Designing and Developing ICT Curriculum in the 21st Century using a Modernistic Curriculum Model in Contemporary Higher Education

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Abstract

The design and development of ICT curriculum at higher education institutions in recent times is highly complex. The aim of this paper is to present a product model for the design and development of a variety of three year ICT programme types. This is achieved by conducting an in-depth study into existing ICT product models as well as extrapolating the critical skills for students in the 21st century from the extant of literature. The strategy of inquiry employed was a case study of curriculum renewal in the Department of Information Technology at the Durban University of Technology. The research study was qualitative with Participatory Action Research and Focus Group Interviews employed for data collection. The findings resulted in the creation of a best practice product model for the renewal of ICT curriculum. This model impacts how ICT programmes are designed and developed at higher education institutions in the 21st century. As an implication of this study the researchers suggest that this model be reviewed and updated regularly to accommodate the dynamic nature of ICT.

Keywords: *curriculum design; product model; curriculum model; curriculum renewal; general education*

1. Introduction

Information and Communication Technology (ICT) is constantly changing and improving the practices within all aspects of life in the 21st century (Sharma, 2011). This has led to rapid advances in technological developments (Ekstrom et al., 2006). Routine tasks are being automated and knowledge is rapidly increasing and becoming specialized (National Assessment and Accreditation Council Bangalore India, 2007). Consequently, there is a lack of qualified people for the higher number of jobs linked to new technologies (Career Space, 2001).

It is the responsibility of higher education institutions to design and deliver high quality education to competent individuals by equipping them with the relevant knowledge, values and skills to solve the needs of society in their chosen discipline (National Assessment and Accreditation Council Bangalore India, 2007). It is therefore crucial for higher education institutions that offer ICT programmes to adequately meet the demands of ICT (Ekstrom et al., 2006). Graduates of this century must be equipped with skills to adapt, innovate, communicate, share and use information to solve complex problems (Binkley et al., 2010).

However the design of ICT curriculum in the 21st century is neither simplistic nor linear and it is apparent from the literature that researchers hold different meanings on what constitutes an ideal curriculum model. Alexander (2012) believes that factors such as access, articulation, core knowledge, specializations and electives need to be considered (Alexander, 2012). While Ekstrom et al. (2006) proposes that ICT knowledge areas are important to take into consideration, Noll and Wilkins (2002) propose a curriculum matrix that incorporates business knowledge, advanced information systems applications, programming, user support and analysis. Hence there exists a need to evaluate existing models to create a modernistic model for the design and development of ICT curriculum in the 21st century.

The following key questions are answered:

1. What are the existing models available for ICT curriculum renewal?
2. Can the components of existing models be used to create a modernistic ICT curriculum model whilst at the same time taking into consideration critical skills for ICT professionals in the 21st century?
3. Can the now synthesized modernistic ICT curriculum model be validated empirically?

2. Literature Review

In line with the research questions, we firstly review the extant literature as it relates to existing ICT product models as used in this paper, and secondly identify critical skills required for ICT professionals in the 21st century.

2.1 Existing ICT curriculum models for curriculum design

A curriculum is often described as a course of study offered by an academic institution (Career Space, 2001) . Green (1998) defines curriculum as the formal and informal process by which learners gain knowledge and understanding, develop skills, and improve attitudes and values. When a curriculum undergoes a review or change, it involves re-planning the breadth or scope of knowledge in accordance with the current expectations of society (Green, 1998).

The curriculum design and development literature abounds with frameworks and models commonly viewed as either product or process models (O'Neill, 2010). A product model emphasizes plans and intentions and a process model emphasizes activities and effects (O'Neill, 2010). A model helps designers to systematically and transparently map out the curriculum (O'Neill, 2010). The scope of this paper is to derive a product model for the renewal of ICT curriculum in the 21st century.

Tyler's product model applies the following basic principles for constructing the learning environment: identify the rationale of the curriculum, define the educational experiences related to the rationale, describe the organization of the educational experiences and define the evaluation of these experiences(O'Neill, 2010). Due to its high degree of prescription, this model provides a sense of security and promotes standardisation of a curriculum (Koo Hok-chun, 2002). A variation of Tyler's model, the Backward Design Model focuses on setting goals using graduate attributes and competencies (skills required) before choosing instructional methods and forms of assessment(Wiggins & McTighe, 2005).

Table 1 includes a summary of the seven principles defined by the Angus Council (2002) for ensuring excellence in curriculum design.

Table 1. The seven principles of curriculum design (Angus Council, 2002)

Principle	Description
Challenge and enjoyment	Active learning opportunities to develop and demonstrate creativity.
Breadth	Opportunities for a wide range of activities to improve learning.
Progression	Progressively building on earlier knowledge and achievements.
Depth	Draw on different strands of learning and achieve more advanced levels of understanding
Personalisation and choice	Curriculum should respond to individual needs and support particular aptitudes and talents.
Coherence	Learning activities should combine to form a coherent whole. There should be clear links between the different aspects of learning.
Relevance	Learning activities must be relevant to the present and the future.

A well-designed curriculum provides learners with the necessary skills to sustain their learning by ensuring that their learning experiences are challenging, engaging, motivating and relevant (Angus Council, 2002).

Although it is essential for ICT graduates in the 21st century to be equipped with a wide-range of technical, personal and business skills, an emphasis on lifelong learning is equally important (Career Space, 2001). Working in teams on real life projects or simulations thereof narrows the skills gap between higher education and industry (Career Space, 2001). A study conducted in Europe revealed that these skills are required by both SME's (Small to Medium Enterprise) and larger companies (Career Space, 2001). This study resulted in the following model for ICT curriculum design that highlights the graduate competencies using a two co-ordinate axes (Depth of Knowledge and Breadth of Knowledge) as depicted in Figure 1.

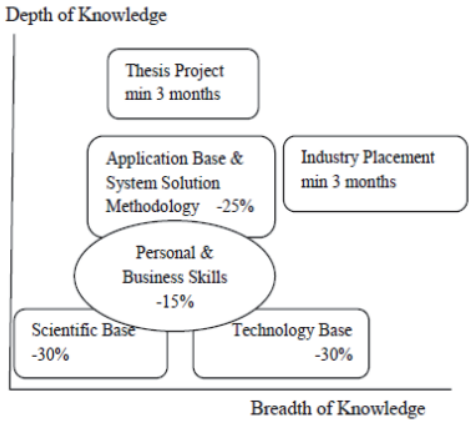

Figure 1. ICT curriculum model emphasising Breadth and Depth of knowledge (Career Space, 2001)

The design of ICT curriculum that incorporates the above model should consist of the following hierarchically organised units (Career Space, 2001):

(a) sets of core modules;
(b) sets of area−specific core modules;
(c) sets of optional (elective) modules.

When designing a robust curriculum, it is important to include relevant stakeholders, review current curricula and assess existing resources (Noll & Wilkins, 2002). The curriculum model implemented by Noll and Wilkins (2002) was used to design a curriculum for Information Systems (IS) which is a field of ICT. Data pertaining to the enrolment of students into a programme and the recruitment and placement of graduates informs the ongoing process of curriculum renewal (Noll & Wilkins, 2002).

The study revealed the importance of integrating general education skills like writing, working in teams, delivering presentations, managing projects and developing interpersonal skills into a curriculum (Noll & Wilkins, 2002). The IS curriculum matrix in Figure 2 was derived from the Noll and Wilkins (2002) curriculum development model.

Core Skills—Required for All Concentrations	***Elective Areas for All Concentrations— Offered as Special Topics***
▪ Knowledge of business functional areas ▪ Ability to interpret business problems and develop appropriate technical solution ▪ Ability to understand the business environment ▪ Knowledge of specific industry ▪ Ability to work collaboratively in a team project environment ▪ Ability to develop and deliver effective, informative and persuasive presentations ▪ Ability to plan, organize, and lead projects ▪ Ability to plan, organize, and write technical manuals, documentation, and reports	▪ E-Commerce ▪ DSS-GSS ▪ Expert Systems ▪ Knowledge Management Systems ▪ Executive Support Systems

Concentrations		
Programming—	**Analyst—**	**User Support—**
Required Areas ▪ Database modeling & development ▪ Software applications development & selection ▪ CASE tools ▪ Languages: C++; Java; web related	**Required Areas** ▪ Hardware acquisition (evaluation and selection) ▪ Systems analysis ▪ IS planning, management & evaluation ▪ Information access & security	**Required Areas** ▪ Telecommunications/ networks ▪ End-user computing support ▪ Help desk/information center ▪ Training/education
Elective Areas ▪ Hardware acquisition (evaluation and selection) ▪ Systems analysis ▪ IS planning, management & evaluation ▪ Information access & security	**Elective Areas** ▪ Database modeling & development ▪ Software applications development & selection ▪ CASE tools ▪ Languages: C++; Java web related ▪ Telecommunications/networks ▪ End-user computing support ▪ Help desk/information center ▪ Training/education	**Elective Areas** ▪ Hardware acquisition (evaluation and selection) ▪ Systems analysis ▪ IS planning, management & evaluation ▪ Information access & security

Figure 2. Proposed IS Curriculum matrix (Noll & Wilkins, 2002)

The progressive curriculum model presented in Figure 3 used Backward design to develop undergraduate ICT qualifications for Universities of Technology in South Africa (Alexander, 2012). The model satisfies the requirements of higher education, industry and vendor specific certification programmes (Alexander, 2012).

The key feature of this progressive model is that it promotes access to ICT education and internship programmes as well as articulation between a higher certificate and diploma (Alexander, 2012). The model allows for specialization and flexibility through the inclusion of core, specialization, fundamental and elective modules (Alexander, 2012). Professional and personal communication is emphasized across all years of study (Alexander, 2012). The common first year of study provides the foundational or base knowledge which allows students to make an informed decision before choosing their specialization area ((Alexander, 2012);(Noll & Wilkins, 2002)).

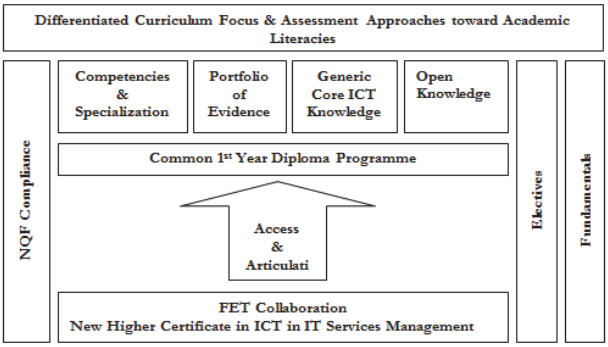

Figure 3. Progressive Curriculum Model (Alexander, 2012)

Software Engineering is a discipline in ICT which focuses on the development of models, requirements engineering, high-level design, software processes, quality engineering, working in teams**,** testing, measurement and analysis, and planning (Hilburn & Bagert, 1999). The high level of skills expected of a Software Engineer requires a curriculum that is dynamic and well-designed (Hilburn & Bagert, 1999).

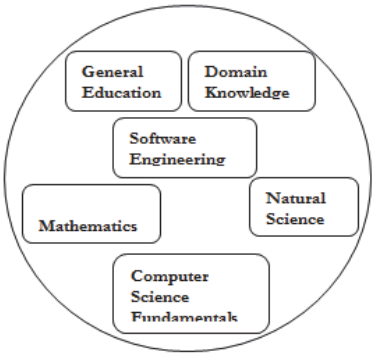

Figure 4. Curriculum Content Model (Hilburn & Bagert, 1999)

The Software Engineering Curriculum Content model in Figure 4 includes domain knowledge, software engineering, mathematics, natural science, computer fundamentals and general education (Hilburn & Bagert, 1999). The model promotes a balance between product activities and process activities in curriculum design. Ethical, professional and social issues that are related to the discipline as well as team work and team dynamics is emphasised (Hilburn & Bagert, 1999).

The existing ICT curriculum models presented in this paper have applied the key principles of curriculum design as identified in Angus Council (2002). Arising from Alexander (2012), Hilburn and Bagert (1999), Noll and Wilkins (2002) and Career Space (2001) the following are common elements of an ICT curriculum model, namely:

- ICT Core
- Specialization
- Electives

In the next section we discuss the critical skills required in ICT curriculum for the 21st century.

2.2 Critical skills required in ICT curriculum for the 21st century

Existing ICT models need to be updated with the critical skills needed for the 21st century. In the SA higher education landscape there are various sources for identifying critical skills for upcoming ICT professionals. The Department of Labour has categorized skills offered in the SA labour market into a standardized framework called Organizing Framework for Occupations (OFO) (Department of Higher Education and Training, 2013). The ICT skills that are scarce and critical in the country are published by the Department of Labour in a National Master Scarce Skills List (Department of Labour, 2012). Further to this the Media, Information and Communication Technology (MICT) Seta responsible for ICT industry training and development publishes a sector skills plan identifying critical and scarce skills within the industry using OFO codes (Media and Information and Communication Technology Seta, 2012). Thus any ICT curriculum renewal strategy must seek to engage with documents that identify ICT areas of need. These areas of need can be triangulated with feedback from industry practitioners.

The design and development of new curriculum must cater for the skills required by the 21st century learner. Binkley et al. (2010) categorized 21st century skills internationally as ways of thinking such as critical thinking and problem solving; ways of working which includes communication and collaboration; tools for working which refers to ICT and information literacy and skills for living in the world such as citizenship and social responsibility. More specifically stated as cited by Moylan (2009) critical 21st century skills are:

1. Critical thinking and problem-solving;
2. Creativity and innovation
3. Collaboration, teamwork and leadership
4. Cross-cultural understanding
5. Communications and information fluency
6. Computing and ICT fluency
7. Career and learning self-reliance

According to Moylan (2009), Project based learning is the key to ensure that learners obtain these critical skills for the 21st century. Project based learning allows students to learn in all six levels of "Blooms Taxonomy" (Moylan, 2009). Another important component of the curriculum is skills that can be acquired through General Education. General Education focuses on bringing in a combination of basic skills such as writing skills, mathematics and other broader skills from other Departments and Faculties within the Higher Education Institution (HEI) into a programme (Fuess & Mitchell, 2011). It is the collection of experiences crafted by the institution to provide students with a breadth of experiences and a broad knowledge base that sharpen students' problem-solving, interpersonal, oral and written communication skills as well as their cultural and linguistic literacy (Bourke, Bray, & Horton, 2009).

According to Fuess and Mitchell (2011) American undergraduate education typically involves General Education. In recounting the University of Nebraska-Lincoln's experience with General Education reform, Fuess and Mitchell (2011) highlights practical skills such as communication skills, critical and creative thinking, building knowledge of diverse people and cultures, exercising individual and social responsibilities through the study of ethical principles and reasoning and integrating abilities and capacities and adapting them to new settings, questions and responsibilities as objectives for General Education.

A study of the top twenty six doctoral granting institutions and top twenty five liberal arts institutions in America showed that the philosophies presented for various General Education models are preparation for life, citizenship and lifelong learning (Bourke et al., 2009). Institutions can implement General Education by using a core General Education curriculum or by distributing General Education within the modules of the programme (Bourke et al., 2009). Despite the General Education model that an institution chooses, what is clear is that General Education is an important component of the curriculum (Bourke et al., 2009).

Another challenge for curriculum developers is to design curriculum that serves global priorities as well (Haigh, 2002). According to Haigh (2002) internationalization of the curriculum is the process of designing a curriculum that meets the needs of an international student body. Learning and teaching activities in the classroom can be adapted to include international perspectives (Haigh, 2002). Globalization of the curriculum creates graduates that are capable of engaging a culture of communication and work that is becoming increasingly global (Rizvi & Walsh, 1998). Hence graduates must acquire the skills needed to operate globally and at the same time the University must be able to cater for a multicultural context (Haigh, 2002). Universities also see themselves operating in a global environment and therefore realize that a careful re-examination of the goals of curriculum development is required if higher education is to prepare students, teachers and citizens for the global environments (Rizvi & Walsh, 1998).

The literature review has highlighted all the components that can be packaged into the new modernistic ICT

curriculum product model. In summary, ICT core areas, ICT are specific knowledge and ICT specialization modules should comprise the knowledge areas in ICT. The modules can appear as common and elective modules over 3 years. Industry referenced vendor specific knowledge should also be incorporated in the curriculum. The curriculum must include interdisciplinary modules. A capstone project or Work Integrated Learning (WIL) must integrate ICT knowledge and provide exposure to the world of work. General education, Internationalisation, Globalisation and critical skills for the 21st century must be embedded within the curriculum.

Having defined the components of the modernistic product model for ICT, the next section discusses a programme of research aimed at applying this curriculum product model for the renewal of ICT curriculum at the SA HEI under study.

3. Setting and Methodology

The research setting this paper reports on was a residential higher education institution based in South Africa. The research was focused on creating a product model for ICT curriculum design and development and how this model was validated empirically in the Department of Information Technology at the Durban University of Technology. Thus a case study approach was used as a strategy of inquiry. One of the strengths of the case study approach is that it allows the researcher to use a variety of data collection methods as part of the investigation, for example, a case study can mix interviews and questionnaires (Denscombe, 2012). Yin (1999) advocates that the more data collection methods used in the same study, the stronger the case study evidence would be. The goal was to triangulate evidence from the various methods of data collection to reinforce a single point. In keeping with the aim of creating a curriculum model for designing and developing curriculum, the research methodology was a qualitative empirical research approach that incorporated Participatory Action Research and Focus Group Interviews (Moutan, 1996).

In Participatory Action Research the researchers were part of the study and were responsible for bringing academics together to find solutions to problems through discussions and data gathering. According to Rabiee (2004) a focus group interview is a technique involving the use of in-depth group interviews in which participants are selected because they are a purposive and related to the curriculum renewal process. Several focus group interviews were conducted with staff, students and industry practitioners. In the next section we report on and discuss the results achieved.

4. Discussion

The literature review was deployed to inform the various steps undertaken in arriving at our product model as shown in Figure 5:

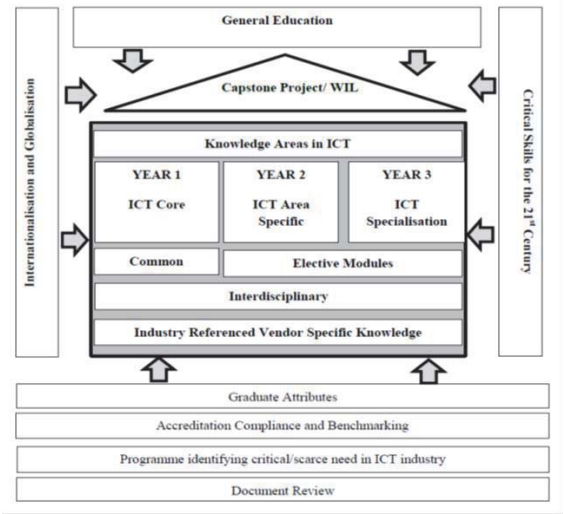

Figure 5. Modernistic ICT product model

The model incorporates the best components of existing models. We present and discuss how the synthesized product model derived in Figure 5 was validated empirically for the renewal of ICT curriculum at the Durban University of

Technology leading to the creation of a new three year diploma.

The Department of Information Technology appointed 12 academics from within to the curriculum committee. They were tasked with the responsibility for renewing ICT curriculum and creating a new programme qualification mix that is strongly aligned to the current and future needs of the ICT industry. The curriculum model depicted in Figure 5 is used to describe how the process of designing and developing ICT curriculum unfolded at the department.

The first three horizontal pillars of the curriculum model in Figure 5 represent the foundational work that was conducted during the planning phase of the process. The activities conducted were inspired by the Backward Design Model as cited in Alexander (2012). In Backward Design one starts with the end or goals of what is to be achieved (Wiggins & McTighe, 2005).

In keeping with this, the curriculum committee had to conduct an extensive document review to identify critical skills required for ICT professionals in the 21st century. The Document Review was a way of collecting data by reviewing existing documents (Moutan, 1996). Not only did the Document Review analyse critical skills for the ICT industry but it also included an in-depth textual analysis of national and international strategic documents that consequently, administered and guided the process of curriculum design and development (Shiroka-Pula, Dedaj, & Aliu, 2014). These regulatory documents included the OFO's, Seta sector skills plans, DOL documents on critical and scarce skills and CHE accreditation documentation. The process was important in identifying the ICT programmes that were in demand and hence ICT specializations that needed to be designed. The new Higher Education Sub Framework (HEQSF) approved by the minister of higher education and training provided the rules and regulations around the accreditation of new ICT programmes (Council of Higher Education, 2012). This document ensures standardization of all programme types and levels of all Higher Education qualifications in South Africa. Once programmes and specializations were identified, the graduate attributes for the respective programmes were formulated.

The General Education model was prescribed by the HEI's Senate after months of consultative meetings. The University Senate commissioned that General Education be incorporated into all Institutional programmes either as core curriculum or embedded into the programme using the following guidelines:

The General Education component must cover thirty percent of the actual total credits of an undergraduate programme comprising of; ten percent- institution-wide (outside of the home Faculty and Academic Department); ten percent - Faculty-based and ten percent - programme-based. The Institutions goals for General Education were to build a student-centered educational experience embedded in the local context; to prepare students for an increasingly diverse and complex globalised work environment and to cultivate an engaged and critical citizenry in the context of an emerging and fragile democracy in an ever changing world order.

The following seven themes were identified after feedback from the various faculties:

1. Environmental Sustainability
2. History, Politics, Economics and Philosophical systems
3. Culture and Society
4. Work Preparedness
5. Entrepreneurship
6. Personal Development
7. Health and Wellness

The decision of the curriculum committee was to incorporate General Education as the core curriculum model (Fuess & Mitchell, 2011).

Internationalization of the curriculum was achieved through benchmarking modules with global Institutions and incorporating vendor specific content into the curriculum. Core ICT knowledge, area specific knowledge and specialization areas were benchmarked with the ACM/IEEE (2008) and the programmes of leading higher education institutions globally. The HEQSF provided guidelines for incorporating the project and/ or work integrated learning into the curriculum. Although the curriculum committee had the ultimate responsibility of designing the curriculum, it did not do so without input from members of the entire Academic Department and industry practitioners through a series of reviews.

Table 2 shows the design of the Diploma in ICT in Applications Development for the Department of Information Technology at the Durban University of Technology. This Diploma was designed by application of the newly created product model shown in Figure 5 as discussed herein.

Table 2. Diploma in ICT in Applications Development

Internationalization						
	Gen Ed	**Capstoe Project/WIL**	**ICT Core**	**Area Specific**	**Specialization**	**Vendor Specific Knowledge**
Year 3	**Faculty Institution Programme, Theory of ICT Professional Practice**	**App. Dev Project**			**App. Dev 3 IS 3 HCI**	
Year 2	**Faculty Institution Programme**	**App. Dev Project**		**App. Dev. 2 IS 2 Mobile Computing IT Project Mangt**		**Info. Mangt**
Year 1	**Cornerstone, Faculty Institution Programme**	**App. Dev Project**	**Networks, Op. Syst. Security, IS1 App. Dev. 1**			**Comm. Nets**
Graduate Attributes – Critical Skills for the 21st Century						

The table above shows key modules of the Diploma in ICT in Applications Development over three years in the various compartments. General Education modules are identified each year as Faculty, Institution and Programme based general education modules. At institution level students are required to choose from a basket of modules.

The Department of Information Technology resides within the Faculty of Accounting and Informatics so at Faculty level the modules prescribed were Business Fundamentals 1 and 2, Spirit of Entrepreneurship and ICT Innovations and Emerging Technologies. The module on Application Development Project is responsible for integrating the work covered on each year of study. Networks, Operating Systems, Information Systems 1 and Applications Development 1 were identified as core ICT modules in year 1. Applications Development 2, Information Systems 2, Mobile Computing and IT Project Management were identified as area specific knowledge in year 2. Applications Development 3, Information Systems 3 and Human Computer Interaction were identified as the specialization modules. Vendor Specific Knowledge was packaged in the Information Management and Communication Networks module. The design and development of this programme ensured that while local needs had been catered for, modules had a global appeal. All modules ensured that graduate attributes incorporated the critical skills of the 21st century.

5. Conclusion

It is necessary for Higher Education Institutions to produce ICT graduates that are robust and can meet the challenges of an ever evolving and dynamic ICT environment (Adegbehingbe & Eyono Obono, 2012). Hence the need to build curricula that is effective. This paper has presented the product model for the renewal of ICT programmes at a SA HEI in the 21st century. One of the primary motivations to produce a model was to provide a distinct path for the renewal of ICT curriculum in the SA Higher Education landscape. A second reason was to build a highly effective and sustainable ICT curriculum. This paper provides a blue print for institutions locally and abroad wishing to design ICT programmes that are relevant to the 21st century. The literature has revealed that there is very little research conducted in SA on viable product models in the ICT field thus ample scope exists within this research area. The curriculum committee at the HEI also recognizes the dynamic nature of the ICT environment and recommends that there be an ongoing review process that allows the product model shown in Figure 5 to be reviewed and updated on a recurring basis.

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