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Towards a New Undergraduate ICT Curriculum for Universities of Technology in South Africa

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Background and purpose of study

This paper presents salient aspects of the national discourse around the development of a suite of industry-oriented ICT vocational programmes to be hosted and delivered mainly by Universities of Technology in South Africa.

The curriculum development effort was commissioned by the Higher Education ICT Association[1] (HEICTA), a consortium of Universities of Technology[2] and Comprehensive Universities[3], in collaboration with broad representation from the national ICT industry.

The curriculum model is referenced to the latest South African "Framework for Qualification Standards in Higher Education" (HEQF) [1]. The curriculum model furthermore provides an interpretation of the role of Universities of Technology in the context of the South African Higher Education landscape based on the seminal works of Roy du Pré [2, 3].

The curriculum development process is also specifically informed by the CSIR[4] Meraka Institute's "ICT Research & Development and Innovation (RDI) Implementation Roadmap" project [4], where the relevance of the curriculum to the needs of the ICT industry is interrogated with specific reference to re-energizing the national ICT economy for competitiveness and creation of employment.

The curriculum design incorporates structured articulation between the Further Education and Training (FET) sector to the Higher Education sector and will attempt to address the "inverted pyramid crisis" within the South African education landscape [5].

Methods

An action research approach was adopted to realise the macro curriculum model under the auspices of HEICTA. The method involved cyclical and iterative engagement of the curriculum development task where objectives, structure, practice, implementation mechanisms and more were treated towards synthesising curriculum alignment with the aforementioned development imperatives. The curriculum modelling culminated in seven areas of specialisation within ICT being identified. Universities within the HEICTA consortium were mandated to undertake detailed curriculum development of selected specialisations.

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1 The author is the current Chairperson of HEICTA

2 Cape Peninsula University of Technology (CPUT), Vaal University of Technology, Central University of Technology, Mangosutho University of Technology, Durban University of Technology

3 University of Johannesburg, Nelson Mandela Metropolitan University, Walter Sisulu University

4 Council for Scientific and Industrial Research, South Africa

The Focus Group method [6] was preferred for implementing the detailed curriculum development project. All relevant forums, such as - industry advisory committee meetings and inter-institutional meetings, were used to feed the curriculum development process.

The specialisations were benchmarked against the Organising Framework for Occupations (OFO) of the South African Department of Labour [7] and the Association for Computing Machinery (ACM) body of knowledge [8], for implementation relevance and academic conformity respectively.

A pilot implementation of the content and delivery methodology is planned (for 2012) and formal research initiatives have been defined to evaluate the efficacy of the proposed new curriculum.

Results

The paper reports on the transformation of Universities of Technology through curriculum development from being mainly teaching institutions towards becoming institutions of research and development. This marks an academic shift from programmes focussed mainly towards technological skills transfer towards broad curriculum alignment to national development imperatives. This shift features the promotion and facilitation of knowledge skills, technological competencies, critical cross-field skills and attitudinal skills of students. It is proposed that this academic shift will enhance the skilfulness of University of Technology and Comprehensive University graduates to enable economy-changing shifts in the ICT industry by unlocking the potential of graduates to engage in innovative practices.

Roy du Pré (2010) further underscores the need of Universities of Technology to provide leadership in technology through R&D programmes and platforms for promoting innovation and technology transfer [3]. He also petitions for Universities of Technology to embrace the values of "globalisation and democratisation" in developing curricula or to state it more colloquially - "think globally, act locally". Technology leadership will be achieved through "curriculum development around the graduate profiles defined by industry" and by affording cognitive skills development equal status to technological competency.

The macro model for the curriculum development process for a new suite of ICT qualifications was initiated and managed by HEICTA. The first qualification to be developed by HEICTA was a three-year Diploma qualification which made provision for specialisation in one of seven areas, namely – Applications Development, Business Informatics, Communication Networks, Data Management, Intelligent Industrial Systems, Multimedia Technology and Support Services. These areas of specialisation were established through extensive research, international benchmarking and national discourse involving the ICT industry and the academic institutions within the HEICTA consortium. Universities could opt to offer one or more specialisations. A one-year Higher Certificate qualification was developed to serve as both an integrated foundation year for the Diploma qualification and an alternate access path to the Diploma qualification, other than Matric – the South African secondary schooling certificate. The combination of Higher Certificate and Diploma offerings is considered to constitute an "extended curriculum" approach for improving efficiency and throughput. It is intended that Further Education and Training (FET) colleges be allowed to offer the Higher Certificate qualification on a franchise basis in collaboration with a hosting University of Technology or Comprehensive University. It was further intended that the first year of the Diploma be structured to

maximise articulation from the Higher Certificate and provide a common platform for supporting the various specialisation offerings of a specific university. HEICTA will support further curriculum development initiatives to deliver a comprehensive suite of ICT qualifications, including – an Advanced Certificate, an Advanced Diploma, a Postgraduate Diploma, a first Degree, a Master's Degree and a Doctoral Degree.

HEICTA proposed that the purpose of the Diploma qualification is to provide a career-focussed professional qualification featuring industry-referenced skills transfer with regard to knowledge skills, technological competencies, critical cross-field skills and attitudinal skills. A Diploma graduate will be knowledgeable and competent in the discourse and practice of the ICT discipline; but also have specialist knowledge of a particular sub-discipline of ICT; and would have been subject to a range of professional and personal development initiatives relevant to the ICT industry and lifelong learning respectively.

HEICTA has identified a set of Generic Exit Level Outcomes for the Diploma qualification, as presented in Table 1 (below):

Table 1: Generic Exit Level Outcomes for the Diploma qualification

All Diploma graduates in ICT are able to:
• Demonstrate knowledge and competency of specific technical concepts and practices that define the ICT discipline and industry,
• Communicate effectively within the ICT discipline and recipient disciplines,
• Act professionally and ethically in delivering ICT services and products,
• Apply ICT solutions towards improving business and social environments,
• Produce software programming solutions appropriate to the field of specialisation,
• Solve problems through creative and innovative implementation of ICT solutions,
• Demonstrate defined project management skills,
• Demonstrate knowledge of Information Security concepts as a salient component of ICT service provision,
• Collaborate effectively in project teams to accomplish specific goals,
• Engage in the effective delivery of an integrated capstone project and associated portfolio of evidence, featuring - knowledge, competencies, critical cross-field, and attitudinal skills; and techniques specific to the specialisation, and
• Demonstrate knowledge of best practices and performance standards in the area of specialisation.

HEICTA has also identified a set of Specialised Exit Level Outcomes for each of the seven areas of specialisation in the Diploma qualification, as presented in Table 2 (below):

Table 2: Specialised Exit Level Outcomes for the Diploma qualification

Diploma graduates in ICT specialising in Applications Development are able to: • Create and modify general computer applications software or specialised utility programs for stand alone and distributed environments including the web environment, • Analyse user needs and produce a suitable specification for a system, covering a medium sized business problem, • Develop computer programs to demonstrate the ability to store, locate and retrieve information from different data sources, and • Deploy a suitable, secure software solution based on a given scenario demonstrating an understanding of systems architectures.
Diploma graduates in ICT specialising in Business Applications are able to: • Analyse business and system requirements for SMME business problems towards an ICT solution, • Design an ICT solution for SMME business problems, • Compile and execute a test plan to validate an ICT solution, and • Assist in the alignment of ICT and business processes to integrate an ICT solution into the business.
Diploma graduates in ICT specialising in Database Applications are able to: • Administer databases, using appropriate database administration tools and techniques, to ensure the efficient running of the business systems, • Configure a database to specified performance levels and availability criteria, • Interact with data sources to satisfy organisational data requirements, • Create physical data structures to match a given logical model, and • Maintain a Database Management System to comply with changing business environments.
Diploma graduates in ICT specialising in Communication Networks are able to: • Develop communication networks in response to a needs assessment, • Solve communication network problems for various given scenarios, • Administer a communication network, and • Implement and maintain a secure communication network.
Diploma graduates in ICT specialising in Intelligent Industrial Applications are able to: • Integrate basic embedded design principles and technical programming concepts in order to generate autonomous intelligent industrial automation systems, • Develop specific embedded solutions within the factory automation domain, • Analyse industry processes and models in order to develop hardware and software simulations, and • Develop autonomous robotics for intelligent industry automation.

Diploma graduates in ICT specialising in Multimedia Applications are able to: • Design multimedia presentations and applications using appropriate technologies, • Communicate conceptual information effectively in the digital medium, • Design multimedia elements according to aesthetic and technology design principles for use in integrated multimedia presentations and applications, • Develop multimedia presentations and applications integrating various multimedia elements on a given platform, and • Employ a variety of multimedia technologies according to protocols and standards.
Diploma graduates in ICT specialising in Support Services are able to: • Identify the various types of end users and explore their possible needs in different ICT support environments, • Troubleshoot and maintain computer devices used by end users, • Support end users in the use of existing standardised company software packages, and • Manage ICT service centres in alignment with ICT policy.

The academic standard of the curriculum is governed by the National Qualifications Framework (NQF) [1]. The Diploma (in ICT) is offered essentially at NQF level 6, with the Higher Certificate and the first year of the Diploma being presented at NQF level 5. The NQF has been restructured since this research was conducted. This implementation of the curriculum still features half of the third year credits being offered at NQF level 7.

The NQF requires that the curriculum be specified against various specific dimensions that declare the depth of exposure of the proposed learning experience. Table 3 (below) presents the specification of NQF Dimensions for Generic Outcomes:

Table 3: S NQF level vs. NQF Dimensions for Generic Outcomes

NQF Dimension	**NQF5**	**NQF6**	**NQF7**
Scope of Knowledge	Broad disciplinary knowledge	Specialist disciplinary knowledge	Specialist professional knowledge
Knowledge Literacy	Awareness of the BOK	Explanation of schools of thought	Rationalisation of contested knowledge
Method and procedure	Apply standard methods	Select appropriate methods	Select methods
Problem solving	Defined problems in familiar contexts	Defined problems in unfamiliar contexts	Complex real-world problems
Ethics and professional practice	Awareness of Code of Ethics	Awareness of Ethical Dilemma	Demonstrate ethics and professionalism
Accessing, processing and managing information	Basic information literacy	Selective information gathering	Strategic information gathering and validation

Producing and communicating information	Understanding of IP, copyright and plagiarism	Present complex information reliably	Present own ideas, arguments, and engage professional discourse
Context and Systems	Familiar contexts and intra-system interactions	Unfamiliar contexts and inter- systems interactions	Awareness of actions and decision on inter-systems performance
Management of learning	Structured learning	Task-specific and peer supported learning	Self-directed and collaborative learning
Accountability	Record of own actions	Management and record of group actions	Management of group tasks in contested environment

The specification of NQF Dimensions for each of the seven Specialised Outcomes also needs to be developed (similar to the table above) in order to focus the Learning Outcomes for the specialisations.

The next task in the curriculum development process is to develop the Learning Outcomes. It is not within the scope of this paper to report on the actual Learning Outcomes developed. It is perhaps instructive to share the framework against which Learning Outcomes were developed as presented in Table 4 (below):

Table 4: Framework for Developing Learning Outcomes

Learning Outcomes (Knowledge)	At the end of this topic the student will be able to: NQF5, Comprehension: Explain… NQF6, Analysis: Analyse… NQF7, Evaluation: Appraise…
Learning Outcomes (Competencies)	At the end of this topic the student will be able to: NQF5, Application: Prepare/produce… NQF5, Synthesis: Formulate… NQF6, Synthesis: Design… NQF7, Synthesis: Develop/implement…
Learning Outcomes (CCF Skills)	At the end of this topic the student will be able to: Communicate effectively in formal oral presentation re... Communicate effectively in formal written correspondence re... Communicate effectively in academic writing re... Strategically gather information re... Creatively extend conception re... Critically analyse (selected) aspects re... Solve problems re... Participate in teamwork and contribute to outcomes re... Strategic planning re...

Learning Outcomes (Attitude)	At the end of this topic the student will show journal/portfolio evidence of activity and/or reflective engagement of: Self-awareness / Time Management / Vision / Wellness ...as part of a personal development plan Ethics / Professional Code of Conduct / Cross-cultural Awareness / Career Planning ...as part of a structured professional development programme

The Learning Outcomes thus having been generated, the final stage of the curriculum development process is to develop the Assessment Criteria. The strategy adopted was to deploy "standardised" assessment rubrics for various "academic literacies" to elucidate the NQF Dimensions. It was fortuitous that the Association of American Colleges and Universities (AACU) had already done most of the ground work [11]. It is however expected that Assessment Criteria would vary from institution to institution.

Table 5 (below) illustrates the relatedness of "Academic Literacies" or Assessment Rubrics to NQF Dimensions:

Table 5: Academic Literacies / Assessment Rubrics vs. NQF Dimensions

NQF Dimension	**Academic Literacy / Assessment Rubric**
Scope of Knowledge	Reading Written Communication Critical Thinking
Knowledge Literacy	Inquiry and Analysis
Method and procedure	Integrative Learning
Problem solving	Problem Solving
Ethics and professional practice	Ethical Reasoning
Accessing, processing and managing information	Information Literacy
Producing and communicating information	Oral Communication Quantitative Literacy Intercultural Knowledge and Competence
Context and Systems	Creative Thinking
Management of learning	Lifelong Learning
Accountability	Teamwork

Table 6 (below) provides the expanded dimensions of the AACU Assessment Rubrics [11]:

Table 6: AACU (VALUE) Assessment Rubrics

Reading	Comprehension; Genres; Relationship to text; Analysis; Interpretation, Reader's voice
Written Communication	Context and purpose for writing; Content development; Genre and disciplinary conventions; Sources and evidence; Control of syntax and mechanics

Critical Thinking	Explanation of issues; Evidence; Influence of context and assumptions; Perspective; Conclusion
Inquiry and Analysis	Topic selection; Extant BOK; Design process; Analysis; Conclusion; Limitations and implications
Integrative Learning	Connections to experience; Connections to discipline; Transfer; Integrated communication; Reflection and self-assessment
Problem Solving	Define problem; Identify strategies; Propose solution; Evaluate potential solutions; Implement solution; Evaluate outcomes
Ethical Reasoning	Ethical self awareness; Different ethical perspectives; Ethical issue recognition; Application of ethics; Evaluation of ethics
Information Literacy	Determine extent of information need; Access the needed information; Evaluate information and its sources critically; Use information effectively; Access information ethically and legally
Oral Communication	Organisation; Language; Delivery; Supporting material; Central Message
Quantitative Literacy	Interpretation; Representation; Calculation; Application / Analysis; Assumptions; Communication
Intercultural Knowledge and Competence	Culture of self-awareness; Knowledge of cultural worldview frameworks; Empathy; Verbal and non-verbal communication; Curiosity; Openness
Creative Thinking	Acquiring competencies; Taking risks; Solving problems; Embracing contradictions; Innovative thinking; Connecting, synthesising and transforming
Foundations of Lifelong Learning	Curiosity; Initiative; Independence; Transfer; Reflection
Teamwork	Contributes to team meetings; Facilitates the contribution of team members; Individual contributions outside of team meetings; Fosters constructive team climate; Responds to conflict

The Cape Peninsula University of Technology (CPUT) Case Study

This section presents a particular interpretation of the new curriculum model to CPUT.

CPUT has opted to offer only three specialisations in its offering of the Diploma in ICT qualification, namely – Applications Development, Communication Networks and Multimedia Applications. The CPUT Higher Certificate qualification focuses on IT Services with an ITIL "flavour".

With due recognition for the need to comply with the academic standards as articulated in Table 3, the vertical progression through the qualification is further governed by a thematic interpretation of NQF per level of the qualification. Horizontal coherence of the curriculum is achieved by featuring an integrated project at each level of the curriculum.

Figure 1 (below) illustrates the implementation of Curriculum Focus, Assessment Approach, and Academic Literacy exposure achieved in the CPUT curriculum statement.

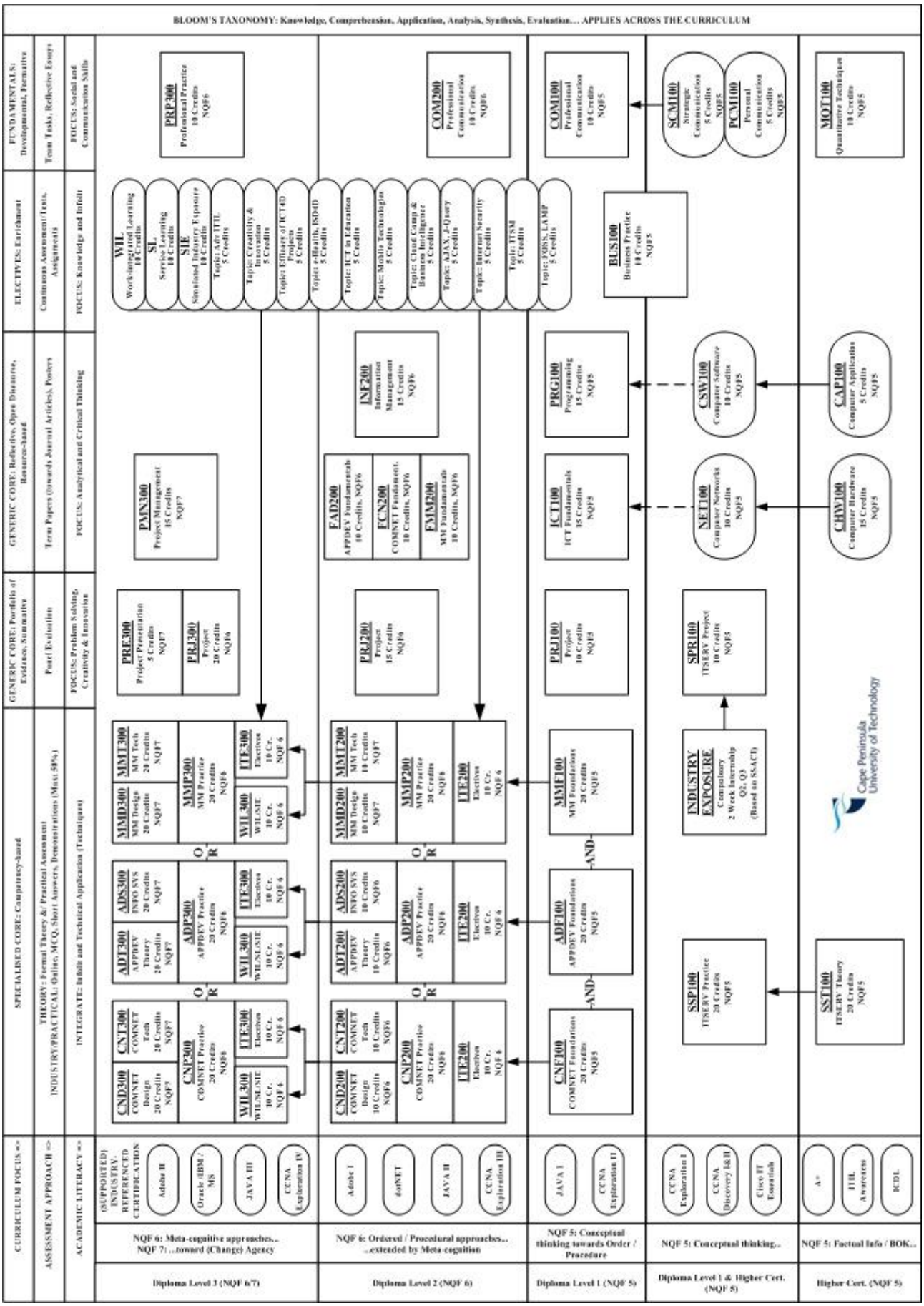

Figure 1: CPUT Curriculum Implementation

With reference to Figure 1 (above): It should be noted that a number of industry-referenced certification options are supported and mapped to the new curriculum as a value-add offering to students. Content is presented in various categories, namely - specialised core, generic core, elective and fundamental. The new curriculum model features – the incorporation of a Higher Certificate qualification as a foundation qualification to the Diploma qualification; a common first year for the Diploma for all specialisations; multi-level and multi-focus assessment rubrics incorporated into curriculum statements; and the incorporation of value-adding industry-referenced qualifications across the curriculum.

Figure 2 (below) illustrates the implementation of a new organisational model for CPUT to support the new curriculum. The model incorporates strategies for effectively realising Work-integrated Learning (WIL), Service Learning (SL) and Simulated Industry Exposure (SIE) programmes. CPUT has established several Business Units and Portfolio areas to be responsive to the needs of students, the community and industry. Short courses (or non-formal courses) are a strategy to allow the university to offer "just-in-time" education to the industry and community.

CPUT will engage in strategic partnerships and industry collaboration to ensure the continued relevance of its curriculum. Of particular note is the establishment of academic collaboration with the FET sector. CPUT will offer its Higher Certificate qualification at three FET colleges on a "franchise basis" as of 2013, namely – College of Cape Town, Northlink FET College, and False Bay FET College.

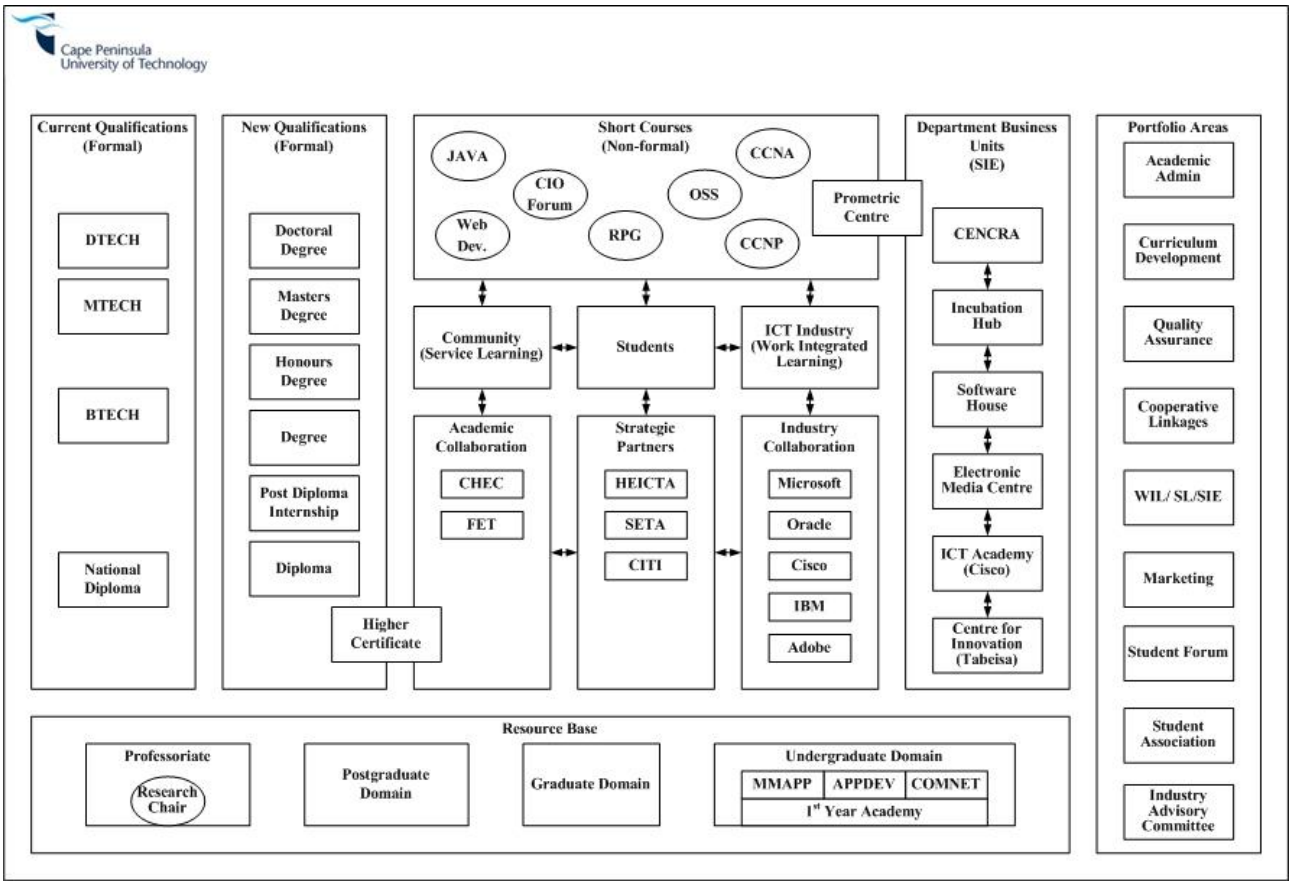

Figure 2: CPUT Organisational Model

Discussion

Discussion is lead around the success modelling and organisational change requirements to support the aspirations of the new undergraduate ICT curriculum for Universities of Technology and Comprehensive Universities in South Africa.

The CSIR Meraka Institute's ICT RDI Roadmap reflects on the state and capabilities of national and key regional ICT industries; and provides analysis and contextualising of these industries to global trends [4]. The report provides a strategic framework for focussing ICT enterprise towards energising national and regional economies and enhancing the global competitiveness of the ICT industry and community development. Higher Education institutions, notwithstanding its broader academic mandate, are required to develop human resources and engage in research and development initiatives in response to the needs of industry and the community. In this regard, the report issues a challenge to Higher Education institutions to facilitate access to ICT education and increase both the quantity and quality of graduates; and to align the curriculum to the ICT RDI Roadmap with respect to the exposure of specific technologies. The report however clearly articulates that the development of ICT capabilities is not the sole responsibility of Higher Education institutions but rather that of partnership arrangements between Higher Education, multi-national companies, large corporations, the SME sector, government, non-government organisations and also communities; or what the report refers to as establishing an "ICT RDI ecosystem". The report identifies various specific regional ICT focus areas and also provides a consolidated set of "market opportunities" at both national and regional levels. Higher Education institutions should interrogate this data within their own curriculum and business models. The petition is therefore clearly for a living curriculum within a flexible organisation where there is keen awareness of national and regional aspirations for wanting to engage specific technologies and the consequent demand for specific technological and other skills. It is also evident that innovation and trans-disciplinary thinking should be the cornerstones of the new curriculum. Graduates should not only have strong disciplinary skills but should be broadly skilful and be able to perform as change agents within the ICT industry and recipient industries and disciplines, i.e. business and social environments.

Traditional Universities, by definition, are well established and their roles with respect to scholarly endeavour are generally well understood. Comprehensive Universities are mandated to offer both Traditional University and new University of Technology type programmes. Universities of Technology were established from Technikons which were teaching institutions focussing on technology transfer within career-focussed programmes. Roy du Pré (2009) in interrogating "the place and role of (the new) Universities of Technology in South Africa", deals with a number of pertinent aspects towards establishing a shared conception of the potential of these institutions [2]. The defining attribute of a University of Technology is its responsiveness to community and industry needs. Curriculum alignment to industry and community needs is realised through Work-integrated Learning and Service Learning programmes respectively. The phrase "just-in-time education" is used to accentuate the responsiveness and flexibility of the University of Technology as core values in its service provision. The University of Technology has a mandate for "right-skilling" through its formal programmes and "re-skilling" the workforce through non-formal short courses, and revitalising the workforce towards economic and social redress. Teaching and Learning must remain the foundation of Universities of Technology, but it is incumbent on these institutions to actively promote innovation and

technology expertise through Research and Development and Innovation programmes – as articulated in the ICT RDI Roadmap.

The Organising Framework for Occupations (OFO) of the Department of Labour indentifies the competencies and key performance areas typically associated with various occupations, and includes "the listing of scarce and critical skills" [8]. The OFO identifies two "Major Groups" (or categories) of employment for ICT practitioners, namely – (1) the ICT Professional and (2) the ICT Technician. Each of these "Major Groups" is further resolved until a specific designation, specialisation and key performance areas are identified. It is required of curriculum developers to be familiar with the specifications of the OFO in order to ensure the efficacy of the curriculum.

Table 7 (below) illustrates an example application to the OFO towards contextualising the occupation of a Web Developer:

Table 7: Example Application of the OFO

OFO Code	OFO Category	Descriptor
2	Major Group	Professionals
25	Sub-major Group	ICT Professionals
251	Minor Group	Software and Applications Developers and Analysts
2513	Unit Group	Web and Multimedia Developers
251302	Occupations	Web Developer
No code	Specialisation	Website Architect

It was decided to use the 2008 "Information Technology Body of Knowledge" framework of the Association for Computing Machinery (ACM) as benchmark for informing the development of Learning Outcomes and validating the HEICTA macro curriculum [9]. The HEICTA curriculum was developed from first principles in a pragmatic approach of surveying academics and industry, conducting focus group sessions and iteratively developing the curriculum statement. The methodology for establishing the ACM statement is not known to this author. The HEICTA curriculum does however have some common characteristics with the ACM curriculum (but will not be further explored here).

Conclusion

This paper provides insight into the discourse around the development of a new undergraduate ICT curriculum for mainly Universities of Technology in South Africa that is an interpretation of the national qualifications strategy and development aspirations towards a vital ICT-driven economy.

The paper presents discussion on considerations of quality assurance and performance criteria and management; and reflects on the skills requirement and re-skilling strategies for lecturing staff.

The establishment of a broad support network[5] at both a local and national level is deemed essential for the successful implementation of the new curriculum to provide ongoing curriculum reflection and refinement; and to provide the necessary academic and environmental development to support roll-out, e.g. scholarships for students, funding for infrastructure development.

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[5] For example - BITF, Citi, City of Cape Town, CSIR Meraka Institute, CSSA, Department of Communications, Department of Science and Technology, MICSETA, Provincial Government of the Western Cape, SACPO, SATN