A Foundation Programme Preparing Students for Future Study in Computing and Engineering Degrees

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***Abstract*— This paper presents the Certificate of Science and Technology (CertScT) a pre-degree programme at Auckland University of Technology in New Zealand, developed with the aim of preparing students to undertake degree level study in Science, Technology, Engineering and Mathematics (STEM) subjects. The history, context and rationale for the programme is outlined together with its structure and content, and pedagogical and programme level strategies that have been adopted to encourage student success. The authors reflect on the success of the programme to date in achieving its aims, based upon observation, reflections and data from internal evaluations of the programme. The paper notes the challenges for the programme posed by external metrics which the New Zealand Government has adopted. The paper concludes with a commentary on the success of the programme in achieving its goals, and the risks to its continuation.**

Keywords—* *Computing Education; Engineering Education; STEM Education; Certificate; Degree; Access; Equity

I. Introduction

This paper presents the Certificate of Science and Technology (CertScT) a pre-degree programme at Auckland University of Technology (AUT) in New Zealand, developed with the aim of preparing students to undertake degree level study in Science, Technology, Engineering and Mathematics (STEM) subjects. The history, context and rationale for the programme is outlined together with its structure and content, and pedagogical and programme level strategies that have been adopted to encourage student success. The authors reflect on the success of the programme to date in achieving its aims, based upon observation, reflections and data from internal evaluations of the programme. The paper notes the challenges for the programme posed by external metrics (educational performance indicators or EPIs), which the New Zealand Government has adopted, and operate perversely counter to the espoused policy of growing numbers of student in STEM disciplines, and building the numbers of underrepresented groups in these programmes. The paper concludes with a commentary on the success of the programme in achieving its goals, and the risks to its continuation.

II. History, Context and Rationale for the Programme

Auckland University of Technology is a new University in New Zealand, yet a well-established educational institution with a history beginning in 1890, and a traditional focus on vocational and professional preparation. Historically programmes were designed with a "staircasing philosophy", where students could progressively achieve success in their education by taking one year certificate and two year diploma programmes and then progressing to three year degree programmes with appropriate recognition of credit gained in these earlier study programmes. The profile of the Institution has now shifted markedly, with some 91.5% of students undertaking higher level study (degree and postgraduate) and the PhD cohort now numbering some 700 students across the University [1]. Thus pre-degree programmes and students studying at the pre-degree level, have been progressively reducing in number. The University has been questioning their role and to what extent pre-degree study is at a level appropriate to a University.

However in the STEM disciplines, the Faculty of Design and Creative Technologies has remained committed to supporting equity of access, to students whose high school grades would bar them from University study in STEM subjects. Typical areas of weakness are mathematics and English literacy. Sometimes this absence of the required subjects is occasioned by poor choices at the high school level, where considerable flexibility in subject choice is available. For Maori (the indigenous people of New Zealand), and Pacific students, early dropping of mathematics as a high school subject is a common phenomenon [2]. For students deemed "non-academic", often the curriculum could involve them being directed into vocational subjects such as hospitality and tourism, or information technology which has only recently adopted a more academically credible computer science thread to its curriculum [3, 4].

Therefore a Certificate in Computing and Mathematical Sciences was submitted for approval by the New Zealand Universities Degree Programme accreditation body, in 2008. Its main goal was to pathway "second chance learners" into Computing and Mathematics undergraduate degrees. In 2010 the qualification was renamed the Certificate of Science and Technology (CertScT) to explicitly include engineering and to provide pathways into the full range of STEM subjects. A secondary but no less important goal was to increase the participation and progression of Maori (the indigenous people of New Zealand), Pacific peoples, and female students who are currently underrepresented in these subjects [5].

III. PROGRAMME STRUCTURE AND CONTENT

The CertScT is a one year study programme comprising eight courses, where each course constitutes a quarter of a student study load per semester. There is one core course (or ‘paper’ in NZ terminology), Academic Literacies. The seven remaining papers are selected from mathematics, physics, programming and English by the programme leader. Papers are nominated based on the student’s pathway (Engineering, Computing or Mathematics) and previous academic record.

Applicants are asked to attend an interview and pre-entry diagnostic testing to establish entry requirements and determine the best course of study.

Students who pass all four papers with a B+ average in the first semester and have completed the equivalent of a final year’s secondary schooling, may be eligible to exit the CertScT prematurely and progress onto their chosen degree (thus ‘staircasing’ to the next level). Students who staircase into a degree before the full 8 papers are completed, do not receive the CertScT qualification and do not count in the completion rates for the programme. Yet this is still a successful study outcome.

IV. PEDAGOGICAL AND PROGRAMME LEVEL STRATEGIES THAT HAVE BEEN ADOPTED TO ENCOURAGE STUDENT SUCCESS

In 2013 additional initiatives were put in place to ensure the success of the programme. These have mainly been in the areas of pedagogical expectations and student support services. In 2013 experienced teachers focussed both on teaching and the scholarship of teaching and learning in their STEM discipline (of which this paper is an example) were employed, consistent with some of the arguments put forward in [6, 7].

A. Pedagogical expectations of these teachers are:

Provide an Active Learning environment in class, which promotes student engagement. Use strategies for knowing students academically; identify at risk students and refer them to support services. Encourage peer connections within class.

Encourage and develop successful study behaviours. Teach in innovative ways for successful student achievement and engagement. Develop and improve course materials to be better attuned to students’ entry level into the programme.

B. Pedagogical expectations of students are

Regularly attend classes. Develop positive peer relationships. Attend a weekly skills workshop. Become reflective learners. Develop study habits.

C. Support strategies utilised within the CertScT.

Pre-entry diagnostic testing. Orientation (including survey attendances). Verification of Attendance (VoA). Student Experience Team (SET). Student advisors. Academic student advisors. Disability Student Support Service (DSS). Skills workshops. Student Learning Centre (SLC). One-on-one mentoring. Learning Contracts. English for Academic Skills Independence (EASI support). Several of these support strategies were put in place for the whole cohort [8] to avoid stigmatising students deemed to be at risk, and to better support students from collectivist cultures for whom group modes of study are more compatible with their world view.

D. Other strategies put in place

Dedicated teaching teams. Professional development to increase the range of teaching strategies. Review of course materials and assessments to improve student engagement and expand variety of support resources. Imbedded student goal setting in courses. Formal re-sit policy. Use of the Student Experience Team to encourage compulsory attendance, (SET staff follow up students who are not attending with personal phone calls and other forms of contact). Smaller class sizes. Extra English support for students with weaknesses in English.

E. Things Noted and Fine Tuned about the Programme

Students who enrol in the CertScT do not meet the entry requirements for degrees in Computer Science, Engineering, or Mathematics. Students either lack knowledge or may not have taken the correct subjects at school. A typical area of weakness is mathematics, in particular fundamental algebra skills. This means that most of the students who come into the CertScT do not have a strong mathematical background, even if they may have been taught Algebra before, in a way that did not connect.

This weakness is reflected in a proportion of students finding the Foundation Algebra and the Foundation Physics A papers challenging. Foundation Algebra focuses primarily on algebra skills necessary for Engineering and Computing including: advanced algebraic manipulation, use of formulae, recognition and understanding of a variety of different functions and their transformations. The Foundation Physics A paper relies heavily on fundamental algebra skills. To address this issue several things were put in place for the programme.

1) In 2013, a dedicated teaching team committed to teaching students in alternative ways than those traditionally used in secondary schools was established.

2) In 2013 the Foundation Algebra manual was rewritten to make the course content more accessible to the students. The manual was very favourably received by students.

3) In 2014 Foundation Mathematics, a prerequisite course to Foundation Algebra and Foundation Physics for students weak in mathematics was introduced. The Foundation Mathematics course aims to build fundamental number and algebra skills, in particular those necessary for success in Foundation Algebra. These skills include basic number work including fractions and indices, algebraic manipulation of expressions and solving algebraic equations. Students who previously would have been placed in and failed Foundation Algebra and/or did not have the mathematics background to cope with Foundation Physics would now be enrolled in Foundation Mathematics before taking either of these papers.

4) In 2014 pre entry diagnostic testing was modified to enable identification of the most appropriate course of study for a student to be enrolled. Pre entry test results are used to place students in the mathematics pathway best suited to their needs (either Foundation Algebra first semester or Foundation

Mathematics first semester followed by Foundation Algebra second semester).

For Foundation Algebra, pass rates before 2013 fluctuated between 44% and 68%. With the introduction of the dedicated teaching teams the pass rate lifted to above 68% in 2013 but there was still a portion of students who were not succeeding in Foundation Algebra. In 2014 Foundation Mathematics was introduced to the programme. From the first Foundation Mathematics cohort to take Foundation Algebra all but three students passed Foundation Algebra. In the past these students would have failed Foundation Algebra and have been potentially lost to the programme. With all the above changes 1) to 4) the pass rates for Foundation Algebra in 2014 and 2015 sat consistently above 74%.

The introduction of Foundation Mathematics has also had a positive effect on Foundation Physics papers, as the problem solving work in Physics A is heavily dependent on fundamental algebra skills. In 2015 Foundation Mathematics was made a prerequisite for Physics A for mathematically weak students.

We can confidently conclude that the student success experienced by the introduction of dedicated teaching teams, new resources and the Foundation Mathematics paper has increased the completion rates of the Foundation Algebra and Foundation Physics papers, increased the completion rates overall for the CertScT and helped students who previously would have been potentially lost to the programme stay engaged in the programme.

All of the above strategies (A to E) have increased the successful completion rates and staircasing rates for the Certificate. With good teaching, good course material and support services in place the CertScT is currently in good shape.

V. - Analytical Work Done and Implications for CertScT

In the course of our progressive modifications and improvements to the programme to support student success, we have sought to evaluate the success of the programme to date in achieving its aims. This process has been based upon ongoing observation, feedback from students, reflections and data from internal evaluations of the programme.

One element in the programme of evaluation is demonstrated through the results of an internal research report from Auckland University of Technology (AUT) [10]. The objective of the report was to research the usefulness of AUT's CertScT as an entry qualification for the University's Computing, Engineering and Mathematics degrees.

The main research question was:

'Is a student's performance in the Certificate of Science and Technology an indicator of their future success in a Computing, Engineering or Mathematics degree?'

Student data on grades from the CertScT and subsequent degrees were analysed. Evidence of correlation between student achievement on the certificate and student achievement on a degree, certificate students' performance over time, certificate versus non certificate students' performance on degrees and native English speaking certificate versus non-native English speaking certificate students' performance on degrees was investigated.

To answer the main research question, the following research sub-questions were addressed:

RQ1. Is there a correlation between students' average grade in the certificate and their average grade in the degree?

RQ2. How do certificate students perform over time in their subsequent degrees?

RQ3. How do certificate students perform in subsequent degrees compared to non-certificate students?

RQ4. Are there any certificate papers that are predictive for subsequent success?

RQ5. Is there a difference between people from a native English background and people who are not native speakers of English?

A. The results from the internal report showed that

RQ1. There is a positive relationship between a student's average grade on the certificate and their average grade on their chosen degree. Linear regression analysis generated a correlation coefficient of 0.4903 with upwards scatter of the data indicating a moderate positive relationship between the two variables. Paper pass rates of students showed a strong relationship between success on the certificate and success on the degree. 86.7% of students taking the certificate (342 out of 395) passed their certificate papers and also passed their papers on the degree. Out of the students who passed their certificate papers 89.1% (342 out of 384) also passed their degree papers. From the average grades of students who passed in both programmes it can be concluded that certificate students who achieved an average grade of B- or better in the certificate are also very likely to pass in their degree. Thus success in the certificate can be seen as an indicator of success in the degree.

RQ2. In general it could be seen that students with an A or B average in the certificate also pass their degree papers. Results for students who had a C average in the certificate were more unstable on the degree with some students passing and some failing.

Length of enrolment for certificate students enrolled in degrees was also looked at as a performance indicator. The highest number of enrolments was for three years, meaning the majority of student completed their degrees. 71.1% of the computer and Engineering students stayed enrolled long enough to finish their degrees.

RQ3. 88.3% of certificate students passed their papers in their degree compared to 87.5% of non-certificate students passing their papers in the degree. The Fisher Exact test (p=75%) showed no significant difference between certificate and non-certificate students' performance on a degree. This is an indicator of success of the certificate. When comparing the average grades achieved on the degrees certificate students achieved marginally below non certificate students in subsequent degrees. The average certificate degree student grade was 1.98 (C grade is equivalent to 2) compared to the average non-certificate student degree grade of 2.20 (C+ grade is equivalent to 2.3). When looking at average grades split by year and degree the results showed that there has been a general increase in preparation from the certificate for later performance on the degree over time. There are 3 cases when certificate students outperformed the non-certificate students on the degree. In Engineering in 2011, Mathematics in 2013 and Computing in 2014. The results suggest that before 2011 the certificate was geared towards Engineering students. From 2011 onwards there has been a move for the certificate to better service all three post certificate degrees- Mathematics, Computing and Engineering.

RQ4. The most predictive certificate paper for success on a subsequent degree was Academic Literacies for Computing and Mathematical Science. This makes sense as Academic Literacies is the one compulsory paper for the Certificate. The five most predictive papers ordered by highest predictability were: Academic Literacies, Foundation Programming, Foundation Logic Skills, Foundation Physics B and Foundation Physics A. Surprisingly the Foundation Algebra paper did not make the top five, coming in as the sixth most predictive paper. It needs to be noted that analysis performed to determine predictability only had a 70% correct classification rate.

RQ5. Across the certificate and certificate students on degrees there are no major differences between students who are native speakers of English and students who are not native speakers of English. This means the certificate is preparing non-native English speakers for success on the degree, and no further action is needed to support non-native English speakers.

B. *Summary of Results*

What does this mean for the CertScT? The results of the internal report confirm the CertScT is preparing students for subsequent degrees. We can confidently say that the programme content, support strategies and pedagogical expectations of staff and students in place are successful in preparing students for future degree study in STEM subjects. Second chance students from various backgrounds now have an opportunity to gain qualifications in STEM who would not otherwise have had the opportunity to do so. The internal report is good vindication of the hard work that people have put into the programme.

VI. -ONGOING DEVELOPMENTS OF PROGRAMME

The CertScT programme is continually reviewed through annual programme leader reports, paper leader reports and ongoing analysis and observation of the programme. Current future developments are

- Review CertScT papers for addition of relevant engineering content. .
- Increase focus on developing behaviours necessary for successful completion of a degree within certificate papers.
- Hold regular meetings and events with certificate students who have progressed onto the same degrees in order to create a supportive environment for these students.
- Balance female to male staff teaching on the CertScT to increase female role models in the STEM subjects.

VII. -FUTURE RESEARCH

To further enhance the CertScT the following would be beneficial future research projects:

- Investigate Maori and Pacific people's performance on the CertScT and subsequent degrees compared to Non Maori and Pacific people, to evaluate the equity benefits of the programme.
- Continue to investigate and campaign for effective funding and appropriate government policy settings for the programme.
- Track Foundation Mathematics students onto degree study and compare their performance with Non Foundation Mathematics students.

VIII. CHALLENGES FOR THE PROGRAMME POSED BY EXTERNAL METRICS

The New Zealand Government signalled through the Tertiary Education Strategy 2010-2015 that it would link funding to educational performance through the use of Educational Performance Indicators (EPIs) [11]. The EPIs [12] reveal that for the University sector the overall course completion rate at Level 3-4 was 75%. AUT's course completion rate at Level 3-4 was 73%. The EPI course completion rate for the CertScT is based on the number of students completing eight papers. Typically entry students may be lacking in either numeracy or literacy subjects and once they have achieved a suitable standard, are ready to progress. Yet those who successfully staircase onto their chosen degree after completing four CertScT papers are not included in the completion rate even though their successful progression is a positive outcome for the programme. Programme data indicates that the CertScT course completion rate for 2011 was 60%. In 2014 this completion rate was even lower. This was of concern given that the TEC expectation is a course completion rate of 85%. TEC has signalled an intention to defund courses with low pass and completion rates. At the same time TEC's EPIs do not reflect the true success of the programme, staircasing students and course completion students. To defund the CertScT would penalise second chance learners, reduce the number of students eligible for computing, engineering or mathematics degrees and work against the government objective to increase student participation in STEM subjects. To defund would also penalise institutions who take on second-chance learners (normally seen as high-risk students).

Discussions to date with TEC have made little headway on their insistence on a whole of programme metric, with potential flow-on effects for continued funding of the programme. It seems ironic that the simplistic EPIs, which the New Zealand Government has adopted to measure educational performance, should operate perversely counter to the policy of growing numbers in STEM disciplines, and building the numbers of underrepresented groups in these programmes. The discussion in [9] about issues with inappropriate targets for introductory programming, demonstrates similar outcomes, which again run counter to Government policy of building student numbers to meet the graduate shortfall in computing disciplines.

The certificate is also potentially at risk by University level decisions about what level of pre-degree study is appropriate in the University's programme portfolio? The current student proportions by level of study are 8.5% pre degree and 91.5% in higher study. Out of the 91.5% in higher study 72.6% are undergraduate, 15.4% are postgraduate and 3.5% are PhD.

With reducing funding for pre-degree programmes and pressure on performance, it would be an easier option for the University to focus on degree level and higher study and cease to offer the certificate programmes. Should there be increased pressure to accommodate students at the postgraduate level, within a constrained funding context, it is easy to see the pre-degree programmes being sacrificed. The current University policy is to retain a commitment to equity of access and maintain a level of pre-degree programmes. For the STEM disciplines in particular this is a critical decision.

IX. CONCLUSION:

The CertScT is a programme that supports equitable access to opportunities for student learning in the STEM disciplines. The programme is successful in its aims for effectively preparing students for success on undergraduate engineering, computing or mathematics degrees. There is some financial benefit for the institution in running the CertScT, when considering pipeline growth of future undergraduate numbers, but a mismatch between TEC's funding policy and true completion rates for the CertScT. This mismatch puts the CertScT in a vulnerable position.

The results of the internal research report [9] showed there is a positive relationship between achievement on the certificate and on the degree. The majority of the students who passed in the certificate also passed in the degree. In general, it can be said that a student who graduates from the certificate with an average of B- or better will also pass their papers in a subsequent degree. Certificate students have a slightly higher pass rate on their degree than non-certificate students, and the general trend of their degree grades is upwards. There was no significant difference found when comparing the results of native and non-native speakers of English.

The overall number of students progressing from the certificate to a degree rose steadily over time. These are students pipelining into degrees who would not otherwise be there. This is in line with the New Zealand Government's objectives to increase the number of students in STEM. There is a policy mismatch in funding for the certificate and students that actually pipeline onto degrees, with successful students pipelining from the midpoint of the programme skewing the 'official' completion rates.

Thus new performance indicators that reflect the true number of students progressing onto Engineering, Computer and Science degrees need to be put in place to adequately fund the CertScT. Continued support at University level is needed to acknowledge the value for STEM pipelined students and to continue to resource the programme adequately, even if through self-interest in recognising the future income generated from the CertScT. Finally it can confidently be concluded that the certificate is preparing the students well for future degree study for those that commit to it. It is furthering the University's equity goals by is providing a means of access to higher level study, and meeting the New Zealand Government's objectives to increase the number and diversity of students studying STEM subjects.

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