Bulletin of Applied Computing and Information Technology

Fluency in Information Technology FITNZ: An ICT Curriculum Meta-Framework for New Zealand High Schools

:: 03:03
December 2005

Tony Clear and Graham Bidois
Auckland University of Technology, New Zealand
Tony.Clear@aut.ac.nz

Clear, T. & Bidois, G. (2005, December), Fluency in Information Technology FITNZ: An ICT Curriculum Meta-Framework for New Zealand High Schools . *Bulletin of Applied Computing and Information Technology* Vol. 3, Issue 3. ISSN 1176-4120. Retrieved February 15, 2006 from http://naccq.ac.nz/bacit/0303/2005Clear_FITNZ.htm

ABSTRACT

This paper proposes an Information and Communications Technology (ICT) Curriculum Meta-Framework to operate at the senior secondary school level in New Zealand. This meta-framework arises from the Fluency in Information Technology ("FITNZ") Project, a collaborative venture between tertiary and secondary sector educators, government and industry. The initiative is intended to address the poor alignment between tertiary education and the Information Technology needs of the industry sector. The confused perceptions of ICT and the fragmented and uneven state of computing education at the secondary level have contributed to the disparity between tertiary education and industry needs. The paper draws on previous work on IT fluency. It also positions the computing disciplines within the Association of Computing Machinery (ACM) computing curricula 2005 document in order to propose a soundly based set of graduate outcomes.

Keywords

IT Fluency, IT Education, ICT education, Computing Curriculum, High School Computing curricula.

1. INTRODUCTION

1.1 The "FITNZ" Project

This paper proposes an Information and Communications Technology (ICT) Curriculum Meta-framework to operate at the senior secondary school level in

New Zealand. This meta-framework arises from the "Fluency in IT for New Zealand (FITNZ) Project" initiated in August 2004 with seed funding from Auckland University of Technology. The project was a collaborative venture between tertiary and secondary sector educators, government and industry. The term "meta-framework" indicates that the proposed IT Fluency model is conceived as an overarching structure intended to coexist with existing ICT curriculum frameworks in the secondary sector.

The first discussion paper from the FITNZ working group (Clear et al., 2004) was the catalyst for further developments addressing the teaching of Information Technology at high school level, based on a blueprint developed from the work on "IT Fluency" of Larry Snyder (1999). For some time increasing concern had been expressed by a number of key NZ computing industry multinationals about the falling applications for computing courses compared with the growing industry demand for graduates. As at March 2005 most of these organisations had committed themselves to the FITNZ project, then sponsored by the E-Regions Trust (Pullar-Strecker, 2005), in an attempt to develop a solution. The aim was to raise $500,000 in support of the project, with the Government committing itself to contributing an equal amount. The FITNZ initiative was endorsed by the NACCQ executive at a meeting in March 2005. Shortly thereafter in May "FITNZ was named in the Government's digital strategy as their initiative to address skills shortages in the ICT industry" (Speight et al., 2005). HiGrowth NZ, as the sponsor for the project, then made seed funding available for phase 1 of the project, which was to formulate a business plan. Subsequent meetings saw the FITNZ working group meet at CISCO premises in Auckland on 24th August 2005. This group comprised representatives from industry; central and local government, secondary and tertiary sectors, and agreed a broad direction for the programme of work. A follow up university sector consultation forum was held at the Auckland office of Microsoft New Zealand on 12th October 2005, at which the heads of schools from the University computing departments around the country gave a qualified endorsement to the project. This now completed business plan (Speight et al., 2005) lays down a programme of work for the project, based upon this broad cross sectoral consensus. It is planned to pilot and fully implement the project over the next two years. It is hoped that this will forge a better alignment between the needs and expectations of industry employers and the tertiary sector. The strategy for achieving this will be through building breadth and depth of expertise in ICT at senior secondary level. This should lead to a better understanding of the variety and scope of the ICT disciplines, the wide range of interesting and challenging employment options available, and the pathways to higher study.

Despite this developing consensus, much work remains to be done, and precise details of the final implementation have yet to be confirmed. The project this paper is based on should be regarded as a "work-in-progress". The opinions expressed in this paper are those of the authors and are not necessarily those of the FITNZ working group.

2. A TYPOLOGY OF THE COMPUTING DISCIPLINES

In their recent CC2005 report on the computing curricula, Shackleford et al. (2005) portray the US experience in the development of the academic computing disciplines. From earlier perspectives of electrical engineering and computer science as cognate disciplines and information systems as quite divergent, a distinct grouping of six disciplines is now emerging. Figure 1 (Shackleford et al., 2005) depicts this grouping. Of these, electrical engineering could be excluded as not a true computing discipline, but the remaining five (computer engineering, computer science, software engineering, information technology, information systems) could be considered as computing related disciplines, each with a distinct but somewhat related focus. For further reference Appendix A below, excerpted from (Shackleford et al, 2005), provides a brief description of each of these five distinct disciplines.

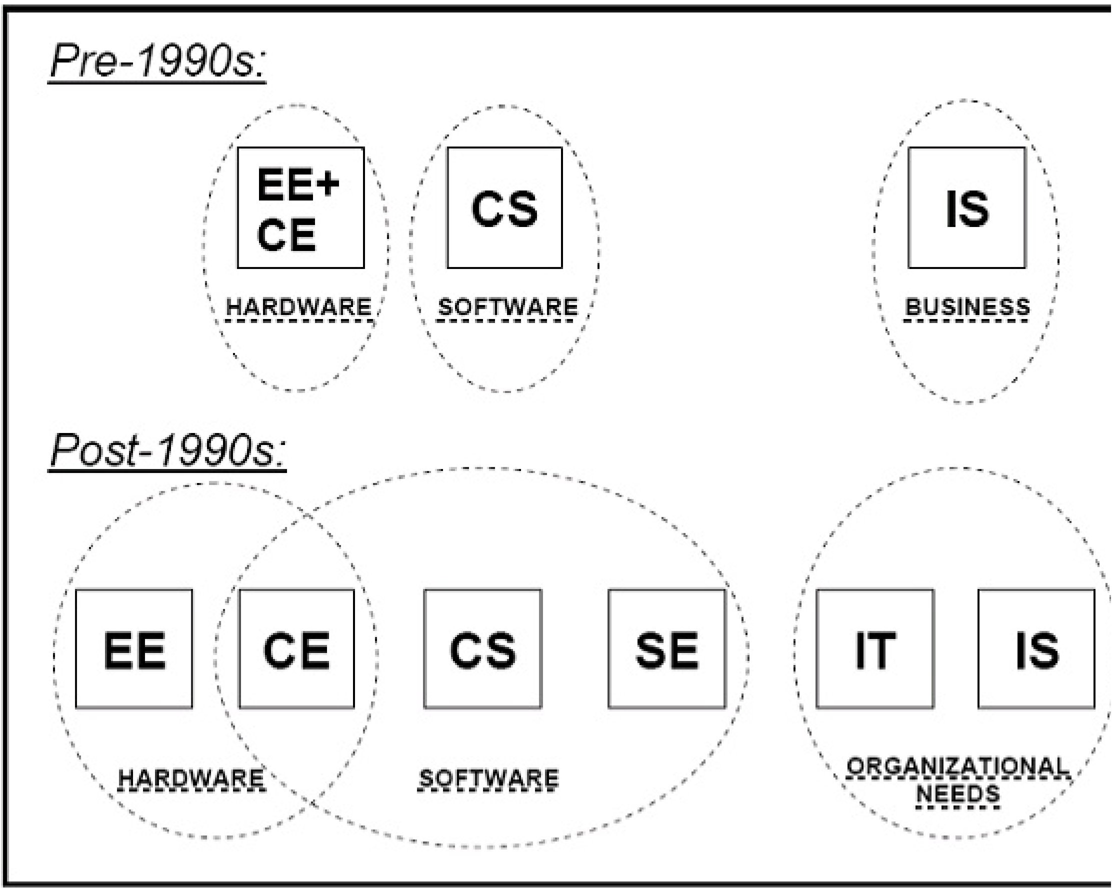

Figure 1. Harder choices: How the disciplines might appear to prospective students [from the CC2005 Report, page 12]

As the title of Figure 1 suggests, the complexity and rapid development of computing and accompanying professional practices makes it a difficult set of disciplines to understand and explain to students, parents, teachers and others not directly involved in the field. In fact, debate has even raged within the academic community for years (Denning, 2005) as to whether Computer Science is actually science. Broader terms such as “Information Technology” and “Information and Communications Technology” have arisen to better reflect the breadth of these disciplines as they are understood by the IT industry and educators. Generally though, there seems to be widespread confusion about the nature and scope of the computing disciplines.

This paper uses the terms “ICT”, “IT” and “computing” as umbrella terms, loosely and somewhat interchangeably. Yet, regardless of the chosen name, it is clear that there is significant demand for individuals with computing knowledge and qualifications. There are compelling reasons to develop a curriculum meta-framework which properly reflects and does justice to this breadth of requirements.

In general, many current efforts at senior secondary school level either capture one small segment of the discipline family and claim it as computing or ICT, or provide a “mishmash” of unrelated elements and believe that coverage has been achieved.

It is worth noting that the current teaching of end-user applications in schools, (word processing and spreadsheets etc.) or what might be considered knowledge worker productivity tools, are considered academically at most as a very minor “End-User Computing” subset of the Information Systems discipline and probably more aptly as a set of tools required and used by all disciplines, not just the computing disciplines.

3. CATEGORISING THE ROLE OF ICT IN THE STUDENT CURRICULUM

The UNESCO (2000) curriculum for schools report categorises the role of ICT in the student curriculum into four distinct groupings. Examples of their application are given in a comprehensive set of appendices to the report. These four classifications are:

- “ICT literacy” a concept less encompassing than the “IT Fluency” advocated in this report. ICT literacy focuses upon curriculum developed from the European Computer Drivers Licence and “covers the use of ICT in daily life in a competent and intelligent way”, such as applying ICT tools and applications to a range of personal tasks.
- “Application of ICT in Subject Areas” covering the application of specific ICT tools which “work within specific subject areas including languages, natural sciences, mathematics, social sciences and art”. This approach applies both more generic tools and ICT skills addressed within the ICT literacy classification, and “specific application software that can only be used in a specific subject area (for example mathematical software that only is of use within the area of mathematics)”.
- “Integration of ICT across the curriculum” in this thematic, project based model “examples of projects are described to demonstrate the use of ICT in a combination of subject areas where work is done on real-world projects and real problems are solved”.
- “ICT Specialisation” “designed for students who plan to go into professions that use ICT such as engineering, business and computer science or who plan to advance to higher education”.

The IT Fluency meta-framework proposed below is intended to support all four of the above UNESCO categorisations, with scope for augmentation to address the chosen aspects of the ICT specialisation selected at individual school level. The way in which schools might implement the IT Fluency model is deliberately left open, given that existing initiatives probably involve a combination of all four of the UNESCO curriculum approaches, and will already address elements of the IT Fluency model to some extent. For instance it is likely that “ICT literacy” is already reasonably well covered.

In this way the programme of work proposed here is consistent with the views of Falloon (2004, p. 49), "It is apparent that for any learning advantage to be gained from computer use, there needs to be developed a unique balance between curriculum design, teaching strategies and pedagogy, and purposeful computer application."

4. PRINCIPLES FOR A CURRICULUM META-FRAMEWORK AT SENIOR SECONDARY LEVEL

4.1 High School Curriculum Developments

The current senior high school curriculum has been the subject of much recent turmoil and change. Teachers have been adapting for the last decade or more, since the introduction in 1993 of the National Curriculum Framework (MoE, 2005). This curriculum "has been developed as an outcomes based model in seven essential learning areas. Each essential learning area is organised according to eight curriculum levels in a national curriculum statement" (Chamberlain, 2001). The learning areas comprise: Language and Languages; Mathematics; Science; Technology; Social Sciences; The Arts; Health and Physical Well-being. Of these areas Technology is the only curriculum area to specifically address ICT, but includes it as one of several candidate technologies for study, in what is quite a broad, integrated and flexibly designed curriculum model, based upon a socio-cultural learning perspective (cf. Compton & Harwood, 2003). This significant curriculum change has of necessity imposed additional workloads on educators. The Educational Review Office has reported that "the workload associated with planning learning programmes, combined with that required to develop meaningful assessment activities, is unnecessarily onerous for some teachers. The curriculum statements do not provide sufficient detail to assist with either of these tasks" (ERO, 2001). The inevitable outcome of such a design is far greater variability in standards between schools, with good teachers flourishing and weaker ones struggling. ICT in particular has suffered from this wide range of outcomes.

At senior high school level these pressures have been accompanied by the controversial move away from the normatively assessed (cf. Tan & Prosser, 2004) University Entrance, bursary and scholarship examinations. This former highly academic curriculum regime was generally considered too narrow and restrictive for the diverse needs of the many senior high school students now continuing their studies, and for whom a far wider range of choices was desired. Although the senior curriculum remains generally crowded, there is now an opportunity created for additional flexibility in courses at the post compulsory year 11, 12, and 13 levels. The introduction of the standards based (cf. Barker, 1995) National Certificate in Educational Achievement (NCEA), includes the Technology subject as an academic option. This includes scope for the study of ICT as one subtopic at senior level within a recognised curriculum subject. The advent of NCEA has also brought an option for the registering of qualifications eligible for NCEA equivalent status. In the ICT area the International Computer Drivers Licence, Microsoft and Cisco qualifications are examples of external courses of study granted NCEA credit equivalence status. Co-existing with this model are options for study towards qualifications from the National Qualifications Framework (NQF), applying competency based assessments (cf. Hager & Gonczi, 1994) through unit standards. Local developments at individual schools are also occurring, many of which are not part of the core curriculum and therefore not eligible for NCEA credit.

4.2 Political Context

These developments related to assessment approaches cannot be separated from the political context. A relevant quote in the context of the American elementary school system comes from Meyers and Rowan (cited in Perrow, 1986 p. 266):

"[The] real function of education is to sort and certify people; imparting skills and knowledge is not really that important. But since our cultural values insist that skills and knowledge are important, these must be affirmed, regardless of the reality. So the classroom activities are sequestered from the view of principals, districts and governments at all levels, and the appearance of educational outcome is measured by meaningless statistics on the number of students processed, the qualifications of teachers, the curriculum, and the number of programs for the disadvantaged. Nothing really measures what students have learned. The public is reassured, the social class system is stabilised, the teaching profession is protected, the cost is low, and a minimally sufficient degree of socialisation and knowledge is produced. Meyers and Rowan call the reassurance a 'rationalising myth' and see the function of schools as largely symbolic".

From such a perspective the recent developments in some New Zealand high schools with a special focus on "sorting and certifying" may be understood. The implementation of NCEA, in spite of a broad consensus about the direction, has been a fraught and contentious process. Conceptually at least, it has been consistent with the views expressed by Tan & Prosser (2004) "Increasingly, standards based assessment or the provision of clear and unambiguous descriptions of required standards of performance by teachers to students is being emphasised as good assessment practice". Yet severe criticisms over the pace of implementation and the inadequate resourcing of the changes have been made by many educators. In response, a small grouping of schools (arguably with pretensions of academic grandeur, predilections towards the colonial English public school system and harkening back to the good old days of normative assessment), are now adopting the Cambridge International Examinations (CIE, 2005).

This international not for profit organisation associated with Cambridge University in the UK offers examinations for 14 - 19 year olds in a wide range of subjects, and in many countries across the globe. Historically the exams have been offered for countries (typically ex British colonies) lacking a national examination system of integrity and credibility. While aspects of NCEA implementation may be justifiably criticised, it is ironic that at the same time that New Zealand adopts its own locally developed NCEA system, some high schools see a need to run back to the apron strings of the "mother country".

However there may be a silver lining for IT Fluency in this cloud: while some schools may elect to align themselves with a series of examinations designed for the third world, through the Cambridge examination system, these examinations do nonetheless provide options for academic studies at English O, AS and A levels (years 11 -13) in computing related subjects. [Although interestingly enough, it was indicated in the October University Consultation forum that the graduates from these subjects are given scant regard in the UK University sector due to the huge variability in quality of teaching and learning at secondary level]. Yet the commercial imperatives now driving the Cambridge Assessment Group have overtaken the former British imperial objectives, and are having some impact on the quality and adaptability of the syllabi now being provided. Hand in hand with this trend towards globalisation and commercialisation, there is also an adaptive trend towards localisation, with a small set of NZ based courses having been developed (e.g. an 'AS' level syllabus in New Zealand History).

An illustrative example of localisation advised to the authors (B. Cusack, personal communication) is the NZ physics curriculum, where the availability of first world laboratory resources in NZ has occasioned an augmented practical component to the syllabus. This localisation of curriculum has been furthered through the Association of Cambridge Schools in New Zealand Inc. (ACSNZ, 2005). It may offer another avenue for those schools wishing to further an adapted Cambridge local curriculum addressing ICT education in New Zealand. However, quite apart from "cultural cringe" concerns, the quality management issues remain unaddressed, and the considerable franchising and examination fees imposed on schools and students by this model, render this a less than desirable option.

4.3 Let Many Flowers Bloom

Given this fragmented, diverse and fluid picture, and the wide variety of existing options addressing the study of ICT at the senior high school level, any new proposal must be compatible with and acceptable to those in the sector who will have to bring it to fruition. Any model proposed while providing guidance and support, must of necessity be permissive and of the "let many flowers bloom" persuasion. Therefore a set of principles to be adopted in designing an ICT [meta-] framework have been proposed by The FITNZ Representative Working Group (Speight et al., 2005, p. 64).

FITNZ "[Meta-]framework Principles

- Non disruptive
- Supplementary
- Complementary
- Have breadth
- Depth (scope for specialization)
- Scope for extension
- Credit for solid study (academic rigor vs. "cabbage computing")
- [Technology and product change] robust"

5. IT FLUENCY

The ability to make use of IT is known as "Fluency with IT" (FIT), a broader conception than IT Literacy. Recent work by Snyder et al. (1999), Snyder (2003) and Dougherty, Clear et al. (2003) has stressed the importance of fluency in Information Technology (IT) for full participation in today's society. IT Fluency does not solely emphasize information manipulation, knowledge worker productivity tools or the skills dimensions of ICT. The latter two skills are often seen in applications based curricula such as the use of desktop applications (word processors, spreadsheets or presentation tools), or certifications such as the Microsoft MOUS qualification. Nor does IT Fluency encompass only the conceptual dimensions of computing as some of the more theoretical and mathematically oriented computing curricula may do.

The elements of the IT Fluency Model are:

- Contemporary skills
- Foundation concepts
- Intellectual capabilities

Dougherty, et al.(2003) have defined these three components (representing complementary and necessary forms of knowledge) as follows:

- "Contemporary skills are needed for job readiness, and provide practical experience on which to build new competence.

- Foundation concepts are the ‘raw material’ for understanding IT as it evolves, giving insight into the potential and limits of IT.
- Intellectual capabilities encourage abstract reasoning about IT to empower a person to exploit IT when possible and recover from the problems using IT”.

Each of these components in turn has been broken down into ten categories (Snyder, 1999), cf. component column in Tables 1-3. The notion of “FITness” has been observed to be “personal (i.e., there is no universal benchmark for defining a single measurement for FITness), graduated (i.e., there are different levels of FITness, rather than just stating that an individual is or is not FIT), and dynamic (implying the need for lifelong learning as technology changes)” (Dougherty et al, 2003).

Tables 1 - 3 broadly suggest required levels of achievement which can be operationalised within curriculum models. Use of the proposed curriculum meta-framework would result in year 11, 12 and 13 graduates of the senior secondary school system attaining a consistent and identifiable set of capabilities. This operationalisation attempts to address the early criticism of the IT Fluency model by Denning (2000):

> *“the report lacks clarity about the level of competency fluency represents. Levels of competence are defined by standards of action, not by the concepts one knows. Most professions distinguish among at least six levels of professional competence: beginner, rookie, entry-level professional, expert, virtuoso and mastery. Does fluency refer to the beginner level?”*

The benefit of the FITness model is that the intended combination of conceptual knowledge, specific skills and broader intellectual capabilities would both reinforce, and in turn be reinforced by, other subjects in the high school curriculum. It could be expected to be achieved through a combination of the four UNESCO (2000) categories (ICT Literacy; application of ICT in subject areas; integration of ICT across the curriculum; and ICT specialisation).

Table 1. Intellectual Capabilities

Category - Intellectual Capabilities	**Suggested achievement levels for year 11, 12 & 13 ICT graduates**		
Component	**Year 11**	**Year 12**	**Year 13**
Engage in sustained reasoning	1	2	3,4
Manage complexity	1	2	3,4
Test a solution	1	2	3,4
Manage problems in faulty solutions	1	2	3,4
Organize and navigate information structures and evaluate information	1	2	3,4
Collaborate	1	2	3,4
Communicate to other audiences	1	2	3,4
Expect the unexpected	1	2	3,4
Anticipate changing technologies	1	2	3,4
Think about Information Technology abstractly	1	2	3,4
Note: The (1,2,3,4) key here represents NZQA (2005) Levels and may need further consideration, or possibly tighter mapping to NCEA achievement terminology. These NZQA level indicators suggest the depth of study in a particular aspect. Indicative hours of study may also be required, to guide curriculum development			

Thus IT Fluency as proposed here, represents in essence a capability statement to be achieved at a specified level by all secondary students.

6. ACHIEVEMENT LEVELS AND GRADUATE PROFILES - YEARS 12 AND 13

In broad terms two distinct profiles could be expected from the proposed meta-framework:

- a graduate of a year 12 course of study in ICT would have been exposed to all aspects of the IT Fluency meta-framework, and demonstrate at least a low level of capability sufficient to equip them for effective use of IT in their daily lives and future studies.
- at year 13 a graduate would be expected to demonstrate a moderate level of capability sufficient to equip them for effective use of IT in their daily lives and future studies and have a greater depth of expertise in two or more selected areas of ICT. This would equip them for higher study in a "computing related" discipline as delineated in section 2 above and in Appendix A below (cf. Shackleford et al., 2005).

Table 2. Information Technology Concepts

Category - Information Technology Concepts	**Suggested achievement levels for years 11, 12 & 13 ICT graduates**		
Component	**Year 11**	**Year 12**	**Year 13**
Computers	1	2	3,4
Information Systems	1	2	3,4
Networks	1	2	3,4
Digital Representation of Information	1	2	3,4
Information Organisation	1	2	3,4
Modelling and Abstraction	1	2	3,4
Algorithmic thinking and programming	1	2	3,4
Universality	1	2	3,4
Limitations of Information Technology	1	2	3,4
Societal impact of Information and Information Technology	1	2	3,4

While these are considered the key profiles, others could be added. For instance, the year 11 graduate is at a lower level, but is not considered sufficiently distinct to be profiled as IT Fluent. More advanced profiles, which exceed that of the years 12 and 13 IT Fluency meta-framework, could also be developed. Consequently, for those schools wishing to offer an extension programme and for those students studying particular ICT specialist courses of study, the FITNZ profiles outlined here may well be extended.

Tables 1-3 indicate the specific FITness components in which expertise would be demonstrated by a student.

Table 3. - Contemporary Information Technology Skills

Category - Information Technology Skills	**Suggested achievement levels for years 11,12 & 13 ICT graduates**		
Component	**Year 11**	**Year 12**	**Year 13**
Setting up a PC	1	2	3,4
Using basic operating system features	1	2	3,4
Using a word processor	1	2	3,4
Using a graphics to create image-based expressions of ideas	1	2	3,4
Connecting a computer to a network	1	2	3,4
Using the Internet to find information and resources	1	2	3,4
Using a computer to communicate with others	1	2	3,4
Using a spreadsheet	1	2	3,4
Using a database system	1	2	3,4
Using instructional materials to learn how to use new applications or features	1	2	3,4

7. META-FRAMEWORK MAPPING

Given the desire to retain the good aspects of existing practice in the secondary sector, and the intention of identifying levels of achievement within an IT Fluency meta-framework, the FITNZ project will undertake a mapping exercise to provide statements of capability at years 11, 12 and 13 applying current curriculum delivery approaches.

It is expected that this exercise would uncover significant gaps in existing coverage of selected areas of the IT Fluency model. The initial expectation is that the skills area should be reasonably well addressed, while the capabilities should be being developed in several existing subject areas of the curriculum. However linking these elements in an overall gestalt including the IT concepts is likely to be more challenging. Feedback from the University consultation forum suggested that there may be too much conceptual material in the IT Fluency model to be adequately covered.

However, in the course of the mapping exercise it is assumed that some of these elements may be relaxed as not considered wholly core to achieving fluency, while others may need addressing more systematically. It is anticipated that suitable achievement standards, exemplars and recommendations for additional course content, technologies, tools, applications and professional development for teachers may arise from such an exercise. As Chamberlain (2001) has noted: “it is difficult to express progress and quality in words alone. Words are needed to describe criteria, and examples are needed to demonstrate quality exemplars have considerable practical value because they provide concrete referents for verbal descriptions and valuable keys into complex evaluation frameworks”.

An indicative partial mapping for a hypothetical high school is shown in Tables 4 - 5.

Table 4. Intellectual Capabilities

Category - Intellectual Capabilities	**Achievement levels in ICT for year 12 graduates**		
Component	**Year 12**	**Achieved in subject**	**Type of assessment**
Engage in sustained reasoning	2	Mathematics	Achievement std ASnnnnn
Manage complexity	2	Integrated project	Achievement stds ASnnnnn, ASnnnnn, ASnnnnnn, ASnnnnn
Test a solution	2	Computer Networking	CCNA 1 (Note: exceeded at level 3)
Manage problems in faulty solutions	2	Computer Networking	CCNA 1 (Note: exceeded at level 3)
Organize and navigate information structures and evaluate information	2	Biology	Achievement std ASnnnnn
Collaborate	2	Te Reo Maori	Achievement std ASnnnnn
Communicate to other audiences	2	English	Achievement std ASnnnnn
Expect the unexpected	2	Media studies	Achievement std ASnnnnn
Anticipate changing technologies	2	Not addressed	
Think about Information Technology abstractly	2	Not addressed	

Table 5. Information Technology Concepts

Category - Information Technology Concepts	**Achievement levels in ICT for year 12 graduates**		
Component	**Year 12**	**Achieved in subject**	**Type of assessment**
Computers	2	Demonstrate knowledge of the components of PCs ?	Unit std 2783 (Note: exceeded at level 3)
Information Systems	2	Not addressed	
Networks	2	Computer Networking	CCNA 1 (Note: exceeded at level 3)
Digital Representation of Information	2	Computer Networking	CCNA 1 (Note: exceeded at level 3)
Information Organisation	2	Not addressed	
Modelling and Abstraction	2	Not addressed	
Algorithmic thinking and programming	2	PP400 Programming Principles	NACCQ (Mastery) (Note: exceeded at level 4)
Universality	2	Not addressed	
Limitations of Information Technology	2	Not addressed	
Societal impact of Information and Information Technology	2	Technology	Achievement standard ASnnnnn

7.1 Benefits of IT Fluency

The key issue that the IT Fluency model attempts to address are the decreasing numbers of students continuing to study computing related subjects at higher levels, in spite of the increasing demand for technically proficient graduates in the IT industry. It is postulated that this mismatch arises through the negative impacts of the limited understanding and active misconceptions about the computing related disciplines at the high school level. It is hoped that by introducing the IT Fluency model an IT Fluent population may be better positioned to take advantage of IT as a pervasive component of their daily lives, and to be better able to exploit its innovative potential. It is also hoped that a much firmer base of IT capability will underpin higher levels of expertise in our IT industry and help develop the role of the industry in New Zealand’s economic future. While the success of this initiative in achieving the desired outcomes cannot be guaranteed, there are positive indications from work conducted at the tertiary level with US. non majors (Aiken et al., 2000; Kock et al., 2002;

Dougherty et al., 2002) where integrated case study approaches have been adopted in designing specific course pilots. Kock et al. (2002) drew the following picture in their study:

> *"students on average did not have a good knowledge of IT (Q1), were not particularly interested in taking IT courses (Q2), and were not generally attracted to IT (Q3) prior to taking the course and working on the cases". However although the course did not encourage them to take more IT courses in the future, it "had a positive influence on their perception of IT's potential for solving complex tasks (Q6); and had a positive influence on their general perception of IT".*
>
> *The study also noted that students who were strongly interested in IT prior to taking the case studies were more inclined to consider taking more IT courses in the future and pursue an IT career.*

Dougherty et al. (2002) also commented that "lifelong learning begins with a basic understanding and appreciation of [IT's] role", and noted that while this experience did not promote a career change towards IT, it did improve appreciation of IT .

Considering that these students by their original choice of study were not inclined towards IT, this could be considered a respectable outcome. Translated into the earlier context of the senior high school when decisions about higher study may not yet have been made, greater appreciation of IT may serve to increase its attractiveness as a study choice at tertiary level. The IT Fluency initiative is based to a large extent on these premises.

8. BREADTH & DEPTH OF FITNZ

The IT Fluency meta-framework proposed above could be augmented by more specialised ICT curriculum framework models to offer study pathways at a higher level and provide an advanced, in depth academic course of study in ICT more closely linked to tertiary curricula offerings. Thus IT Fluency could be considered to provide a base platform of capability from which specialisations might extend. For many schools and students, attaining the capability levels in IT Fluency demanded by the more general meta-framework to at least a year 12 level might be considered sufficient. However, for others wishing to offer a specialist ICT curriculum, the year 13 IT Fluency programme, augmented by other specific curriculum approaches, would help to address this more specialised need.

8.1 A Specialist ICT Curriculum Framework

It is argued here that a partnership model is the only productive way to ensure the availability of a quality specialist ICT curriculum framework, of the required depth and breadth, which is adequately resourced and professionally delivered.

Elements of such a model would include:

- Provision of a comprehensive and quality specialist ICT curriculum framework under the umbrella of the NACCQ family of qualifications, from NZQA levels 3 - 5. This offers flexibility for the schools to select key courses to include in their offerings, and will provide a coherent pathway for students to higher study, (whether that be in computing or other disciplines).

    - Note: the NACCQ framework already has a partnering arrangement with CISCO to include elements of the CISCO curriculum within its course offerings, [For instance the NACCQ Blue Book (Roberton, 2005) modules IE500 and NW500 map to the Cisco IT essentials 1 and Cisco CCNA 1 respectively] (cf. Roberton & Corbett, 2004, Speight et al., 2005). Thus the ability to align with vendor qualifications under a more comprehensive curriculum framework can be supported.
    - A selection of NACCQ modules is being proposed through NZQA for NCEA credit recognition.
- Or as proposed at the October 12th University Consultation Forum, an alternative specialist subject paper at year 13 covering selected aspects of the IT Fluency model. The goal here would be a unified introduction to study in the computing disciplines, with a respected academic course which would provide a common base for entry to University level study. Key concepts to be addressed in this course would be: information organisation; modelling and abstraction; algorithmic thinking and programming; societal impact of information and Information Technology. A deficiency in the original IT Fluency model was also noted, regarding the absence of any focus on contexts of use and usability. In recognition of the scope of coverage, (from CS to IS) the course might properly be named “computer and information sciences”.
- Confirmation of NCEA credit inclusion for this curriculum, and negotiation of well understood and compatible pathways of study, with equitable acceptance of credit at tertiary institutions to which students might apply for higher study.
- Linking of this specialist curriculum to other prerequisite subject choices from the core high school curriculum, to ensure that pathways to higher study are planned and options preserved
- Mapping of elements of this specialist ICT curriculum framework against the umbrella IT Fluency meta-framework to ensure that full coverage is achieved.
- A voluntary [or potentially mandatory?] accreditation scheme (operated by NACCQ and perhaps adapted from the ABET, 2004 model) ensuring quality provision of ICT specialist education for schools wishing to teach this curriculum
- Participation in the NACCQ moderation scheme for schools delivering these courses
- Provision of a mentoring scheme by local NACCQ institutions and Universities partnering with those schools participating in FITNZ. This would involve quality monitoring and oversight, meta-framework support and support with delivery of aspects of the courses as required. NACCQ sponsored teacher professional development programmes would also be provided in partnership with industry or other parties such as colleges of education, with whom the schools wish to work.
- Another key element of the NACCQ mentoring scheme would be industry support and mentoring through a guest lecturer programme, sponsorship of specialized software and hardware resources, and financial support for teacher professional development.
- Scholarships for high achievers in ICT would also be supported through this linkage, with the opportunity to offer scholarships for underrepresented groups in IT such as women, Maori and Pacific students.

9. ALTERNATIVE STRATEGIES FOR A SPECIALIST ICT CURRICULUM

As can be seen from 8.1 above the approaches to provision of a specialist ICT curriculum are varied. The choice appears to be between:

1. a more permissive model based upon what the schools working with their partners can do well, or
2. a more prescriptive approach advocated by the University sector to ensure some predictability in the degree of prior knowledge that can be assumed in students who have studied computing as a specialist subject at High school level.
   The latter strategy would need the same supporting structures, identified in 8.1 above, in developing and maintaining a quality curriculum and its delivery. Considerable teacher professional development would be required to avoid the variability of delivery issue that plagues the teaching of computing as an academic subject in many countries around the world.
3. A combination of the above two strategies being pursued in tandem.

In considering the choice of strategy, at one level the debate could be seen to be one of the "branding" of computing as a subject. The current status of computing as a subject at high school level is generally considered to be low. A large element of this low status is attributed to confusion with the skills dimension of ICT and lack of knowledge and awareness of the scope of computing both professionally and in its broad range of challenging academic disciplines. However a further element lies in the interpretation of the name Information Technology and its linking with the Technology subject. Technology has been a subject long recognised as an area for non academic students - regardless of the quality of the curriculum now available (cf. Compton & Harwood, 2003).

The counter strategy advocated by the University sector suggests a re-positioning of computing as a legitimate academic subject. This might possibly be effected by a renaming including the higher status word "science" in the chosen title, and through offering a new "academic" subject which students can take at year 13.

Thus we can see, crudely stated, a debate over the role of ICT in:

- generalist, administrative, technical and professional contexts (beige through white collar occupations)
- IT Technician and technologist roles (blue collar through t-shirt occupations)
- IT Professional and managerial roles (white collar occupations)

Positioning a new year 13 subject in computing may address the IT professional and managerial roles, and help raise the status of the disciplines.

9.1 The Role of Mathematics as a Prerequisite Subject

A prerequisite of level 2 maths could serve to further emphasise the exclusivity of the new computing subject; given the significant jump in the level of study, the recognised academic standing of mathematics studied at level 2 and the large drop-off (approximately 50%) in successful student numbers between level 1 and level 2 maths (NZQAb, 2005). However with level one maths as the University entrance standard, a level two prerequisite could be seen as unduly high. It would serve to exclude many at an early stage. The issues already being experienced at tertiary levels with under representation of key groups - women, Maori and Pasifika, may be exacerbated and moved lower down in the education system. While numeracy and literacy are important preparation for study in computing, an undue focus on mathematical prowess may deter students from computing related disciplines. For the non computer science disciplines, the degree of mathematical competency required is certainly open to debate, as is the reliability of mathematical success as a predictor. The relative merits of maths with statistics, vs. calculus is also a question for consideration. A more open stance would serve to increase the eligible pool of students.

Therefore a considered decision about the level at which a maths prerequisite should be set is a significant issue. The choice seems to be between: a more exclusive high status subject competing for its share of the smaller pool of academic students among the other available subjects, versus a more open subject with a more mixed student body, able to slot in at different roles in the IT professional through IT Technician career hierarchy (assuming they persevere with the subject).

10. PARTNERSHIP MODELS

The FITNZ project is a multi-party and cross sector initiative. It appears to represent the first occasion that a major coalition of computing industry, secondary and tertiary sector educators and government agencies have united to address the issues related to teaching computing in the secondary system. Individual linkages and partnerships already exist, but not on the scale of this project nor at a national level. Some examples of industry / educational partnership models are: NACCQ and CISCO in the delivery of joint curriculum (Roberton & Corbett, 2004); Microsoft and the NZQA in providing Microsoft certifications as a course of study registered for NCEA credit inclusion (Pascoe, 2003); the NZ and other computer societies in the offering of the International Computer Driving License and European Computer Driving Licenses (NZCS, 2005). The Wellington College Tech Angels scheme (Kong, 2003) links secondary female students with teachers, the tertiary and IT industry sectors; OtagoNet, a grouping of 11 rural schools is linking with Otago Polytechnic to provide a curriculum planned around the NACCQ CIC level 3 curriculum; Manukau Institute of Technology and local secondary schools are providing NACCQ curriculum at high school level (Andrews, 2004); the Cyberwaka Enterprises Cisco Networking Academy Program (CNAP) a joint venture between the Bay of Plenty iwi and The Pacific Islands Matati E Fa Trust, based in Auckland (Te_Puni_Kokiri, 2001); and other CISCO academy programs such as that established with Tangaroa College in Auckland (Collins, 2001).

11. CURRICULUM DELIVERY MODELS

A loose collection of vendor certifications, unit standards, some local initiatives and a small subset of the technology curriculum represent the current state of computing education in many New Zealand high schools. This lack of coherency is unnecessary and undesirable. In countries such as Israel and the United States specific computer science curriculum models have been proposed, with recommendations that computer science be taught as a separate subject (Gal-Ezer & Harel, 1999, Tucker et al., 2003). However, in practice it appears that the experiences in the US have been no more successful than our own. The proposal for an IT Fluency model in this paper extends beyond computer science as a discipline. It supports the four categories of the UNESCO (2000) ICT curriculum report: namely ICT literacy; Application of ICT in Subject Areas; Integration of

ICT across the curriculum; and ICT Specialisation.

The IT Fluency model should be capable of supporting more interdisciplinary delivery models in which the FITness elements may be delivered in a portfolio of courses to suit the local circumstance of each high school. For instance those with existing CISCO academy linkages may include those elements in their overall programme in a standards based assessment approach (Barker, 1995), that can be utilised towards achieving FITNess. NACCQ modules at levels 3, 4 and (if desired, level 5) may then serve to augment such curricular elements. For the more generic graduate profile, many of the elements may already be taught in core academic disciplines (such as biology, English, mathematics, physics) and IT may be used as an integrative device in supporting both the core curriculum delivery and FITNess development, through a "threaded curriculum" model. "The metacurricular approach threads thinking skills, social skills, multiple intelligences, technology, and study skills through the various disciplines" (Fogarty, 1991). "This [threaded] model would require collaboration between different disciplines to investigate some broader transdisciplinary concept (such as the study of time), which would then weave its way through the instructional process, dipping from time to time into specific disciplines to explore the concept in more detail" (Clear, 1997).

Implementing the IT Fluency curriculum meta-framework would occur through a mapping process of the IT Fluency model against existing curricula. Subsequently some careful course redesign would ensue, piloted with selected schools or regions, and carefully avoiding the need to completely disrupt existing courses or impose extra workloads on already stretched high school teachers. The process of general implementation would need careful consideration, with the most likely approach being to endorse it as a national curriculum recommendation at a meta-framework level. It would provide a target capability level in IT Fluency for all students to achieve, with options for more specialised study to build on the base thus developed. It would need to be accompanied by a sound set of guidelines and supporting examples, to reduce the workload and resolve potential confusion for classroom teachers. This may aid its active adoption, as suggested by Le Metais (2002) "Where the curriculum is not statutory (for example in Scotland), teachers tend to follow the guidelines, especially where they include exemplification materials".

NACCQ with its long history of collaborative national computing curriculum developments; relative independence; and its industry, tertiary and high school linkages, is well positioned to advise on suitable national curriculum models and components, and support the maintenance of currency in the IT Fluency and ICT specialist curricula and the educators providing them.

12. CONCLUSION

This paper has positioned the FITNZ initiative in the context of the new Zealand secondary schools coverage of the computing related disciplines, proposed an IT Fluency curriculum meta-framework and a set of graduate profiles at the senior secondary school level and identified a role for NACCQ in the context of a significant educational partnership between industry, secondary, government and tertiary sectors. It has proposed a flexible model for high school computing curricula which avoids radically disrupting existing arrangements, while achieving a consistent and measurable level of student capability in IT. The model remains a work-in-progress and this paper is intended to profile developments in the FITNZ project for the consideration of interested parties.

13. ACKNOWLEDGEMENTS

This paper represents a reviewed, revised and significantly extended version of a paper presented at the 18th Annual NACCQ conference (Clear & Bidois, 2005). The FITNZ curriculum model and the programme of work profiled in this paper are the outcome of the joint efforts of the FITNZ Representative Working Group, developed since the early Auckland University of Technology sponsored meetings in 2004. Elements of the FITNZ meta-framework have been progressively developing, as outlined in Clear et al. (2004), Clear & Bidois (2005), Speight et al. (2005). Key agents in the development and leadership of this initiative have been Judy Speight and Faye Langdon, working with Hilary Carlile and Garry Roberton as chair of NACCQ.

The authors of this paper have also been associated with the project since its inception. Without the enthusiasm and drive of these key people, and the commitment to collaborate of those participating in the project there would be little to write. However this paper represents the views of the authors, and not necessarily those of the FITNZ project itself.

The Phase 1 steering group and representative working group members are acknowledged in Tables 6-8.

Table 6. FITNZ Phase one Project Steering Group Members

Name	**Organisation**	**Project Role**
Garth Biggs	HiGrowth	Project Sponsor
Chris Mathews	e-regions	e-regions Chairman
Judy Speight	ITT WRKZ	Project Leader
Hilary Carlile	ITT WRKZ	Project Director
Craig Taylor	NZTE	Steering Group, Government Advisor
Murray Brown	Min Edu.	Project Funder
Faye Langdon	Langdon Consulting	Steering Group, Specialist Advisor
David Barker	Cisco	Steering Group, Industry Advocate
Garry Roberton	NACCQ	Steering Group, Educators Advocate

Table 7. FITNZ Phase one Representative Working Group Members

	Name	Organisation
Educators	Garry Roberton	NACCQ
	Maurice Alford	Lytton High School
	Fred Alvrez	Te Runanga O Te Rarawa
	Sam Uasi	Tangaroa College
	Tony Clear	AUT
	Geoff Gibbs	Ministry of Education
Industry	Graham Duncan	Computer Press
		CISCO
	Mark Jamieson	Oracle
	Arthur Kebbell	Computing New Zealand
	John Shortt	Green Light Group
	Debbie Noon	IBM
Government	Murray Brown	Ministry of Education
	File Timateo	Manukau City Council
	Teena Abbey	Immigration Services
	Paul Pearson	Tertiary Education Commission
	Grant Power	Department of Labour
Subject Matter Experts	Val Gyde	NatColl
	Prue Purser	CCC
	Margot Phillips	NZCS
	Peter Cooke	PPTA
	Helen Anderson	MIT
	Paul Curry	NZIST
	Faye Langdon	Langdon Consulting

Table 8. FITNZ University Consultation Forum (12 Oct 2005) Attendees

SECTOR	Name	Organisation
University	Professor George Benwell	Otago University -Information Sciences
	Dr Neville Churcher	Canterbury University-Computer Science & Software Engineering
	Associate Professor Chris Philips	Massey University - Institute of Information Sciences and Technology
	Dr. Clare Churcher	Lincoln University - Applied Computing, Mathematics And Statistics
	Professor Sid Huff	Victoria University- Information Management
	Dr Peter Andreae	Victoria University- Mathematics &Computer Science
	Professor Dennis Viehland	Massey University -Information Systems
	Professor Steve Reeves	Waikato University - Computer Science
	Professor John Hosking	Auckland University - Computer Science
	Associate Professor Gill Dobbie	Auckland University - Software Engineering
	Tony Clear	Auckland University of Technology - Computer &Information Sciences
Industry	Ross Peat Paul Lo Sean McBreen	Microsoft New Zealand
	Robert Gosling	Oracle New Zealand
	Katrina Troughton	IBM New Zealand
FITNZ	Faye Langdon	Langdon Consulting Ltd
	Judy Speight	ITTWRKZ Ltd

REFERENCES

ABET. (2004). Criteria for Accrediting Computing Programs [Online available: http://www.abet.org/criteria.html Accessed 27/10/2004]. Baltimore: Accreditation Board for Engineering and Technology, Inc. Computing Accreditation Commission.

ACSNZ. (2005). Association of Cambridge Schools in New Zealand. Retrieved 2 Oct, 2005, from http://www.cie.org.uk/CIE/WebSite/home.jsp

Aiken, R., Kock, N., & Mandviwalla, M. (2000). Fluency in Information Technology: A Second Course For Non-Majors. Paper presented at the ACM Technical Symposium (SIGCSE 2000), Austin, Texas.

Andrews M. (2004, 6-9 Jul). NACCQ modules in schools. Paper presented at the 17th Annual NACCQ Conference, Christchurch, New Zealand.

Barker, A. (1995). Standards Based Assessment: The Vision and Broader Factors. In R. Peddie & B. Tuck (Eds.), Setting the Standards: Issues for Assessment in National Qualifications (pp. 21). Palmerson North: Dunmore Press.

Chamberlain, M. (2005, Mar 2001). The Development of Exemplars in New Zealand - Background and Rationale. Retrieved 7 Oct, 2005, from http://www.tki.org.nz/r/assessment/research/research1_e.php

CIE. (2005). CIEOnline- University of Cambridge International Examinations (CIE). Retrieved 2 Oct, 2005, from http://www.cie.org.uk/CIE/WebSite/home.jsp

Clear, T. (1997, Dec). Coupling and Cohesion Among Disciplines: Some Curriculum Paradigms. SIGCSE Bulletin, 29, 14-16.

Clear, T., & Bidois, G. (2005). FITNZ - Graduate profiles for ICT education at senior secondary level. In S. Mann & T. Clear (Eds.), 18th Annual NACCQ Conference (pp. 145-150). Tauranga, New Zealand: NACCQ.

Clear, T., Bidois, G., Langdon, F., Roberton, G., & Speight, J. (2004). "FIT" NZ ? Fluency with IT, New Zealand - A Discussion Paper on Graduate Profiles at the Senior Secondary Level (Unpublished Draft). Auckland: Auckland University of Technology.

Compton, V., & Harwood, C. (2003). Enhancing Technological Practice: An Assessment Framework for Technology Education in New Zealand. International Journal of Technology and Design Education, 13, 1-26.

Collins, S. (2001). Bridging the digital divide. Retrieved 04 April, 2005, from http://www.nzherald.co.nz/print.cfm?objectid=229844

Denning, P. (2000). A Commentary on Fluency in Information Technology. Inventio (Online Journal), 1(2), Retrieved from http://www.doiiit.gmu.edu/Archives/Spring00/pdenning.html 11/10/2005.

Denning, P. (2005). Is Computer Science Science? Communications of the ACM, 48(4), 27-31.

Dougherty, J., Clear, T., Cooper, S., Dececchi, T., Richards, B., & Wilusz, T. (2003, Jun). Information Technology Fluency in Practice. SIGCSE Bulletin, 35, 153 - 171.

Dougherty, J., Kock, N., Sandas, C., & Aiken, R. (2002). Teaching The Use of Complex IT in Specific Domains: Developing, Assessing and Refining a Curriculum Development Framework. Education and Information Technologies, 7(2), 137-154.

ERO. (2001, Apr 2001). The New Zealand Curriculum: an ERO Perspective. Retrieved 7 Oct, 2005, from http://www.ero.govt.nz/Publications/pubs2001/Curriculum/curric1.htm

Fogarty R. (1991). Ten Ways To Integrate Curriculum, Educational Leadership, October, 49(2), 61 65

Falloon, G. (2004). An Analysis of the Impact of an E-Classroom Environment on

the Social, Cognitive and Affective Elements of Student Work Practices. Unpublished Doctor of Science Education Thesis, Curtin University of Technology, Perth.
Gal-Ezer, J., & Harel, D. (1999). Curriculum for a high school computer science curriculum. Computer Science Education, 9(2), 114-147.
Hager, P., & Gonczi, A. (1994). General issues about assessment of competence. Assessment and Evaluation in Higher Education, 19(1), 3-17.
Kock, N., Aiken, R., & Sandas, C. (2002). Using Complex IT in Specific Domains: Developing, and Assessing a Course For Non-Majors. IEEE Transactions on Education, 45(1), 50-56.
Kong, C. (2003, Dec 2004). Tech Angels Wellington Girls College. Retrieved 04 April, 2005, from http://www.techangels.org.nz/welcome.htm
LeMetais, J. (2002). New Zealand Stocktake: an international critique (Ministry of Education - commissioned international commentary for the New Zealand Curriculum Stocktake). Wellington: National Foundation for Educational Research.
MoE. (2005, 22 Jun 2005). The New Zealand Curriculum Framework (Summary Description). Retrieved 6 Oct, 2005, from http://www.minedu.govt.nz/index.cfm?layout=document&documentid=3561&data=l
NZCS. (2005). ICDL. Retrieved 11 May, 2005, from http://www.nzcs.org.nz/SITE_Default/products_and_services/icdl/default.asp
NZQA. (2005a). National Qualifications Framework Levels Descriptors. Retrieved 18 Apr, 2005, from http://www.nzqa.ac.nz/framework/levels.html
NZQA. (2005b). Secondary Qualifications Statistics 2004. Retrieved 14 Oct, 2005, from http://www.nzqa.ac.nz/publications/docs/secondarystats-2004.pdf
Pascoe, R. (2003). Is There a MOUS In Your House? Paper presented at the 17 th annual NACCQ Conference, Christchurch.
Perrow, C. (1986). Complex Organisations (3 ed.). New York: McGraw Hill.
Pullar-Strecker, T. (2005, 2 May). $1m Bid to Tackle IT Skills Shortage. The Dominion Post.
Roberton, G. (Ed.). (2005). Blue Book, New Zealand polytechnic qualifications in information and communication technology (10 ed.). Hamilton: NACCQ.
Roberton G., Corbett E. (2004, 6-9 Jul). Creating Intriguing Synergies with Course Offerings: Integrating industry qualifications - An ITP Perspective. Paper presented at the 17th Annual NACCQ Conference, Christchurch, New Zealand.
Shackelford, R., Cassel, L., Cross, J., Davies, G., Impagliazzo, J., Kamali, R., et al. (2005). Computing Curricula 2005 The Overview Report -Including The Guide to Undergraduate Degree Programs in Computing [Online available: http://www.acm.org/education/Draft_5-23-051.pdf. Accessed 21/07/2005] (Curriculum Report). New York: Joint Task Force ACM, AIS, IEEE-CS.
Snyder, L., Aho, A., Linn, M., Packer, A., Tucker, A., Ullman, J., et al. (1999). Being Fluent with Information Technology [online available http://www7.nationalacademies.org/cstb/pub_fit.html Accessed 27/10/2004]. Washington, D.C.: Committee on Information Technology Literacy, Computer Science and Telecommunications Board (CSTB).
Snyder, L. (2003). Fluency with Information Technology: skills, concepts and capabilities (Preliminary ed.). Boston: Addison Wesley.
Speight, J., & Carlile, H. (2005). Business Plan FITNZ Project (Confidential FITNZ Representative Working Group Report to the NZ HiGrowth Project). Auckland: ITTWRKZ Ltd.
Tan, K., & Prosser, M. (2004). Qualitatively different ways of differentiating student achievement: a phenomenographic study of academics conceptions of grade descriptors. Assessment and Evaluation in Higher Education, 267-282.
Te_Puni_Kokiri. (2001). Information Technology Initiatives Within Mäori

Communities: Notes from a hui of Mäori Information Technology Practitioners. Retrieved 04 April, 2005, from http://www.nzmis.org.nz/download/itiwmc.pdf
Tucker, A., Deek, F., Jones, J., McCowan, D., & Stephenson, C. (2003). A model curriculum for K-12 Computer Science [Online available: http://www.acm.org/education/k12/k12final1022.pdf. Accessed 04/04/2005] (Curriculum Report). New York: ACM K-12 Task Force Curriculum Committee.
vanWeert, T., Buettner, Y., Fulford, C., Kendall, M., Duchateau, C., Hogenbirk, P., et al. (2000). Information and Communication Technology in Secondary Education - A Curriculum for Schools [retrieved from http://wwwedu.ge.ch/cptic/prospective/projets/unesco/en/curriculum2000.pdf, 27/09/2005] (IFIP WG3.1 report). Geneva: UNESCO.

Appendix A

Descriptions of the major computing disciplines

Shackleford et al. (2005, p. 13ff.) describe each of the disciplines as excerpted below, (but note as the authors acknowledge “this report implicitly reflects a North American-centric Orientation (p.1)” and may differ somewhat from country to country).The text below represents an excerption from Shackleford et al. (2005, p. 13ff.)

2.3. Descriptions of the major computing disciplines

"In this section, we characterize each of the five major kinds of computing disciplines. See sections 3.4 and 3.5 for more information on how to understand this important distinction between the names of the computing disciplines and the names of a particular degree program."

2.3.1. Computer Engineering

"Computer engineering is concerned with the design and construction of computers and computer-based systems. It involves the study of hardware, software, communications, and the interaction among them. Its curriculum focuses on the theories, principles, and practices of traditional electrical engineering and mathematics, and applies them to the problems of designing computers and computer-based devices. Computer engineering students study the design of digital hardware systems, including computers, communications systems, and devices that contain computers. They also study software development with a focus on software used within and between digital devices (not software programs directly used by users). The curriculum emphasizes hardware more than software, and it has a strong engineering flavor. Currently, a dominant area within computing engineering is embedded systems, the development of devices that have software components embedded in hardware. For example, devices such as cell phones, digital audio players, digital video recorders, alarm systems, x-ray machines, and laser surgical tools all require integration of hardware and embedded software, and are all the result of computer engineering."

2.3.2. Computer Science

"Computer science spans a wide range, from its theoretical and algorithmic foundations to cutting-edge developments in robotics, computer vision, intelligent systems, bioinformatics, and other exciting areas. We can think of the work of computer scientists as falling into three categories:

- They design and implement software. Computer scientists take on challenging programming jobs. They also supervise other programmers, keeping them aware of new approaches.

- They devise new ways to use computers. Progress in the CS areas of networking, database, and human-computer-interface enabled the development of the World Wide Web. Now, researchers are working to make robots be practical aides that demonstrate intelligence, are using databases to create new knowledge, and are using computers to help decipher the secrets of our DNA.

- They develop effective ways to solve computing problems. For example, computer scientists develop the best possible ways to store information in databases, send data over networks, and display complex images. Their theoretical background allows them to determine the best performance possible, and their study of algorithms helps them develop new approaches that provide better performance. Computer science spans the range from theory to programming. While other disciplines can produce graduates better prepared for specific jobs, computer science offers a comprehensive foundation that permits graduates to adapt to new technologies and new ideas."

2.3.3. Information Systems

"Information systems specialists focus on integrating information technology solutions and business processes to meet the information needs of businesses and other enterprises, enabling them to achieve their objectives in an effective, efficient way. This discipline's perspective on "Information Technology" emphasizes information, and sees technology as an instrument to enable the generation, processing and distribution of needed information. Professionals in this discipline are primarily concerned with the information that computer systems can provide to aid an enterprise in defining and achieving its goals, and the processes that an enterprise can implement and improve using information technology. They must understand both technical and organizational factors, and must be able to help an organization determine how information and technology-enabled business processes can provide a competitive advantage. The information systems specialist plays a key role in determining the requirements for an organization's information systems and is active in their specification, design, and implementation. As a result, such professionals require a sound understanding of organizational principles and practices so that they can serve as an effective bridge between the technical and management communities within an organization, enabling them to work in harmony to ensure that the organization has the information and the systems it needs to support its operations. Information systems professionals are also involved in designing technology-based organizational communication and collaboration systems.

A majority of Information Systems (IS) programs are located in business schools. All IS degrees combine business and computing coursework. A wide variety of IS programs exists under various labels which often reflect the nature of the program. For example, programs in Computer Information Systems usually have the strongest technology focus, and programs in Management Information

Systems can emphasize organizational and behavioral aspects of IS. Degree programs names are not always consistent."

2.3.4. Information Technology

"Information technology is a label that has two meanings. In the broadest sense, the term ‘information technology’ is often used to refer to all of computing. In academia, it refers to undergraduate degree programs that prepare students to meet the technology needs of business, government, healthcare, schools, and other kinds of organizations. In the previous section, we said that Information Systems focuses on the ‘information’ aspects of ‘information technology’. Information Technology is the complement of that perspective: its emphasis is on the technology itself more than on the information it conveys. IT is a new and rapidly growing discipline which started as a grass roots response to the practical, everyday needs of business and other organizations. Today, organizations of every kind are dependent on information technology. They need to have appropriate systems in place. Those systems must work properly, be secure, and be upgraded, maintained, and replaced as appropriate. People throughout an organization require support from IT staff who understand computer systems and their software, and are committed to solving whatever computer related problems they might have. Graduates of information technology programs address these needs. Degree programs in Information Technology arose because degree programs in the other computing disciplines were not producing an adequate supply of graduates capable of handling these very real needs. IT programs exist to produce graduates who possess the right combination of knowledge and practical, hands-on expertise to take care of both an organization’s information technology infrastructure and the people who use it. IT specialists assume responsibility for selecting hardware and software products appropriate for an organization, integrating those products with organizational needs and infrastructure, and installing, customizing and maintaining those applications for the organization’s computer users. Examples of these responsibilities include: the installation of networks; network administration and security; the design of web pages; the development of multimedia resources; the installation of communication components; the oversight of email products; and the planning and management of the technology life-cycle by which an organization’s technology is maintained, upgraded, and replaced."

2.3.5. Software Engineering

"Software engineering is the discipline of developing and maintaining software systems that behave reliably and efficiently, are affordable to develop and maintain. This reflects its origins as outlined in section 2.2.2. However, more recently it has evolved in response to the increased importance of software in safety-critical applications and to the growing impact of large and expensive software systems in a wide range of situations. Software engineering is different in character from other engineering disciplines, due to both the intangible nature of software and to the discontinuous nature of software operation. It seeks to integrate the principles of mathematics and computer science with the engineering practices developed for tangible, physical artifacts. Prospective students can expect to see software engineering presented in two contexts:

- Degree programs in computer science offer one or more software engineering courses as elements of the CS curriculum. Some offer a multi-course concentration in software engineering within CS.

- A number of institutions offer a software engineering degree program.

Degree programs in computer science and in software engineering have many courses in common. Software engineering students learn more about software reliability and maintenance and focus more on techniques for developing and maintaining software that is correct from its inception. While CS students are likely to have heard of the importance of such techniques, the engineering knowledge and experience provided in SE programs goes beyond what CS programs can provide. Such is the importance of this that one of the recommendations of the SE report is that during their program of study students of SE should participate in the development of software to be used in earnest by others. SE students learn how to assess customer needs and develop usable software that meets those needs. Knowing how to provide genuinely useful and usable software is of paramount importance. In the workplace, the term “software engineer” is a job label. There is no standard definition for this term when used in a job description. Its meaning varies widely among employers. It can be a title equivalent to “computer programmer” or a title for someone who manages a large, complex, and/or safety-critical software project. The public must be mindful not confuse the discipline of software engineering with the ambiguous use of the term “software engineer” as used in employment advertisements and job titles."