Thinking algorithmically- searching for a pedagogy

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ABSTRACT

This paper seeks to identify the unique and important aspects of thinking necessary to assist IT students form a clear identity and appropriate skills sets as emerging IT professionals. From a critical realist perspective, the paper reviews the process and outcomes of the post-MRoQ qualifications. Then, through a literature review, it examines learning theory through a variation theoretical lens. The paper imagines a curriculum and learning spaces in which this transformation can more easily take place. As a first step towards engendering innovation in IT education in the post- MRoQ environment, it presents a set of pedagogical challenges to be taken up by the CITRENZ community.

Keywords: Variation theory and IT; pedagogy and IT; innovation and computer education

1. INTRODUCTION

Preparing emerging IT professionals for an IT career is a complex process of a multi-disciplinary nature within broad social, political and economic local, regional, national, and global contexts. Given the ubiquitous nature of information technologies in these and everyday life settings, students tend to have awareness and experience of everyday life IT settings, but have less or little understanding of social, economic and political contexts and IT. Further, the complex inter-relationship of the triple helix of academia, industry and government, as trainers, employers and funders of emerging IT professionals, strongly influences academic qualifications, and the shaping of their provision (Etzkowitz & Leydesdorff, 2000).

Critically reviewing of the outcomes of the 2014-2015 Mandatory Review of Qualifications process (MRoQ) this paper examines its affordances and limitations, including what has been officially sanctioned as a dominant discourse of IT education in ITPs (Turunen & Rafferty, 2013). Applying variation theory to educational policy and practice settings, research findings on learning theory, curriculum content development, delivery and assessment, within innovative learning spaces, this paper explores the challenges which still face ITPs in developing innovative, relevant, and appropriate training for emerging IT professionals in Aotearoa New Zealand to meet the global challenges of the 21st century.

2. QUALIFICATION DEVELOPMENT THROUGH A VARIATION THEORY LENS

Variation research theory, which is derived from phenomenography, seeks to identify how educational policy is experienced, so outcomes can be better understood, and used to develop further analysis and appropriate pedagogy (Tan, 2009). Different levels of conceptual understanding and different levels of practical proficiency relate to these dimensions of variation (Eckerdal, 2015). It is a useful tool for analysis in the post MRoQ qualification landscape. To understand what has occurred, a brief account of the process, as experienced from the viewpoint of an ITP participant, is now described.

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2.1 MRoQ Review

Originally the review process required an immense paradigm shift by the New Zealand Qualifications Authority (NZQA) as they believed the only qualifications involved would relate to Information Technology (IT) as a Tool. It was only after a nationwide survey that NZQA accepted the concept of IT as a Profession (NZQA, 2013). From this point in 2013 to the listing of the final qualifications to survive in the initial landscape on 25 May 2015, the pathway from the Targeted Review of Qualifications (TRoQ) to MRoQ and the final listing was often fraught with difficulties. These included IT professionally-orientated academic requirements, the conflicting views of some of the IT industry candidates, the lack of IT-as-a-Profession knowledge on the part of some of the NZQA working party facilitators, and NZQA quality assurance staff.

2.2 Process of Development

The qualification landscape, as developed by the then-TRoQ Steering Group, was split up amongst various working parties to develop their qualification document. This comprised the strategic purpose statement, graduate profile, education pathway, employment pathway, and entry requirements. This was required without being allowed, by the NZQA-appointed facilitator, to discuss possible content. Members of the working parties found this highly frustrating and a barrier to effective qualification development. Eventually, the NZQA-appointed facilitators relented and the working parties began to make progress.

The working party process consisted of either one or more days of meeting, initially in Wellington and then, eventually, in Auckland. After each working party meeting, the material developed by each working party and recorded by the NZQA-appointed facilitator, was referred back to the NZQA Wellington staff for checking against NZQA protocols and NZQA structured processes. Then the working party was recalled to discuss these re-developments. The material from each working party was put to the Steering Group for comment and the working parties could be recalled to consider these comments.

Eventually, the material from the working parties was circulated in a wider sense for consultation – with a brief time-frame; so brief, that many found it impossible to consider the material within it. After each period of consultation, the working parties were recalled to consider the further re-development as required by the consultation process. This consultation process took place on three separate occasions. Finally, the material was sent to the NZQA Quality Assurance Staff Member and when further changes were made the working parties were recalled one last time. Subsequent changes by the NZQA Quality Assurance Staff Member were then dealt with by group telephone calls for each of the working parties.

A particular source of conflict lay between the professionally-orientated academics and the Private Training Enterprise (PTE) representatives. The inclusion of IT orientated professional business skills such as communication, inter-personal skills, basic business knowledge/understanding, and professionalism and ethics was highly contentious. This issue frequently frustrated both parties as the ITP representatives argued for their inclusion yet PTE considered these topics had no place within their industry certification programmes of study. At times it seemed that these two "camps" were so diametrically opposed that there would be no chance whatsoever of finding a middle ground.

2.3 Qualification outcomes

The qualification landscape documents changed considerably over the 18 months or so of the MRoQ process. One of the earliest versions of the NZQA drafted version of the qualification document for the Level 4 New Zealand Certificate as at 15 November, 2013 has it called the New Zealand Certificate in Information Technology (Level 4), whereas at 3 July, 2014 the same qualification is called the New Zealand Certificate in Information Technology Essentials and again the same as at 1 May, 2015. Table 1 shows some of the changes over this same period to the Graduate Profile section (D. Garrett, personal communications, 15 November, 2013, 3 July, 2014 and 1 May, 2015).

Table 1: Comparisons of the Graduate Profile Section

Date	Tracked Changes
15/11/13	1. *Demonstrate skills and knowledge relevant to a specified discipline within IT. (25-30 credits)* 2. *Apply fundamental software development techniques to develop simple, single-user applications (10 credits)* 3. *Apply basic knowledge and concepts of computer hardware, networks and operating systems to diagnose and correct common simple IT problems (10 credits)* 4. *Explore graphics and multimedia and apply techniques in media design. (5-10 credits)* 5. *Effectively use a range of appropriate applications to document or communicate data or information. (10-15 credits)* 6. *Select and apply appropriate professional and ethical principles and practices. (5 credits)* 7. *Select and apply appropriate communication modes for a range of contexts. (10 credits)* 8. *Select and apply project management and planning tools to review and revise briefs and outcomes in on-going consultation with stakeholders. (5-10 credits)*
3/7/14	1. *Demonstrate skills and knowledge relevant to specified disciplines within IT (information technology, information systems, web design, software development). (40 credits)* 2. *Apply project management and planning tools. (10 credits)* 3. *Select and apply appropriate professional, ethical and legal principles and practices. (5 credits)* 4. *Communicate clearly and professionally in a range of contexts within the IT industry. (5 credits)*
1/5/15	1. *Apply essential knowledge and concepts of computer hardware, operating systems, applications, and networks to provide support for hardware and software resources and a foundation for the IT Profession* 2. *Apply essential knowledge and concepts of business analysis, database, and user experience to provide a foundation for supporting organisational information systems requirements.* 3. *Contribute to user interface design using essential knowledge and concepts of web design.* 4. *Apply essential knowledge and concepts of software development to provide a foundation for developing applications.* 5. *Apply project management and planning tools to meet the requirements of specified briefs and provide a foundation for the IT Profession.* 6. *Apply appropriate professional, ethical and legal principles and practices to comply with legal and organisational requirements and provide a foundation for the IT Profession.* 7. *Communicate clearly and professionally to maintain relationships and achieve objectives in a range of contexts within the IT industry.*

Some could argue that the changes are for the better – but not all the changes were made by the working groups and therefore did not follow the agreed 'due processes'. In making these changes to fit the NZQA Quality Assurance requirements, was meaning lost from the original 15 November 2013 version, when the 1 May 2015 version was listed and came into 'law'. Certainly between November, 2013 and July, 2014 the Graduate Profile was refined down from eight different components to only four – then then by May, 2015 the Graduate Profile was back up to seven components. Table 2 shows some of the changes over the same period to the Qualification Outcomes section (D. Garrett, personal communications, 15 November, 2013, 3 July, 2014 and 1 May, 2015).

Table 2: Comparisons of the Qualification Outcomes Section

Date	Section	Tracked Changes
15/11/13	Qualification Outcomes	None listed as yet – focus only on the Strategic Purpose Statement, the Graduate Profile and the Education Pathway – without the members of the working parties feeling comfortable about their contributions at this stage.
3/7/14	Qualification Outcomes 1. Demonstrate skills and knowledge relevant to specified disciplines within IT (information technology, information systems, web design, software development).	Information technology (10 credits) Experiential learning of basic knowledge and concepts of computer hardware, operating systems, applications, and networks: • Hardware - standard computer components, maintenance, assembly, disassembly, device drivers • Experience using one operating system but knowledge of a range of operating systems – basic configuration, standard command line utilities; • Security concepts – end user level • Concepts of local and remote storage technologies • Internet-based services
1/5/15	Qualification Outcomes: 2. Apply essential knowledge and concepts of computer hardware, operating systems, applications, and networks to provide support for hardware and software resources and a foundation for the IT Profession. (Credits 10)	Programmes must include experiential learning of basic Information Technology knowledge and concepts including: • Hardware - standard computer components, maintenance, assembly, disassembly; • Knowledge of a range of operating systems, with experience using one operating system – installation, basic configuration, standard command line utilities; installing device drivers; • Basic networking concepts, devices, and internet-based services; • Security concepts – end user level; • Concepts of local and remote storage technologies.

Table 3 shows some further changes over the same period to another part of the Qualification Outcomes section (D. Garrett, personal communications, 15 November, 2013, 3 July, 2014 and 1 May, 2015).

Table 3: Further Comparisons of the Qualification Outcomes Section

Date	Section	Tracked Changes
15/11/13	Qualification Outcomes	Nothing listed at this point in time.
3/7/14	Qualification Outcomes 3. Demonstrate skills and knowledge relevant to specified disciplines within IT (information technology, information systems, web design, software development).	*Web design (10 credits)* Experiential learning of essential knowledge and concepts of web design • Multimedia – graphics, sound, video, text • Interactivity, scripting and/or database • Techniques and tools in media design, • Consideration of user experience, documentation and accessibility
1/5/15	Qualification Outcomes: 3. Contribute to user interface design using essential knowledge and concepts of web design. (Credits 10)	Programmes must include experiential learning of essential knowledge and concepts of web design including: • Multimedia – graphics, sound, video, text; • Interactivity, scripting and/or database content management system (CMS) • Techniques and tools in media design; • Consideration of user experience (Ux), documentation and accessibility.

Once again, some could argue that the changes are for the better – but, again, not all the changes were made by the working groups and therefore did not follow the agreed 'due processes. In making these changes to fit the NZQA Quality Assurance requirements, was meaning lost from the original 15 November, 2013 version in the 1 May, 2015 version that was listed and came into 'law'. Do the changes truly reflect the spirit and the meaning as created by the working parties or have the NZQA changes made some level of difference to the quality of the new qualifications? Further, are the ways that the credits are designed, which can be further particularized into discrete unit standards, a useful outcome, or another dilemma to manage?

3. STUDENT CENTRED LEARNING THEORY FOR EMERGING IT PROFESSIONALS

Given that the qualifications are now listed, it is helpful to address the issue of contemporary learning theory, as it applies to the students who enrol, participate, and complete these qualifications, with the goal of either being employed within the IT industry or continue into a higher qualification, such as a degree. What theories of learning are helpful to apply in this context?

Contemporary learning theory continues to identify that the needs of the learners are important to consider when constructing the curriculum and its delivery.

Maged (2014) considered complexity of ensuring preparedness of pre-service teachers to meet the needs of students in culturally diverse learning settings, and found that this varied in both programmes and their conceptual understanding. In other words, it is likely that there is a wide variation in understanding and expectation of students within computing, among those of us who are teaching them. The more diverse and inclusive the range of students becomes, including school leavers, women, adults retraining for a better career, international students, students with disabilities in the autism spectrum, transgender students, the greater the challenge to our understanding and delivery of meeting their learning needs.

Another discourse which is gaining ground within learning theory is the consideration that tests and examinations construct limitations and adverse consequences for learners, such as fear of failure, underachievement, and an over reliance on rote learning rather than deeper understanding that can be demonstrated in practical ways. It is suggested that performance based assessment, portfolio assessment, classroom based assessment, and authentic assessment are parallel or alternative means to adopt to eliminate these negative effects. However, it is equally important to not reproduce these conditions within alternative assessments, as the same negative outcomes can arise such as students fearing they will fail and suffering from performance anxiety which impairs performance (Tan, 2012).

Cognitive styles have been found to influence concepts of differentiation, with teacher trainees with higher levels of analysis and intuition having a more developed understanding than other cognitive styles. It is suggested that this may equally apply in IT education. The use of a constructivist pedagogical tool, a Personal Learning Styles Pedagogy, devised by Evans, Waring, Zhang and Sternberg, 2009, has been evaluated as an effective approach when developing appropriate scaffolding of learning (Evans & Waring, 2011) and could be applied in ITP educational settings. Gardner's model can be used to develop critical and creative thinking, which is part of algorithmic thinking (Saravanan, 2005).

Differentiation is a learning theory derived from cognitive science which suggests that new neural pathways are formed and strengthened within the brain by having multiple ways of encouraging them to develop. Interconnection and cross referencing builds IT knowledge, rather than memorising. Using different instruction and assessment reaches a wider range of students who possess diverse levels of prior learning, mastery, and motivation in mixed ability classes (Tomlinson, et al 2004). Further research of these approaches in IT education and its outcomes for student retention and completion can be explored.

4. CURRICULUM DESIGN, CONTENT DELIVERY, AND ASSESSMENT

Educational reform focuses on better ways of preparing students for a knowledge based economy, globalisation, and life in the 21st century. Generally, these goals are operationalised through adapting the curriculum, implementing new models of learning and innovation, lifelong learning, and the internationalisation of education (Lee, 2012).

One of the biggest challenges faced by tertiary IT educators is confronting the historical knowledge gap between primary and secondary schools' delivery of IT as a tool, as primarily for teachers (Jones & Cowie 2011) and developing an understanding that IT is an industry which requires trained and qualified IT professionals to be effective, innovative, and profitable. Further, while some schools have taken up the digital technologies curriculum, and teach business applications such as word processing and spreadsheets, computer science, (programming), digital media (web development), and infrastructure, (networking, CISCO and hardware) this is by no means nationwide.

While shortages in the workforce can be met by enabling skilled IT professionals as immigrants to take up these positions, this policy does not give opportunities to Aotearoa-New Zealand young adults, and adults seeking to retrain in a better career. Many ITP students have had little if any computer education. Their IT knowledge and skills are variable, school to school, and region to region.

This has also occurred in South Korea, where an absence of policy and comprehensive evaluation method has led to a decline of computer related subjects and students in computer education, since the computer science curriculum was implemented in 2007 (Choi, An, & Lee, 2015). Conversely, in Israel, wider provision of computer science education in high school has led to more engagement of both men and women to take up tertiary education and pursue an IT career (Armoni & Gal-Ezer, 2014).

In the United States, nine out of ten K-12 schools do not offer computer programming coursework. Only fourteen states require a student to fulfil math, science, or foreign language credit for high school graduation, two states require no computer science for that purpose, and four states award a special diploma, endorsement, or other recognition for high school graduates in computer science (Zinth, 2015). Gender inclusion is minimal. In 2013, 81% of Advanced Placement Computer Science A exam candidates were male, with 82.5% being white, Asian, Asian American, or Pacific Islander (Zinth, 2015).

Inclusion and diversity is the motivating ethical stance behind a new Computer Science programme, 'Exploring Computer Science' in Los Angeles which enables students from many backgrounds to study the fundamentals of computer science by working in group projects that are meaningful. Students work together to design web pages of interest, collect and analyse data about issues of interest, and build and program robots to dance to their favourite songs (Margolis, Goode, & Ryoo, 2015).

Further, being employed to essentially manage and analyse digital information and communication, acquiring and developing excellent interpersonal, written and spoken skills in a variety of business contexts, including with international clients, face to face and online, means that IT professionals need the same degree of fluency as those working in journalism, broadcasting, and business, in all its contexts. An analysis of the post MRoQ qualifications indicates the outcome has unfortunately not specifically developed content for that purpose. Having met the need for separate quantified technical skills related to the fields of networking, web development and multimedia, software engineering, and business analysis, the qualifications now overemphasize these aspects in the Certificate level, and then silo these fields into distinct entities, without fully addressing the communication needs of these future IT employees.

While there is full opportunity for emerging IT professionals to explore potential fields, by having a broad range of technical fields at Certificate level, there is little opportunity to master the commonly used business applications which underpin their work. Further, these qualifications integrate professionalism into each field, which poses a challenge for the IT educators. Innovative ways of integrating communication and professional practice into the curriculum delivery of IT technical skills presents a challenge. However, these important skills can be acquired through the ways that the technical curriculum is delivered and assessed.

Different approaches to bring about innovation in curriculum delivery have been researched. For example, maths and science lecturers participated in action research (Khiat, et al 2011). This may assist innovation to be taken up more broadly across ITPS, and discussion about the best ways to achieve change is a good starting point.

Research into effective curriculum design and delivery has highlighted the need for educators to have a strong belief in the value and effectiveness of innovative curriculum design, content, and delivery. Where such beliefs are strongly held and shape the method of instruction, there is a high correlation between teacher efficacy and constructivist instruction. Conversely, where there is a low belief in innovative curriculum design, there is a low correlation between teacher efficacy and didactic instruction (Nie, et al, 2013). Educators need space, time, and responsibility to make decisions about curriculum, and ensure that these align to required processes, which those in leadership roles must address, if successful outcomes are to be achieved (Chew & Andrews, 2010).

Challenging students are now more likely to be present within an IT classroom, as a global phenomenon (Pang, 2012). Negative affect, self critical attitude, and self efficacy beliefs account for how these students impact on their teachers, and their related stress, rather than the characteristics of the institution. Further, an emphasis on assessment for learning is effective where there are effective feedback practices, assessment for sustainable learning, and assessment for integrating holistic learning (Tan, 2011). It has been suggested that oppositional behaviour arises out of a deep feeling of educational and economic exclusion, and that while credentials and staying out of prison are understood, social and psychological benefits are sought through that response (Nolan, 2011).

Peer assessment does contribute to learning and involvement in the assessment processes where there is a high quality of peer feedback, ability with language, and a novel and un repetitive processes bring used ((Bryant & Carless, 2010).

So, we need to examine our current practices. Do exams override learning needs? Do we privilege learning of content over an understanding of methods and best practices? Do we worry about pass rates rather than see that our retention and success rates reflect excellence in meeting the needs of our learners to acquire relevant and essential IT knowledge and skills?

5. LEARNING SPACES

Sectors where delivery of IT skills takes place are likely to change into the future, and with this, educational goals, structure, policy and practice. Conservative-hierarchical, pragmatic-competitive, and utopian-co-operative scenarios have been predicted (Power, 2009).

The growing importance of having learning spaces that are diverse and foster skills and knowledge development is a recurring theme in educational literature. One of the dimensions implicit in becoming an IT professional is the recognition of the importance of creativity. A recent study of 1069 computer and non-computer scientists in China, and 971 in United States articulated creative computer scientists as being smart/effective, outgoing, creative thinking, and unsociable. (Tang, Baer, & Kauffman, 2015). How can a learning space enable and be responsive to these qualities, and their effects?

Given that most ITP IT education traditionally takes place in computer suites, where students sit at a computer and undertake labs, and in classrooms, where students sit at desks, in rows, or groups, and face towards a screen and to varying degrees, listen to a person, with whom they may or may not interact, it is timely to take up the challenge of experiential learning that has been embedded into the novice qualifications.

Kolb and Kolb (2005) suggest learning spaces as a framework to consider the interaction between student learning styles and an institutional learning environment. This is beyond the view of a space as being solely a physical entity, though it is a component. Thinking has moved beyond this (Cannon, 1981) yet the need to consider how information is being presented, to or by learners, the kind of interaction, and the kind of activity that learners are engaged in, are still central to the success of that learning space.

Brown and Long (2006) consider that three trends have been identified which impact on learning spaces. These include: the need to incorporate social and active learning strategies that are based on learning principles; recognition of human centred design, and the use of diverse devices to enable learning. Further, these trends arise out of education being seen holistically, and delivered within a constructivist learning paradigm, with digital technologies.

They suggest that learning environments need to provide availability of food, drink, comfortable chairs and furniture, as well as accessing digital technologies. Active learning, formative assessment, social engagement, mobility and multiple pathways through content take place within. Suggesting that the whole campus is a place for learning, is taken up by the EPIC Centre, in Christchurch, where IT companies deliberately mix staff in a common setting and forums to share strategies and knowledge for successful innovation (Wendy Rockhouse, personal communication, 4 August, 2015). Further, site visits, to learn about workplace culture and to participate in the working environments of agile programming have been taken up in some ITPs.

It is not a step too far to envisage that future learning in IT may take place not within academic institutions, but in places like EPIC, where novice programmers, game designers, and web developers, learn skills and best practice, and who move between learning and working in a workplace setting. What can be done to foster this, to stimulate f innovation in pedagogy and IT as an industry?

6. CONCLUSIONS

The qualification reforms are only one way in which we need to adopt change, and continual improvement in our pedagogy. Small finite unit standards of learning run counter to research about how people best learn in the 21st century. As we implement these changes, it is the hope of the authors that this paper gives some encouragement to look with fresh eyes on what we are doing in teaching and learning IT as academics with our students.

7. RECOMMENDATIONS

CITRENZ encourages innovation in pedagogy within the implementation of the new post MRoQ listed qualifications in ITPs.

This may include; sharing of best practice through observation, workshops, and the development of curriculum delivery, that is grounded within appropriate innovative learning theory and practice, and explores new learning spaces and relationships with the IT industry to foster collaboration and co-operation to meet the learning needs of emerging IT professionals in ITP settings.

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