entering into the ECEN major without NCEA mathematics and physics, through the introductory courses (MATH132 & PHYS122), is likely to fail their B average and are extremely unlikely to graduate with an engineering degree. It is laudable to offer opportunities to students with lower levels of academic preparation often as a result of disadvantage. However, SECS takes on these students that can not be expected to succeed, partly in an effort to grow and meet financial targets. It is not unfair to say that as the university accepts these students enrolment, it should make a stronger effort to help these students succeed.

It is the authors' intention to work towards developing more appropriate introductory courses and a future paper will detail these developments.

VII. Supplementary Information

A. NCEA Qualification and GES explanation

The NCEA qualification is the national standard of educational achievement required for students at high school and has traditionally, alongside the University Entrance (UE) qualification, been the benchmark that NZ universities use for establishing entrance criteria since 2004. NCEA comprises three certificates, awarded at Levels 1, 2 and 3. Students begin studying for their NCEA Level 1 in Year 11 and continue through Years 12 and 13 (from ages 15-16 through to 17-18). Year 13 level 3 NCEA is the final year students will spend at high school in New Zealand. In NCEA, each assessment standard passed awards a student a certain number of 'credits'. In order to achieve any of the three main NCEA levels, a certain number of credits must be attained at the appropriate levels. UE is awarded to students that achieve a pass in NCEA Level 3, 14 Level 3 credits in three approved subjects, 10 literacy credits at Level 2 or above and 10 numeracy credits at Level 1 or above. To guarantee entry most NZ universities require completion of UE and attainment of an NCEA rank score titled Guaranteed Entry Score (GES). Entry with an NCEA score lower than the GES is possible but not guaranteed [5]. GES is calculated on the basis of their best 80 level 3 NCEA credits in approved subjects. The credits are weighted by their grade result: 4 points for Excellence, 3 points for Merit, and 2 points for Achieved. For guaranteed entry the University of Auckland (New Zealand's largest university) requires University Entrance Standard NCEA level 3, 14 credits in approved standards 10 credits in numeracy and 10 credits in literacy standards, and a GES rank score of 260. In addition they require specific Level 3 NCEA Calculus and Physics achievement standards for engineering students [6].

B. New Zealand and American Grades.

Grades awarded for courses at Victoria University range from K, E and D grades (failing grades) to A+ grades. The minimum passing grade is a C-, that corresponds to a score of approximately 50-54% over the entire course assessment. [17].

REFERENCES

[1] D.A. Carnegie and C.A. Watterson , "Increasing student retetntion and success: Survey Results and the success of initiatives to create an engineering student community," Proceedings of the 2nd IEEE Global Engineering Education Conference, Amman, Jordan, pp. 191 – 200, April 2011.

[2] C.A. Watterson, W.N. Browne, and D.A. Carnegie, "Steps to increase student engagement and retention in first year engineering," Proceedings of the 2nd IEEE International Conference on Teaching, Assessment and Learning, Bali, Indonesia, pp. 1 – 6, August 2013.

[3] C.P. Moore, C.A. Watterson, and J.A. Eldridge, "Practical laboratory classes to improve engagement and achievement amongst engineering students taking first-year mathematics," Frontiers in Education Conference, pp 1 – 7, October, 2016.

[4] D.A. Carnegie and C.A. Watterson , "Issues of recruitment and retention for a new engineering provider," Proceedings of the 43rd Frontiers in Education Conference, Oklahoma City, Oklahoma, pp. 665 – 671, October 2013.

[5] D.A. Carnegie, C.A. Watterson, P. Andreae, and W.N. Browne, "Prediction of success in engineering study," Proceedings of the 3rd IEEE Global Engineering Education Conference, Marrakesh, Morocco, pp. 57 – 65, April 2012.

[6] K. Spooner and T. Clear "A Foundation Programme Preparing Students for Future Study in Computing and Engineering Degrees" Paper presented at 2016 International Conference on Learning and Teching in Computing and Engineering, Mumbai, India. 2016.

[7] Univeristy of Auckland, "National Certification of Educational Achievement (NCEA) - The University of Auckland", 2016. Retrieved from https://tinyurl.com/ycwo2nq8 20 Feb 2017.

[8] D.A. Carnegie, J.A. Eldridge and C.A. Watterson, "Beyond Academic quality: Lessons from the creation of a new Engineering Degree," Proceedings of the Frontiers in Education Conference, October, 2017 unpublished.

[9] S. Bates, and R. Galloway "The inverted classroom in a large enrolment introductory physics course: a case study" Paper presented at HEA STEM Conference, London, United Kingdom. 2012.

[10] J. Guisasola, J.M. Almudi, M. Ceberio, and J.L Zubimendi "A teaching strategy for enhancement of physics learning in the first year of industrial enginering" Eur. J. Eng. Ed., vol. 22, no. 4, pp. 379-391, 2002.

[11] S. Freeman *et al.* "Active learning increases student performance in science, engineering, and mathematics" PNAS, vol. 111, no. 23, pp. 8410 - 8415, June 2014.

[12] M.A. McDaniel *et al.* "Dissociative conceptual and quantitative problem solving outcomes across interactive engagement and traditional format introductory physics" Phys. Rev. Phys. Edu. Res., vol. 12, 020141, 2016.

[13] B. S. Bloom, Taxonomy of Educational Objectives, Handbook I: The Cognitive Domain. David McKay Co Inc, 1956.

[14] T.M. Andrews, M.J. Leonard, C.A. Colgrove, and S.T. Kalinowski "Active Learning NOT Associated with Student Learning in a Random Sample of College Biology Courses" CBE Life Sciences Education, vol. 10, pp. 394-405, 2011.

[15] J.M. Fraser, A.L. Timan, K. Miller, J.E. Dowd, L. Tucker, and E. Mazur "Teaching and physics education research: briding the gap" Rep. Prog. Phys., vol. 77, 032401, 2014

[16] R. Talbert "The inverted classroom in introductory calculus: Best practices and potential benefits for the preparation of engineers" Paper presented at ASEE Annual Conference, Indianapolis, USA. 2014

[17] "Victoria University Assessment Handbook", VUW, Wellington, New Zealand 2014