CHANGING COMPUTING CURRICULA IN AFRICAN UNIVERSITIES: *EVALUATING PROGRESS AND CHALLENGES VIA DESIGN-REALITY GAP ANALYSIS*

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ABSTRACT
Information and communication technologies (ICTs) are diffusing rapidly into all African nations. Effective use of the new technology requires a step-change in local skill levels; including a step-change in ICT-related university education. Part of that process must be an updating of university computing curricula, ranging from computer science through to information systems. Adoption of international curricula offers a ready means for updating, but African universities face challenges of implementing these curricula – curricula that were typically designed for Western rather than African realities.

To help understand the issues surrounding implementation of international computing curricula in Africa, we selected a case example: Ethiopian higher education. Using the design—reality gap model and its 'OPTIMISM' checklist of dimensions, we analysed what ensued following its 2008 decision to adopt a new IEEE/ACM-inspired computing curriculum. We find that significant progress has been made, but that important gaps between design and reality – and, hence, challenges – remain. We are therefore able to identify specific actions along particular dimensions such as technology and skills that will help close design—reality gaps, and secure greater implementation. We propose that this analysis method will prove a valuable strategic tool for computing curriculum reform in other African nations.

KEYWORDS: Higher Education; Computing Curricula; Design-Reality Gap; Africa

1. INTRODUCTION

Although low, information and communication technology (ICT) usage levels are rising rapidly across Africa: mobile phone subscriptions are growing by 50% per year and more; Internet user numbers are growing by 20-30% (Heeks, 2010). However, the contribution of ICTs to development in Africa is hampered because effective usage requires more than just the presence of technology (Dada, 2006). It also requires a human, informational and institutional infrastructure of data, skills, leadership, policy, etc.

In this paper, we focus on the human infrastructure – the competency profile of attitudes, skills and knowledge – that is widely-known to partly mediate the relation between technology and development (Nissanke, 2006). The necessary competencies are broad and need to be provided by a range of education and training institutions. These include private training institutes, schools and colleges but here we focus on the key role played by higher education; specifically the role of computing-related training[1] within universities.

Since the 1980s, universities have been somewhat pushed to the sidelines in development circles, as evidence emerged of the important role of basic schooling for poverty allevation and the other key human development aspirations that now form the Millennium Development Goals. However, since the mid-2000s there has been something of a higher education revival, with growing recognition of the vital role that universities have played in

[1] We will use 'computing' in discussing degrees and curricula because that is the overall term used by relevant curriculum bodies, and by the universities themselves. The term covers a range of skills areas, from 'hard' computer science, though interaction design, to 'soft' information systems.

the fast-growing emerging-market economies such as the BRICs (Brazil, Russia, India, China), and with greater strategic focus and investment in higher education within Africa itself (Jowi, 2009).

Unfortunately, decades of underinvestment cannot be undone at a stroke, and African universities face many problems that must be addressed before their potential role in formation of each country's information society is realised. An encapsulation of this can be found in the outmoded computing curricula that many African universities are using: curricula often dating from the mainframe era[2]. An outmoded computing curriculum principally causes inappropriate competencies to be developed: the skills and knowledge that graduates have are not those required by African employers seeking to apply ICTs; the requisite skills and knowledge are not taught. But these curricula can also dissuade potential students from joining an ICT-related degree, can increase the chance that they drop out, or can divert them into non-ICT work on graduation (Mander, 2006; Zhao et al, 2010). In both quantitative and qualitative ways, then, outmoded curricula are damaging the link between ICTs and development.

African universities addressing this predicament can do so by an internally-guided process of reform. On the other hand, professional global associations such as the IEEE (Institute of Electrical and Electronics Engineers) and the ACM (Association for Computing Machinery) have invested considerable resources in update and design of the supposedly-generic curricula that they make available. It is therefore logical that African universities would make use of such curricula, as a number of them have (Baryamureeba, 2006; Plane & Venter, 2008; Tedre *et al*, 2009a).

Any curriculum update (indeed any organisational change) faces difficulties. But adoption of international curricula within Africa may face particular challenges for two reasons. First, as noted, the underinvestment and current under-resourcing of higher education on the continent, which make any changes that much harder to achieve (Reddy, 2002). Second, the rather less than 'global' nature of international curricula which are, in practice, designed by organisations dominated by US membership, and hence designed primarily for US (or, at least, Western nation) higher education.

Yet little, if any, research appears to have been undertaken on this issue despite it being a process in which many universities on the continent are likely to be involved, and despite the contribution that successful curriculum update can play in making more effective developmental use of digital technologies.

We therefore focused our research – and this paper – on the question, "What challenges do African universities face in updating their computing curricula?". Given our own resource constraints, we have chosen to instantiate that question through study of universities in one country, Ethiopia, recognising both the commonalities but also the differences between higher education systems in different African countries which thus require us to adopt a contingent, context-sensitive conceptual framework.

The structure of the rest of the paper that builds towards answering our question is as follows. In section 2, we review the literature on computing curricula and curriculum change in developing countries, and we present our core conceptual framework – the design—reality gap model – that will be used to analyse the challenges of computing curriculum change. After an outline of our research methods in section 3, we use the eight-part 'OPTIMISM' checklist to analyse the curriculum change in Ethiopia along a series of different dimensions. Finally, in section 5, we present some conclusions about the specific case, but also more generally.

[2] Of course, Western universities also face a challenge of computing curriculum update (e.g. Mander 2006).

2. REVIEW AND CONCEPTUALISATION

The value of higher education to development has long been recognised (e.g. Thompson *et al*, 1976). But, as noted in the Introduction, African universities became something of an educational Cinderella in development circles from the 1980s – pushed away from the limelight in favour of the not-so-ugly sisters of primary and secondary schooling. This happened for two inter-related reasons: the "crisis" of higher education brought on by under-resourcing and mismanagement, and economic evidence pointing to few developmental returns from investment in higher education (Salmi, 1992). From the turn of the 21st century, though, things began to change. Donor institutions started to recognise and promote the role of universities in national development (e.g. World Bank, 2000); universities were pushed back up the development agenda within Africa (CfA, 2005), and new evidence emerged of a statistically-robust link between HE investment and economic growth (Gyimah-Brempong *et al*, 2006). It was recognised, though, that any rejuvenation of African higher education would require not just an increase in resourcing, but also the development of new curricula, especially in the area of science and technology (World Bank, 2000; Reddy 2002).

We can see a similar curve for IT-related higher education. There was early recognition of the importance of digital technologies in development, and of the need for higher education to provide one element of the necessary skills base (Scheepmaker & Zinn 1970). But the general decline in higher education led investment and curricula to atrophy. Only in the 2000s was this trend reversed. First – and as noted above – as higher education saw a general resurgence. Second, due to the massive increases in diffusion and use of ICTs within developing countries. Connections were readily made between, on the one hand, both the growth of IT industries in developing countries and the more general use of ICTs for development and, on the other, the need for both investment and change in computer education in universities (Colle & Roman, 2003; Colle, 2005; Baryamureeba, 2006; Heeks, 2006).

Before looking at curriculum change, we need to clarify two aspects. The term "curriculum" can have quite a broad meaning; covering not just teaching content but also the overall learning environment and the broader attitudes that are explicitly or implicitly communicated to learners (Stenhouse, 1975; Kelly, 2004). However, it is the teaching content that represents the core of the curriculum, particularly the syllabus – a written description purposefully prepared to communicate the objectives, content, sequencing and partitioning, assessment methods and so on, of a learning experience which provides detailed advice and guidance to both academic managers and educators (Marsh, 2009). The focus in our case study will be largely on the changes to that syllabus core, though our analysis will show how such changes in themselves trigger requirements for broader changes.

Second, we can clarify the subject areas we cover. We use the term "computing" to cover a range of disciplines in the field of information and communication technologies. Figure 1 shows the variations between different undergraduate computing degree programmes. Figure 1A shows the computing space moving from theory on the left to applications on the right. A series of layers indicate broad themes or fields within computing with hardware shown at the lowest level and organisations on the highest level. The five computing first degree disciplines of Computer Engineering, Computer Science, Information Systems, Information Technology and Software Engineering are shown in the remaining diagrams in Figure 1, indicating the differences in emphasis. As noted below, in our particular case study, only three of these were offered – Computer Science, IS and IT.

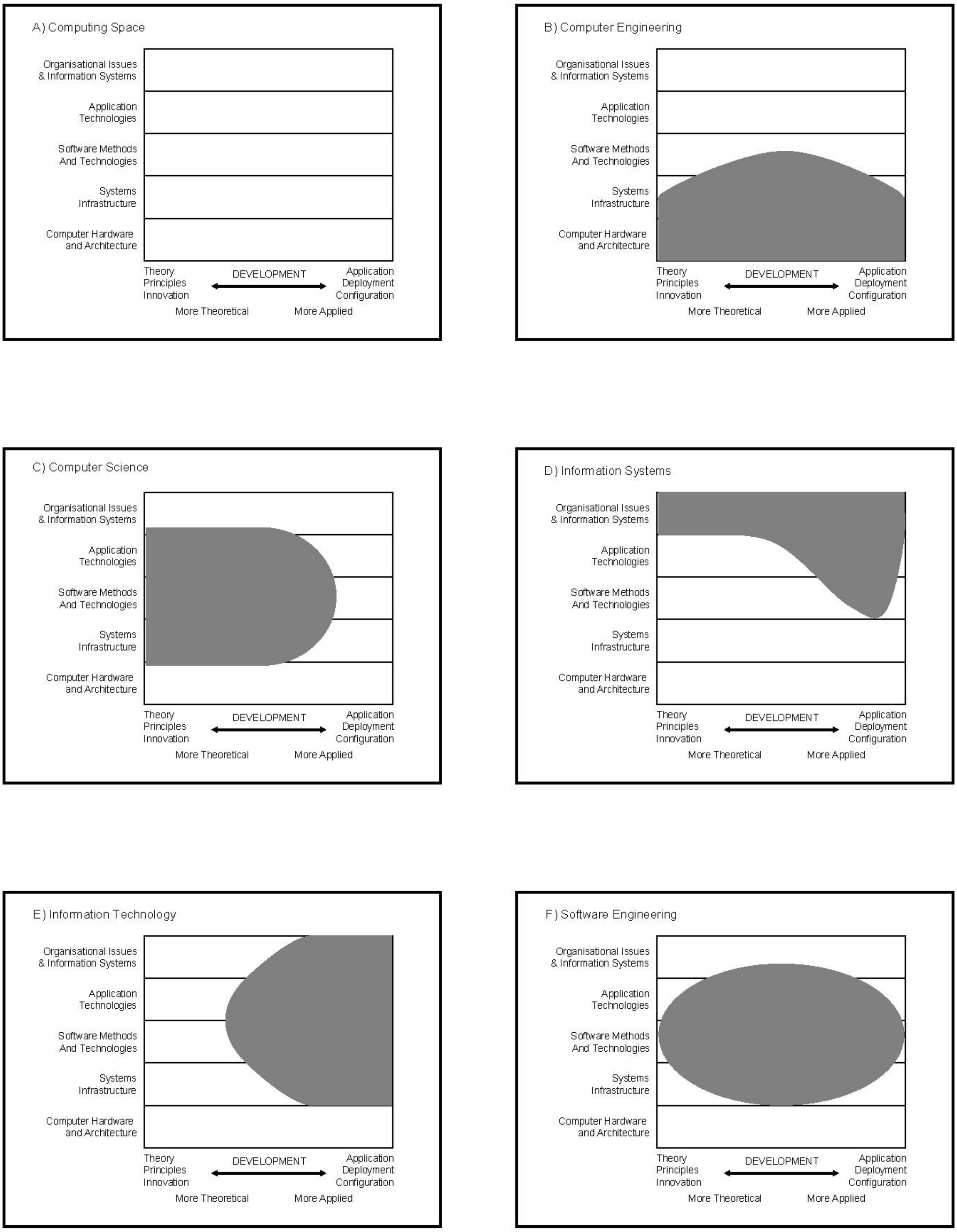

Figure 1. The Computing Discipline Teaching Space (ACM/IEEE 2005)

There is, of course, a literature on changing computing curricula in higher education (e.g. Mander, 2006; Hart, 2006; Lunt & Ekstrom, 2008) with a limited literature on computing curricula in developing countries (e.g. Ezer, 2006) including a very few items looking specifically at Africa (e.g. Soriyan *et al*, 2005; Tedre *et al*, 2009b). In reviewing this literature, we find two lacunae. First, the majority of the literature assumes a universalism in

IT education – that a single framework or overarching approach will be suitable for all universities. This tends to be challenged by the work dealing with developing countries: Soriyan *et al* (2005) argue that existing computing curricula do not prepare students for the demands of work in the Nigerian context; Tedre *et al* (2009b) argue the need for customisation of the computing syllabus to the specifics of the Tanzanian context.

Second, the focus for almost all writing has been on content rather than on process. In other words, prior work has talked almost exclusively about how to design computing curricula, but little about the implementation of those curricula. On the rare occasions where there was discussion about implementation (e.g. Kabicher *et al*, 2008; Ni, 2009; Tedre *et al*, 2009b), this is not done on the basis of a systematic or conceptualised framework but reports factors drawn out by practitioners from their own experiences.

In addressing our research topic of computing curriculum change in Africa, we therefore wanted to focus particularly on implementation – as noted above, especially on the challenges that arose during implementation. To do this, we wanted a model that would be sensitive to the particular realities we found in an African context, and a model that would be both conceptualised and systematic. We turned to the design—reality gap model; a general framework for analysis of change, but one which has been particularly applied to cases involving ICTs in developing countries (Heeks, 2002).

The design—reality gap model was developed from the literature on social construction of technology (e.g. Suchman, 1987; Akrich, 1992), and on contingency in organisational change (e.g. Venkatraman, 1989). It argues that there are particular assumptions and requirements built into the design of any organisational change. In turn, those design expectations may match or mismatch the real situation found in the context of implementation; hence creating the potential for a gap between design and reality.

The model can be applied in two main ways. First, as a risk analysis tool. In this approach, design and reality are assessed cross-sectionally; at a particular moment in time during project implementation. On the basis of case analysis, it can be seen that the larger the assessed design—reality gap, the greater the risk of project failure (e.g. Macias-Garza and Heeks, 2006; Hawari & Heeks, 2010). Equally, the smaller the gap, the greater the chance of success. But the model can also be applied as a project evaluation tool. In this approach, design and reality are assessed longitudinally; with the expectations within the design compared to the reality some time later after implementation (though recognising that implementation is often an ongoing process that can rarely be seen as completed). This enables assessment of the extent of success or failure of a change project, and also identification of those areas in which further change is both required but also challenging (e.g. Baqir *et al*, 2009). It is the latter approach that we adopt here.

To make the model systematic, it was necessary to identify a set of key dimensions along which a gap between design and reality might exist. Some of these have already been alluded to earlier in this paper such as issues of skills, technology and other resources. Drawing on this and other work cited above using the design—reality gap model, we find eight dimensions – summarised by the OPTIMISM acronym – are necessary and sufficient to provide a comprehensive understanding of design—reality gaps:

- Objectives and values (both formal strategies and culture, and informal goals)
- Processes (from individual tasks up to broader business processes)
- Technology (not just ICTs but other relevant technologies)
- Information (data stores, data flows, etc.)
- Management systems and structures
- Investment resources (particularly time and money)
- Staffing and skills (both the quantitative and qualitative aspects of competencies)
- Milieu (the external political, economic, socio-cultural, technological and legal environment)

Putting these dimensions together with the notion of gaps produces the model for understanding organisational change, including curriculum change in higher education, that is shown in Figure 2. We will explain next how this was specifically applied in our particular study.

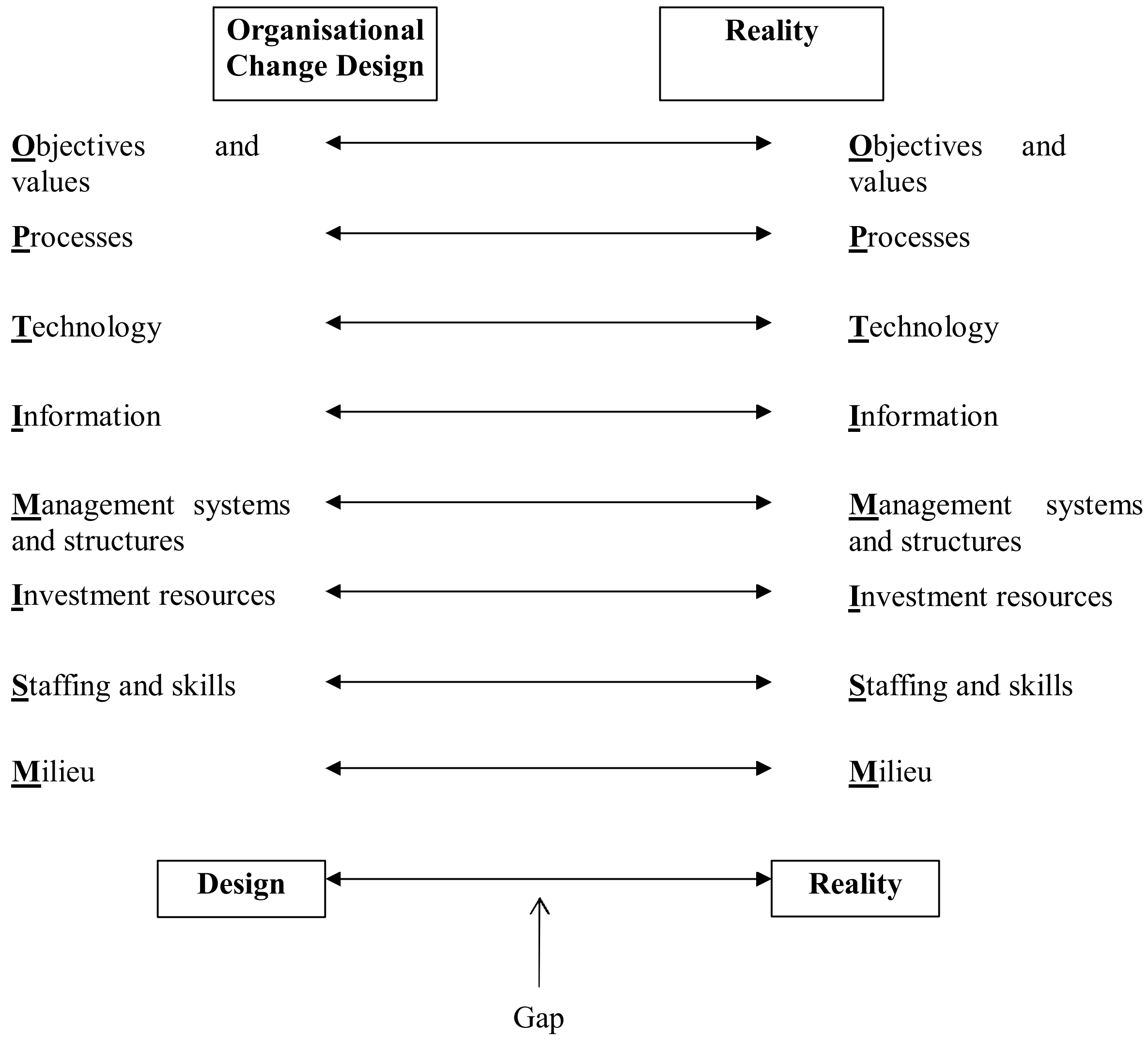

Figure 2. The Design—Reality Gap Model for Analysing Change

3. RESEARCH METHOD AND CASE BACKGROUND

Design—reality gap analysis can be seen to draw from the realist traditions of research, while recognising the subjectivity that may be present in assessment of both design and reality, even when using rating scales. A qualitative research methodology was therefore appropriate, but one that adopted triangulation of both sources and methods; using a combination of interviews with those involved in both design and implementation, analysis of design documentation, and observational surveys of implementation realities (Patton, 2002).

Our choice of Ethiopia was a selection of convenience: author Bass was working there as an ICT Advisor to the Ministry of Education and intimately involved in the process of curriculum change. We also note there will be some specificities in Ethiopia such as its ICT policies but that in other ways it is typical of many African nations in seeking to reform both higher education and ICT teaching within a resource-constrained environment and a relatively bureaucratic management tradition.

In specific terms, then, this paper will use the design—reality gap model to analyse computing curriculum change in one particular African nation. However, our interest is not so much with the particularities of the Ethiopian case but with the model. The generalisability of the paper comes less from the specific findings in this one country, and more from the development of a better conceptual base for understanding and managing computing curriculum change implementation in Africa. The paper's main contribution is in applying the design—reality gap framework, and in demonstrating its analytical and practical value, including the derivation of recommendations for practice.

The research reported here relied on field visits to nine of the 22 public universities in Ethiopia: the longer-established universities of Addis Ababa, Hawassa, Arba Minch, Bahir Dar as well as those at Debre Marcos, Debre Birhan, Wolaita Sodo, Dilla, and Dire Dawa which were set up in 2007. These visits were conducted to undertake ICT status surveys and explore computing course teaching and learning. In addition, visits to six of the universities (Addis Ababa, Debre Marcos, Debre Birhan, Hawassa, Wolaita Sodo, Dilla) during May to October 2009 were conducted specifically to investigate implementation of the four-year computing curricula.

The field visits were supplemented with a qualitative study conducted using in-depth, open-ended interviews with 20 staff, conducted in English, during October 2009 and March 2010. The interviewees were staff members coming from four public universities (thirteen from Debre Birhan, three from Bahir Dar, two from Addis Ababa, and two from Hawassa). The locations of the universities are shown in Figure 3. Staff ranged from newly qualified Graduate Teaching Assistants to Faculty Deans. The interviews were conducted using an interview guide based on the OPTIMISM model. Interviewees were asked probing follow-up questions on new and emerging topics as well as given opportunities to raise any other issues they considered relevant. The interviews were recorded and audio content analysed. The interview contents were iteratively categorised and coded. The initial categorisation was based on the OPTIMISM model, but with careful consideration given to emergent topics.

Figure 3. Location Map Of Selected Public Universities in Ethiopia[3]

Alongside observational data gathered through the visits and open-ended interviews, documentary analysis was conducted including analysis of higher education legislation and federal government ICT strategy and education strategy. In addition, two curricula were analysed: "old," three-year duration, computer science curricula which were superseded (and produced their final graduates in 2011); and "new," four-year duration, computing curricula (nine computer science, three information systems, and four information technology) developed during 2008-09 from nine (out of a total of 22) Ethiopian public universities as shown in Table 1. To obtain as broad a picture as possible, the decision was made to select some of these curricula from universities that were visited, but some from those that had not been visited.

[3] Locations are approximate.

Public University	**Computing First Degrees Offered**		
	Computer Science	Information Systems	Information Technology
Addis Ababa	✓	✓	
Aksum [4]	✓		✓
Ambo University College	✓		
Debre Birhan [4]	✓		✓
Dire Dawa [4]	✓		
Jimma	✓	✓	✓
Mizan Tepi [4]	✓		
Samara [4]	✓		
Wollo [4]	✓	✓	✓

Table 1. Computing First Degree Programmes Analysed (Selected Public Universities)

3.1 Higher Education in Ethiopia

The Government of Ethiopia has a stated objective to use the development, deployment and exploitation of ICTs to help develop Ethiopia into a "socially progressive and prosperous nation with a globally competitive, modern, dynamic and robust economy" (EICTDA, 2002). Simultaneously, the education sector has been identified by the Government as a priority area. Thus Ethiopia presents a good example of a developing country in which the use of ICTs in education has central government support.

While management of schools and colleges is largely the responsibility of decentralised Regional Education Bureaux, public universities are directly funded by, and accountable to, the federal Ministry of Education. The country has been implementing ambitious university expansion plans (Saint, 2004). The number of universities was more than doubled in 2007, from nine to 22. A further ten universities were planned, though there have been warnings about the difficulty of maintaining quality during a period of such rapid expansion (Tessema, 2009).

In general, resourcing is an issue. All children enjoy free education up to Grade 8, after which cost is based on achievement. Thus, students achieving sufficiently high grades are not charged fees and are entitled to modest financial support to continue education into the tertiary or higher education sector. In terms of ICT resources, our survey of the ICT status of public universities conducted in May 2009 shows modest access to computers for students in the established public universities (those inaugurated prior to 2007) as shown in Table 2.

[4] These universities were among the group established in 2007.

The new public universities (established in 2007) were only able offer students very limited levels of computer access (the computer to student ratio at Wolaita Sodo is 1:69 and at Debre Marcos in 1:111). The IT support staffing levels at these institutions are also modest. Several institutions report recruitment challenges with IT support posts standing vacant; reflecting the nationwide shortage of technical personnel.

Institution		Number of Students[5]	Number of Computers	Computer to Student Ratio
Wolaita Sodo [6]		3,653	52	1:69
Dilla [6]		5,899	134	1:44
Debre Marcos [6]		6,462	58	1:111
Hawassa	***Regular***	12,356	242	1:51
	Masters	281	35	1:8
	Wondo Genet Campus	1,180	0	No Student Access
Addis Ababa	***Regular*** [7]	33,872	1,608	1:21
	Technology Faculty	6,749	425	1:16
	Medical Faculty	3,275	66	1:50

Table 2. Computer-to-Student Ratios (Selected Public Universities)

Having given some background context of the education system in the country we can now turn our attention to the computing curriculum change process.

3.2 The Computing Curricula Change Process

There was a widespread recognition that previous "three-year" computing curricula did not meet the needs of the country (see example in Appendix 1). Deans, heads of department and instructors (an inclusive term used locally to include associate professors, assistant professors and graduate teaching assistants) all spoke of graduates unable to acquire sufficient skills or levels of competency under the three-year curriculum. Previous curriculum documents in the country had focused almost completely on course content and knowledge (rather than skills)

[5] The number of students includes those registered for the regular programme but excludes evening and weekend programme students.
[6] Wolaita Sodo, Dilla and Debre Marcos universities were recently founded, in 2007. One campus at Dilla was formerly a college of teacher education.
[7] This figure includes regular, summer and postgraduate students.

acquisition. Those earlier curricula documents had said very little about teaching, learning or assessment processes. This encouraged a focus on lectures, for knowledge transfer, and assessment using mid-semester and terminal exams. There was also recognition that graduates emerging from these degrees did not have the competencies needed to meet the needs of potential employers.

The curriculum change process was conducted in all higher education subject areas over a two-to-three-year time span. The curriculum change process was sponsored by a council of Academic and Research Vice-Presidents from all the public universities in Ethiopia and chaired by the State Minister for Higher Education. The Council was also attended by representatives from selected government agencies, such as the Higher Education Strategy Centre, Higher Education Quality and Relevance Agency, and the Ethiopian ICT Development Agency.

The computing curriculum change process was conducted through the formation of a Working Group, of which author Bass was a member, which produced a set of guidance notes and benchmark documents in May 2008 (Bass *et al*, 2008). The Guidance Notes were presented to the Council of Academic Vice Presidents by the State Minister and formally adopted. The documents were then circulated to the presidents of all public universities, on behalf of the Ministry of Education, by the Higher Education Strategy Centre.

The Working Group recognised that university staff who developed curricula lacked suitably detailed resources materials. Often, departments tended to copy course specifications from other local universities. Course specification and even programme specifications tended to lack detail, leaving scope for excessive overlap between courses and repetition of basic material.

The Working Group used international curricula documents to help overcome the shortage of resources materials. The Guidance Notes drew on curriculum guidelines produced by working groups formed by (predominantly US) professional bodies; notably the Association for Computer Machinery (ACM) and the Institute of Electrical and Electronic Engineers (IEEE) Computer Society. Influential source documents included Computing Curricula 2005: The Overview Report (ACM/IEEE 2005) and Computing Curricula 2001 Computer Science, from the Joint Task Force on Computing Curricula IEEE Computer Society and Association for Computing Machinery (ACM/IEEE 2001).

The Guidance Notes were promulgated through a series of national workshops attended by representatives of the public universities. Staff within individual computing departments produced new draft curricula that were peer reviewed by other universities in geographical clusters. The curricula were then processed through the usual internal approval processes at Faculty and Senate level. After Senate approval, several universities forwarded their curricula to the Higher Education Strategy Centre for information, as summarised in Table 1.

Most public university Senates approved the new four-year duration computing degrees. Jimma university's Senate, however, approved a three-year duration degree. A further national workshop of public university representatives was convened to resolve this apparent lack of consensus. At the Workshop, subject groups – in computer science, information systems and information technology – presented findings supportive of the four-year duration. The State Minister wrote to public universities during the summer of 2009 formally approving the additional year of study for computing subjects. This represented a reversal of an earlier policy decision to move some university level teaching into the higher education preparatory school sector and reduce university degrees from four years to three years. Examples of the new four-year curricula – for Computer Science and for Information Technology – can be found in Appendices 2 and 3.

4. Analysis of the Computing Curriculum Change Process

We have explored the educational system in the country as the context for curriculum change and have examined the motivation and process of computing curriculum change. We can now examine the implementation of the new four-year computing curriculum. Our examination makes the assumption that there will be gaps between the ideal educational setting as described in the curriculum documents (the design) and the reality observed in institutions; hence the applicability of the design—reality gap model. As per the model, we will explore those gaps using each of the eight OPTIMISM dimensions in turn.

4.1 Objectives and Values

Design Expectations

We have identified sets of issues around both the objectives of the curriculum change process and the pedagogical objectives of the computing curricula. As noted above, computing curriculum change forms part of a wider change process, across the higher education sector, initiated by the Ministry of Education in an effort to improve higher education relevance and quality. But its particular and main objective – indeed, the core driver of computing curriculum change – was to enable students to acquire new subject-specific skills.

Moving beyond this general goal, the Working Group had observed a lack of relevant theory courses and also the prevalence of mathematics courses selected due to their availability rather than relevance to the computing discipline. To address these concerns the Guidance Notes included the following two issues as priority objectives for curriculum change (Bass *et al*, 2008):

- Theoretical underpinnings: ensuring sufficient relevant and appropriate theory to enable advanced study, and
- Statement of learning outcomes: ensuring degree programme goals were expressed in terms of learning outcomes for the first time in the country.

The previous three-year computing curriculum focused on knowledge objectives only; without detailed articulation of the skills students should acquire. The new curriculum represented the first time learning outcomes, at both course and programme level, had been used to focus attention on what a student should learn – creating opportunities for students to acquire subject-specific skills and transferable skills – rather than on what content teachers should teach. The mapping of course learning outcomes to programme learning outcomes was described in some detail in the Guidance Notes and attracted a lot of interest in national workshops provided for representatives of public universities across the country (*ibid.*). It moved away from the emphasis of the previous three-year programmes which, in contrast, was on producing graduates in the shortest possible time.

Reality

The core value and objectives of curriculum change design did appear to be shared in reality by key stakeholders. Many interviewees spoke of the new focus on graduate capabilities in terms of subject-specific skills. They appreciated the pressing need for graduates to be able to competently and successfully undertake computing tasks. They also accepted that graduates possessing subject-specific skills are important to meeting the development needs of the country.

Review of the curriculum documents approved by Senates at the nine universities listed in Table 1 shows that new and more relevant mathematical theory courses have been mandated. Some universities have moved further than others. Addis Ababa, for example, has added only one new "Discrete Mathematics and Combinatorics" (*sic*) course in their Computer Science degree, but has retained three traditional mathematics courses in the areas of linear algebra and calculus. In contrast, new (post-2007) universities such as Aksum, Debre Birhan and Dire Dawa have introduced two theory-based courses: "Discrete Mathematics and Combinatory" and "Introduction to Formal Language Theory". Change in reality has also been varied across degree types: for example a number of Computer Science degrees had retained their traditional calculus courses – of questionable relevance – but this was not the case in the Information Technology degrees, which made use only of discrete and applied mathematics courses that were seen as contributed appropriately to programme goals.

As a result of the learning outcome mapping undertaken, new courses have been specified, developed and taught. Likewise, all the new four-year curricula observed have defined learning outcomes. And those instructors involved in the change process are inclined to take the view that there have been positive changes to programme objectives.

However, there are concerns that implementation challenges are considerable and perhaps insurmountable. For example, instructors not involved in the curriculum change process tend to focus exclusively on the specific courses that they teach. They find it difficult to focus on broader, programme-level goals and objectives. This means that courses tend to be taught without detailed consideration of their contribution to the overall programme. Courses are often characterised by uniformity, rather than diversity, in approaches to teaching and assessment. This uniformity denies students the opportunity of experiencing a wide range of learning interactions. While the mapping of course learning outcomes to programme learning outcomes generated interest during the curriculum change process, it has not become an organic part of the thinking of most instructors.

Design—Reality Gap

As ascertained from interviews and observations, there appears to be a relatively good match between the reality of individual stakeholder values and the design expectations that value and set the goal of achieving new student skills. At a documentary level, too, the objectives and values of curricula have changed in reality. Most institutions have increased the number and relevance of their theory courses. This process is more evident in the new universities and in the new degree programmes (Information Technology and Information Systems).

Courses and degree programmes now use learning outcomes to articulate objectives for student learning relating to both knowledge and skills. This represents a considerable shift in thinking from the objectives of the previous curriculum. Those instructors involved in the curriculum change process have become convinced by the new ethos of emphasis on active learning of subject-specific skills and diversified assessment. But instructors not involved in the change process still find it difficult to see how the courses they teach contribute to a broader educational agenda.

We have seen that in reality there has been a considerable shift in the curriculum documentation in terms of the type and role of theory in the curriculum. Also there has been a considerable shift towards the use of learning outcomes to identify pedagogical objectives. Adding in the evidence on changes commensurate with valuing new student skill goals, we can say there is a small-to-medium design-reality gap in terms of computing curriculum objectives and values. We will have more to say about the extent to which these new objectives have influenced teaching and learning processes and have been communicated to teaching staff in our consideration of the dimensions that follow.

4.2 Processes

Design Expectations

Historically, teaching processes in Ethiopia have tended to rely on traditional lecture methods. This reflects a didactic attitude of teachers, who see teaching processes as restricted to information transfer to students. The previous three-year computing curriculum had also used summative assessment in the form of terminal examinations almost exclusively. Yet summative assessment serves institutional purposes and does little to contribute insights helpful to the student's own learning (Stenhouse, 1975).

Continuous assessment is intended to be formative in nature, giving students opportunities to gain insights into the strengths and weaknesses of their own learning. Continuous assessment also enables the assessment of hands-on practical skills, as well as knowledge, thus supporting skills acquisition. So practical assignments conducted in labs can be assessed, as well as a student's knowledge of the subject. Diversification of assessment is linked to the need for students to acquire subject-specific skills during undergraduate studies. Graduates are being called upon to contribute to the development of the country and so must be able to complete practical tasks related to their discipline.

Against this background, the curriculum change priority areas identified in the Guidance Notes included support for teaching and assessment diversity (Bass *et al*, 2008). The design therefore envisaged new teaching and learning processes that moved beyond lectures and terminal exams to include laboratory work and continuous assessment of project work and assignments. These new teaching and learning processes focussed on creating opportunities for students to have a practical engagement with the subject matter.

Reality

In some ways, the institutions we investigated have embraced the need for continuous assessment. Debre Birhan University, for example, has established an institution-wide assessment policy that prescribes a maximum 40% weighting for final examination and 60% for continuous assessment that must be applied to all courses. Although positive in some ways – since staff are forced to conduct a significant level of continuous assessment – this precludes flexibility and diversity within a degree programme. So, for example, a project course with a 100% project assignment assessment component, is not possible within such a policy. Meanwhile other universities, such as Jimma and Addis Ababa, have not chosen to adopt such an institutional policy standard. However, they have increased the volume and frequency of assessment so that some of it is formative (i.e. undertaken before the end of teaching).

Sadly though, there has not been a corresponding increase in assessment diversity. In principle, mandating a mix of examinations and continuous assessment means that the students should demonstrate satisfactory performance in project or laboratory work to score well in a course. However, shortages of resources, and the perception that class sizes are too large, mean that assessments based on class attendance, quizzes and class tests are being substituted for project and laboratory assignments. These quizzes and class tests are often multiple-choice, to simplify marking. Hence the reality is increased frequency of traditional assessments rather than diversified assessment methods. This new regime is popular since more frequent assessment creates a significant incentive for students to attend classes. But this punitive use of assessment runs counter to formative uses of assessment that support and assist student learning (Stenhouse, 1975).

Design—Reality Gap

There have been some moves to address in reality the two key process design changes: changes to teaching processes, and changes to assessment processes. Yet (as discussed below) there are serious constraints to broadening the base of practical work, and moves towards more continuous assessment have been positive but somewhat uneven and not matched by moves to more diverse forms of assessment. We can conclude that there is a medium design-reality gap in terms of assessment processes, underpinned by challenges that go beyond computing curriculum change.

4.3 Technology

Design Expectations

The computing curriculum change Guidance Notes describe the need for sufficient computer classrooms to support teaching (Bass *et al*, 2008). This includes not just direct teaching use but also capacity to support the needs of independent study. The need to establish specialist computer classrooms to support particular technologies was also recognised. The guidance document specifically recommends specialist labs to support teaching of networking, embedded systems and operating systems.

Reality

As can be deduced from Table 2, the public university sector is stratified into two groups in terms of technology provision: the new public universities launched in 2007, and the more established universities. The new universities each have a handful of general-purpose computer teaching laboratories (e.g. two in Wolaita Sodo, four in Debre Birhan). Computer classroom capacity is insufficient to provide basic support to existing student numbers. None of the new universities has computer classrooms with specialist hardware, software or networking capabilities needed to support advanced study.

There is some variation between the established universities. Most have a number of general purpose computer classrooms with a handful of specialist laboratories. The specialist laboratories are usually used to support specific year groups (one lab for first years, another lab for second years and so on). There are few computer classrooms dedicated to teaching specialist topics. This results in students who enjoy good levels of access to general purpose computing facilities, but lack access to the specialist technology resources needed to support advanced study.

A further pressure on teaching labs is the need to teach computer use skills to students of non-computing disciplines. These so-called "common courses" introduce office application software, such as word processing and spreadsheets. Computer use courses are mandatory for most numerate subjects, such as the natural sciences. It is widely accepted, especially for the new universities, that building additional computer labs is a pressing priority.

Design—Reality Gap

Our research has identified that insufficient attention has been given to the link between newly-taught subjects and the required support environment. This dimension reflects a large design-reality gap and remains a challenging area for curriculum change. We have identified two types of laboratory needed to support computing teaching:

- Specialist computer classrooms to support advanced topics within the subject area, and
- General-purpose computer classrooms used to teach computer use and standard office applications to the wider student body.

In the new university sector there is a complete lack of specialist computer classrooms. There is also insufficient general purpose computer classroom provision. This shortage of computing laboratory space, in terms of number of seats, was the most significant technology shortfall identified in the new universities.

There is insufficient specialist computer classroom provision in the more established public university sector. Few institutions can boast specialist laboratories for teaching programming technologies, databases or networking. Specialist labs are needed to provide access to specific (often proprietary) software, to support teaching advanced courses. Generally these established institutions either have sufficient general purpose computer classrooms (such as in the Technology Faculty at Addis Ababa University) or they have plans in place to increase provision in this area. Hawassa, for example, was implementing expansion plans for their general purpose computer classroom provision. Implementation of these plans had already, at the time of writing, resulted in a 100% increase in the number of computer classroom places available.

In part, this gap has arisen due to the lack of recognition (by university management and Ministry of Education officials, for example) that a consequence of computing curriculum change would be creation of demand for new technologies and new computing infrastructure. Teachers directly involved in implementing the new curriculum, of course, have been very aware of these new technology needs. These technology needs are exacerbated by demands for diversified, laboratory-based, assessment processes mentioned above. We observed no evidence of planning for future technology needs specifically resulting from curriculum implementation. Instructors teaching new courses in the four-year curriculum thus confront pressing issues in terms of equipment shortages.

4.4 Information

Design Expectations

We interpret information in two ways here. First, related to the actual content of the curriculum. Second, related to information flows necessary for curriculum delivery and change.

Starting with curriculum content, the Working Group was concerned to raise awareness of two shortcomings relating to the design of degree programmes observed in the previous three-year curricula run by public universities. It was observed that some programmes sacrificed depth of study for breadth of topic coverage. This was evidenced by introductory courses on different topics appearing in the first, second and even third year of study. Linked to criticism of degree programmes lacking depth, was the observation that there was a lack of logical progression from one course to another.

The Working Group addressed these concerns by including advice about these issues in the guidelines (Bass *et al*, 2008). Also, sessions in national workshops for university representatives specifically addressed the need for logical progression from introductory to intermediate level courses and from intermediate to advanced level courses. This logical progression approach was advocated as a mechanism to achieve depth of study, meaning more advanced study in the curriculum.

The Working Group had less to say explicitly about information flows, but there was an implicit assumption that effective change and effective teaching delivery required effective information flows linking all key stakeholders: students, staff, and external institutions.

Reality

All the degree programmes reviewed from the nine universities summarised in Table 1 show logical progression of courses and improved depth (meaning more advanced) study. For example, in the area of computer programming a sequence of courses has been developed by these universities that starts with initial introductory topics and develops into intermediate courses demanding more advanced study. This sequence of three one-semester courses demonstrates an understanding of the need for logical progression and a commitment to developing greater depth of study.

Further, degree programmes within a named subject area show greater levels of course cohesion to each other than has previously been the case. This indicates greater levels of consensus between universities about the similarities and differences between the named degree subject areas. The universities have approved degree titles accepting international definitions of computing degree subject areas.

A less positive reality, though, was in relation to information flows; perhaps not surprising given that education in a country like Ethiopia is conducted in a resource-constrained environment. There are traditionally shortages of books and a lack of access to good quality e-libraries, with information often accessed informally through peers and personal contact. We identified four areas of information flow that were implicit within the design assumptions for successful curriculum change, but which fell short in reality:

Student Access to Study Information

The shortage of traditional hard-copy books and journals in libraries is widely recognised. Book purchasing is conducted both at a national level and locally by individual universities. The purchasing process is hampered by a shortage of good quality textbooks in the country. Book publishers have not made arrangements to produce reasonably priced, locally printed editions of well-known textbooks, such as those so widely available in South Asia. Given the limitations already noted in ICT infrastructure (which might have otherwise compensated this to some extent), students are not fully able to access the information they require for their studies.

Staff Access to Teaching Materials Preparation Information

Information used by staff to prepare course materials in Ethiopian universities tends to be based on informal and ad hoc personal contacts. The use of online resources such as digital libraries, electronic journals or science archives is not well-developed. Instructors routinely contact former teachers or supervisors for resources and teaching materials. The current status of the university sector necessarily means information sources are in the nine established universities (those inaugurated prior to 2007). Graduates often leave the established universities with a CD of digital resources including electronic books, articles and software. This resource CD is often used as a source of teaching materials. Hence, instructors exhibit a high level of dependence on teaching subjects that they have already been taught. New courses introduced in the curriculum for the first time, and for which there are no teaching materials available, will thus be seen more as a problem rather than an opportunity to develop new learning resources.

The lack of staff access to information resources – especially novel information sources – had an adverse effect on curriculum change and course preparation by encouraging inheritance of resources from the old curriculum. In extreme cases, there has been a danger of courses being split to accommodate the expanded timescale of the four-year curriculum. "Course splitting" means that the content of an existing one-semester course is divided to occupy a two-semester space within the new curriculum. For example, an Advanced Database Management Systems course ends up with almost the same content as an earlier Introduction to Databases course, because instructors do not have the information required to teach the advanced techniques originally envisaged for the course. Course splitting subverts the intention of the four-year curriculum to provide opportunities for students to acquire deeper or more advanced knowledge.

Information About the Curriculum Change

We found evidence that the new computing curriculum ethos had not been sufficiently disseminated to teaching staff not directly involved in the change process. Those staff members were largely unaware that the new curriculum had, at its core, new objectives and teaching and learning processes. We found evidence of insufficient awareness of the new curriculum among some staff and more broadly among the student population.

There has been a lack of formal mechanisms to support the flow of information between universities. Individual departments are relatively isolated from each other. There are no regular opportunities for heads of departments or Faculty Deans to meet each other as a group. This lack of awareness presents an important shortcoming given the implicit assumption within the design that universities will share ideas and practices.

Information Flows with External Stakeholders

Most university instructors have little or no contact with external stakeholders such as suppliers, graduate employers, and ICT-related businesses. There is a perception that university management alone are responsible for external relations. Further, instructors and department heads feel they should focus on responding to pressures from their own university management. This contributes to the impression that institutions have rather little external focus and are perhaps insular; parochial even.

Yet an expectation within the new curriculum was external interaction: both outward, in communicating the new curriculum to stakeholders; and inward, bringing continuous employer input to ongoing curriculum revision. On the first, there was particularly a need to communicate with potential employers the differences between the newly-established subject areas such as information technology and information systems. Some large employers such as the national airline, state telecommunications provider, major banks and government departments would benefit from a greater understanding of the roles suited for graduates of these different degree programmes. Yet that understanding is absent in the absence of requisite information flows.

While there is little in the way of a formal, large-scale ICT industry in Ethiopia, there are some smaller technology retailers and software, hardware and networking service providers. The new curriculum ethos values and encourages their inputs. But our research shows liaison with the commercial sector is almost non-existent. We found no evidence of formal links with external stakeholders, such as industrial liaison committees at computing departmental or Faculty level. Some instructors undertake consulting work, but this is seen solely as an income-generating activity, and does not contribute information inflows to teaching or university life.

Design—Reality Gap

The curriculum change process was successful at the curriculum design level. Degree programmes have become more focused on their named subject areas, incorporating fewer introductory courses on other subjects. However, our research has revealed many challenges to the implementation of these changes in reality.

We found no evidence of instructors directly contacting any university outside Ethiopia for support or assistance. Only one or two departments had any links with professional bodies, whether from Ethiopia or abroad. Some libraries had arranged access to online academic resources, but their usage was not widespread even where network connectivity and reliable electrical power allowed.

Instructors, themselves a product of the prevailing educational culture, have not acquired well-developed information-gathering skills; locked into a self-reinforcing circle due to the lack of well-developed information sources. A lack of knowledge infrastructure makes it difficult for staff members to identify information needs and quickly navigate toward reliable data sources. As a result there is a strong dependence on knowledge sources inherited from their own teachers.

In conclusion we found a medium design—reality gap in terms of information. The challenges faced are considerable but are broader than the computing curriculum change process itself.

4.5 Management Systems and Structures

Design Expectations

The structure of university Faculties and academic departments is only an implicit part of curriculum change, but what emerged during the series of Computing Curriculum Change national workshops was organisation of computing subjects in terms of varied university departments and Faculties. There had been a proliferation of computing courses often in different academic departments and sometimes in different Faculties. The Working Group became aware of tensions about academic management structures. Members of the Working Group argued – as a design requirement – that computing courses should be contained within one academic unit (either a single department or faculty depending upon scale). This was to minimise competition for resources between management units teaching closely-related computing subjects. Another strength of the single administrative unit argument was the ability to allocate resources according to demand, keeping resource utilisation levels high.

The Working Group had more explicitly identified a concern about degree programme quality assurance processes. This was addressed in the Guidance Notes by advocating review and renewal through a formal process of periodic review and revision of courses and degree programmes (Bass *et al*, 2008).

Reality

University managements were by and large identified as being supportive of the structural design requirements of the computing curriculum change process. Debre Birhan, for example, chose to establish a new department to support the new Information Technology degree programme. In addition, a new Faculty was established to accommodate the Computer Science and Information Technology departments. In Hawassa University, the new Information Systems degree programme is offered by the existing Computer Science department.

Some of the institutions, such as Addis Ababa University, have not considered the wider implications of curriculum change. The broader organisational context has not been changed in response to the curriculum change process. For these institutions, bureaucratic administrative processes hamper implementation of the new curriculum. A practical example is the difficulty of overcoming administrative obstacles to opening labs for 24 hours.

The computing curriculum change process, though, needs to be seen in terms of a succession of initiatives and changes sweeping through higher education in Ethiopia. For example, curriculum change was almost simultaneous with another separate national management system reform process. All public institutions, including universities, publicly-owned enterprises and government departments were required to undertake business process reengineering (BPR). The BPR procedure was designed to reduce bureaucracy, improve efficiency and focus organisations on their key target stakeholders. BPR was diligently pursued throughout the public sector, with promising institutional changes resulting in some cases.

For instance, in Debre Birhan BPR led to decentralisation and streamlining of purchasing decisions. This new system devolves budgets to Faculties and decision-making to Faculty Deans. This has reduced purchasing lead times from around three months to as little as a week, for some items. The BPR team making proposals about teaching and learning across all subjects at Debre Birhan was specifically mandated to take the new computing curriculum into consideration in their deliberations. This has influenced the teaching and assessment policies adopted throughout the institution.

More detailed consideration of quality assurance procedures are being introduced by several universities. The new universities in general have yet to put in place detailed institutional review procedures. Curriculum documents produced during the change process include sections on quality assurance. Some institutions make simple commitments to review curricula periodically. Other institutions make more detailed commitments to review individual courses as well as the overall curricula. Addis Ababa, for example, has a university quality assurance policy which includes periodic institutional review and consideration of student feedback.

Design—Reality Gap

In terms of management systems and structures there is a relatively small design—reality gap resulting from the computing curriculum change process, assisted by the ability of some of the newer – often smaller – universities to be more flexible in their structuring; and by the more general readiness for re-structuring promoted by the BPR programme. The design—reality gap is also small in terms of quality assurance procedures. Increased consideration of quality assurance has been encouraged during the curriculum change process and these initiatives are being supported by broader quality assurance pressures within the sector.

4.6 Investment Resources

Design Expectations

The availability of financial resources for investment is obviously a very serious challenge for a country like Ethiopia, but the government has prioritised spending on education. The establishment of new public universities has been supported from the Ministry of Education budget. The Working Group Guidance Notes make reference to the need for investment to support the curriculum change process, and this therefore can be seen as an integral part of the design requirements for change (Bass *et al*, 2008). However, this important issue was not given sufficient attention in the documents or in the curriculum change process. For example, the Guidance Notes make no specific recommendations about the levels of investment required or about investment planning. The issue was only mentioned in passing in national workshops. The investment of time by staff was not raised at all during the curriculum change process. This was an omission which led to the implicit assumptions not always being turned into explict realities.

Reality

There has been a steady increase in government investment in the public university sector. For example, the overall budget for Debre Birhan University increased from c.US$1.5m in 2009 to c.US$2.8m in 2010. This additional funding has enabled development of new teaching labs, infrastructure and – where available – purchase of locally-available teaching materials and resources. Student study visits to other universities, companies or sites of special interest have also been funded.

However, there was no specific investment following the computing curriculum change process. It has been recognised that increasing emphasis on active learning and provision of advanced courses, places extra burdens on laboratory facilities. No funding was specifically made to support any facilities upgrade or specialist technologies demanded by the new curriculum. We observed a lack of confidence, among instructors, that sufficient investment funds are and will be available to meet the needs of the new curriculum.

In terms of the investment of time, we observed staff members contributing considerable amounts of personal time to the preparation of course and teaching materials. This is seen as necessary because they are often new faculty members and because they perceive computing as a rapidly-changing field which requires additional effort in order to keep up to date. They often spend evenings and weekends preparing courses that have been assigned to them at short notice (sometimes only a few days). Demand on staff member time is exacerbated by the need to set and mark the diversified laboratory-based assessments mentioned above. This outside-hours working is often sustained for long periods from one semester to the next.

Design—Reality Gap

To summarise, we have identified recognition that the university sector as a whole is benefiting from increased investment. However, we found no evidence of any investments, or investment plans, specifically designed to support the implementation of the new curriculum. Another pressing issue facing universities is the allocation of teaching staff time to support curriculum change. Currently, the goodwill and commitment of staff to contribute personal time is being relied upon. This represents a medium design—reality gap in terms of investment resources.

4.7 Staffing and Skills

Design Expectations

The design expectations of the new computing curriculum about new student skills created as a result of the change were discussed above, and any reality assessment will have to await graduation of the first cohort. While these were explicit, computing curricula rarely discuss the issue of staff skills but – as became clear in the workshops held during the change process – there were a number of implicit expectations within computing curricula about the presence of adequate numbers of professionally-skilled university staff: both managers and teachers.

Reality

Provision of university teaching staff with appropriate qualifications and experience is perhaps the biggest single problem facing the higher education sector in Ethiopia. The number of staff is generally regarded as being adequate, although they feel under pressure due to expansion of student numbers. However, many staff members are under-qualified and lack experience. Academic leaders of universities have, in many cases, not achieved the rank of full Professor, indeed in some universities they do not even have PhDs. Talented and experienced university managers are in short supply.

Newly appointed staff members – many of whom are fresh graduates – recognise the shortcomings in their own education because they are being called upon to teach subjects where their own expertise is uncertain and tentative. These members of staff feel vulnerable, pointing out they have only achieved the same level of skill as final year undergraduates; that being the specific recruitment criterion for Graduate Teaching Assistants. It is common, especially in the newer universities, that whole faculties only have one or two Masters degree holders and no PhD degree holders, and that GTAs are required to teach entire courses, rather than assisting more experienced instructors.

Instructors find it challenging running practical, lab-based sessions because they have limited experience of this teaching and learning style. The design requirement for diversified assessment methods exposes instructors who have been educated through a system that had a paucity of such learning opportunities. We also found evidence that it was primarily the lack of advanced skills that resulted in instructors duplicating material from introductory courses into advanced courses: the type of "course splitting" described above.

University managers seek to employ experienced academics, but there is no pool of suitably qualified and experienced staff from which to recruit. The Masters programme at Addis Ababa University (currently the only computing Masters programme in the country) only has 20 places per year. There are 22 public universities (expanding to 32), so less than one member of staff from each university can expect to obtain a higher degree each year. This creates a significant backlog of Graduate Teaching Assistants that require higher degrees and has an adverse effect on morale.

The skill shortages are particularly keenly felt in the Information Technology subject area. There are no Information Technology vocational course graduates in the country. Information Technology has previously been taught as a joint degree with education. Education and so-called "common courses" dominate the IT Education programme which is now discontinued. Further, there are no Information Technology MSc courses, to train instructors. Instructors that were taught Information Technology as a minor subject, are being called upon to teach advanced courses at a similar level of difficulty to specialist computer science instructors.

Design—Reality Gap

The explicit focus of curriculum change on student skills tends to swing the spotlight away from inherent design requirements relating to staff skills and, beyond that, to the mechanisms and channels through which those working in universities are themselves trained. When we turn our attention to these latter factors, we observe a picture of a largely dedicated and committed teaching community, hampered by the limitations of their own prior educational experience and a lack of qualifications and experience; limitations that – especially among younger staff – were well recognised. Similarly, there are management skills assumed within the design of curriculum change that were quite often not found in reality. The result was the largest of all the design—reality gaps.

This gap challenges the implementation of curriculum change in several ways, with instructors facing great difficulties in: teaching advanced courses; learning new subjects; designing, building and equipping new computer classrooms; supervising student laboratory and project work; and in conducting diversified laboratory-based assessments. Ministry of Education responses – reserving places on higher degree programmes run by Addis Ababa University for staff from the public university sector, and creating a scheme seeking to attract more highly qualified and experienced staff from abroad – are closing the gap a little, but do not address the need to upgrade the skills of existing and newly appointed staff members. These staff – even assuming they had the commitment, diligence and determination to identify their own learning needs and relevant resources – face a context with few opportunities for self-study or in-service training.

4.8 Milieu

Design Expectations

The acronym PESTLe (Political, Economic, Socio-cultural, Technological, Legal) is often used to summarise key contextual factors than can shape the environment for any organisational change. We can argue that some of these have already been covered: economic in the discussion on investment resources; socio-cultural in the discussion on objectives and values, technological in the discussion on technology. Here, then, we will deal with the political and the legal context.

The first is a sensitive issue, in part due to authorial involvement in the change and in dealing with government; even more due to the lack of enthusiasm of interviewees to touch on the subject. What we can say is that a deep implicit expectation for successful curriculum change is a stable and a-politicised environment. Laws, too, can be sensitive but a further implicit expectation is for a supportive legal framework.

Reality

In terms of politics, successive legislation in Ethiopia has been supportive of academic freedom and university independence. Yet university managers seem anxious to identify and support trends perceived to be emanating from the Ministry of Education or other government sources; a trend that makes conflict less likely and a stable context for curriculum change more likely. The particular relationship between the government and Addis Ababa University has historically been complex, and could have bucked this trend. The University's large size and location in the centre of the city make it difficult to ignore. There has in the past been anti-government student protest that was quickly (and arguably harshly) suppressed and resignations by senior members of the academic management. During the period under study, however, relations have been cordial and constructive, with the University playing a significant role in, for example, public university staff development through provision of higher degree programmes. As a result, the political backdrop appears largely to meet the deep, foundational expectations of curriculum change.

The legal context for the curriculum change process is defined by two major pieces of legislation. The first, Proclamation No. 351 (FDRE, 2003), provided for the establishment of 13 new universities in 2007. The legislation assigned responsibilities to specific officers in public universities and defines educational objectives in terms of the need for student participation and practice-oriented education. Support agencies, such as the Higher Education Quality and Relevance Agency and the Higher Education Strategy Centre were to be created. The legislation defined governing bodies and describes detailed responsibilities placed on specific senior officers. Certainly in terms of institutional formation, all this has materialised in reality and – as described earlier – it has played a part in supporting curriculum change.

The second Proclamation No. 650 (FDRE, 2009) is less prescriptive about management mechanisms but reflects increasing interest by central Government in educational outcomes. The 2009 proclamation mentions "learning outcomes" for the first time and considerably expanded on curriculum and quality enhancement issues compared with earlier legislation. Again, then, this reality can be seen as supportive of the broad design requirements of curriculum change.

Design—Reality Gap

Teasing out the contextual design expectations of curriculum change is not easy: they are almost always implicit and often so foundational they bear little immediate connection to curriculum discussions. But we can see that political requirements appear largely met and that the legislative realities – while not directly related to changes in computing curricula – have been in tune with those changes. Indeed the appearance of the term "learning outcomes" in the 2009 legislation could indicate that the computing curriculum change process influenced the drafting of legislation. We can conclude that the design—reality gap is small in terms of milieu.

5. Discussion and Conclusions

The computing curriculum change process described here is part of a broader, government-sponsored process of improvement in the quality and quantity of higher education in Ethiopia. As for that broader process, the implementation of changes to computing curricula has been uneven, and we have used the design—reality gap model as an evaluation tool and the OPTIMISM dimensions as a specific framework in order to understand what has and has not been achieved, as summarised in Table 3 and Figure 4.

OPTIMISM Dimension	Design—Reality Gap Rating	Comment
Objectives and Values	Small/Medium	Smaller on values and in new degrees and universities; Higher in traditional universities and non-core staff
Processes	Medium	Some changes to teaching and assessment processes, but uneven and more of a gap on assessment diversity
Technology	Large	Particularly large in new universities; and in relation to specialist facilities
Information	Medium	Smaller in relation to curriculum redesign; Larger in relation to information flows to and between student, staff and external stakeholders
Management Systems and Structures	Small	Smaller in new universities, and assisted by the wider BPR process
Investment Resources	Medium	Around computing-specific investments, and availability of staff time
Staffing and Skills	Large	Mainly around lecturing staff skills, and training routes; may be larger in new universities
Milieu	Small	Politics and legal context appear largely supportive

Table 3. Summary of Design—Reality Gaps

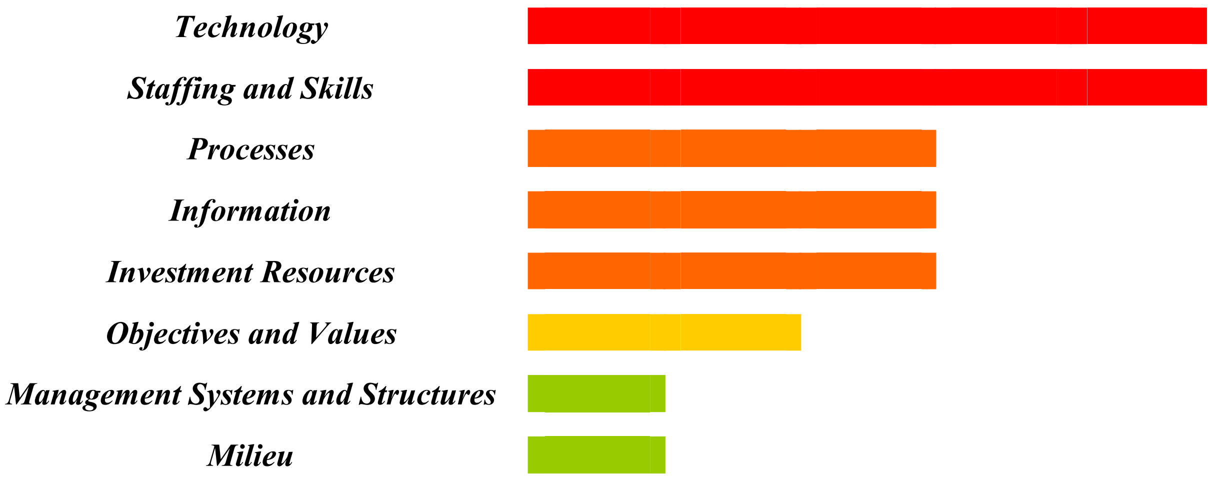

Figure 4. Size of Gaps Between Curriculum Re-Design Expectations and Current Realities

Reviewing the gaps between the design expectations of computing curriculum change in Ethiopia, and the reality one-two years following initial announcement, we can identify successes in several areas. The duration of computing degrees was extended in all public universities from three to four years. The advocacy of continuous assessment has resulted in changed assessment practices; with Debre Birhan University adopting an institution wide policy based on the new computing curriculum. The new computing curriculum documents reviewed make distinctions between subject-specific skills, subject-specific knowledge and transferable skills. Those involved in the computing curriculum change process either directly or through close interaction with those directly involved appear to have been convinced by the merits of greater emphasis on active learning techniques. None of the interviewees argued that more laboratory-based work was unnecessary or undesirable.

However, the challenges for implementation of the new curriculum are considerable, particularly along the Staffing/Skills and the Technology dimensions. There is unanimity about the debilitating effects of skill shortages. Particularly in the newly-established universities, departments and Faculties are being run and students are being taught by staff who – while often highly capable and committed – are seriously underqualified. Other existing gaps such as those relating to teaching and assessment processes derive from this one. There also have to be concerns about the key unmeasured gap – between the design assumptions of the competencies that graduating students will have from 2013 onwards, and the reality of the actual competencies they have – given so many teachers' competencies are the same as those of final year undergraduates.

Almost as challenging as the design—reality skills gap is the gap between current realities and design expectations for investment planning and technology enhancement. New subjects are introduced in the curriculum but there has been no systematic effort to establish the necessary teaching and learning infrastructure to support these initiatives. This issue will become even more pressing as students advance to the final years of the new degree programmes. Advanced courses will be called for in the curriculum but labs with the necessary specialist software or equipment will not have been provided.

Building new lab facilities is a challenge for universities, already suffering from staff skill shortages. University computing departments may only have one or two members with any practical experience of building computing teaching facilities. Preparing labs could be outsourced to local companies but suppliers are often expensive, deliver solutions of uncertain quality and are geographically remote. Outsourcing also misses the chance for internal capacity building and means that staff members do not fully understand the installation they have.

If we step back to compare the two groups of universities – the established and the new – we find design—reality gap variations. Perhaps not unexpectedly, the new universities are more nimble – they have more readily been able to change systems, structures and values to match the requirements of curriculum re-design. But they have also been less well-resourced – and thus less able to change their human and technological infrastructure realities to match re-design requirements.

5.1 Conclusion and Recommendations

Overall, there is a need for universities in Africa and other developing countries to update their computing curricula to cope with the growing and changing demands that ICT diffusion and use are placing on their countries. Almost all the literature on computing curricula focused on syllabus content. Here, though, we have been interested to evaluate a process of implementation. Bar a short commentary below, we are not concerned with the specifics of particular designs but, instead, with finding a systematic way to analyse and evaluate the progress of curriculum change; the intention being that – via this proof of concept – we can provide a model by which other universities and Ministries of Education can evaluate their own progress.

Looking again at the design—reality gaps, we can see varied progress along the OPTIMISM dimensions to close the gap between design expectations and university realities: greater progress in terms of espoused values of those involved; some progress in terms of changes to curricula and to the process of teaching and assessment; too little progress as yet in terms of staff skills and technological infrastructure. What could be done to improve that progress, and to close the remaining gaps between design and reality?

Here we suggest a few – perhaps rather obvious – recommendations. Firstly, to address the large gap associated with developing advanced courses tied to specific technologies, working groups need to be established with a remit to review curriculum needs, develop and implement proposals for developing or enhancing more advanced technical laboratory provision and producing and disseminating teaching materials including laboratory exercises and assessments. These groups should comprise appropriately qualified specialist staff and focus on one or other such areas as software technology and programming, computer networking, and databases.

Secondly, to address the large gap identified in the staffing and skills area, Masters level provision should be expanded by all possible means. Institutions with Masters level teaching capabilities should halt undergraduate teaching temporarily in order to concentrate resources on newly qualified university staff. Existing university staff members would also benefit from targeted in-service training in one or other specialist areas (probably tied to the advanced technologies just mentioned). The provision of Masters level short courses, to boost the skills and confidence of instructors, would be desirable to overcome short-term skill shortages but should not replace efforts to upgrade staff qualifications more generally.

Thirdly, to enable urgent action to address the large gaps in technologies and skills, investment resources need to be ring-fenced to enable capital investment in support of curriculum development. A central fund (perhaps accessed though a competitive bidding process) could be used to purchase specialist equipment or establish laboratory facilities to support specific advanced teaching goals.

Finally, government has a responsibility to follow up on curriculum change processes. Universities should report on progress, ideally using the dimensions of the design—reality gap framework, to refocus attention on the objectives of the change process. Sharing experiences between institutions will undoubtedly facilitate further positive change.

In addition, we would have a recommendation for future curriculum re-design groups: that they make use of the notion of design and reality, and make use of an OPTIMISM-like checklist to bring out for discussion not just the explicit design expectations on teaching processes, computing technology and staffing, but also the implicit ones e.g. those around values, information flows, management structures, investment funding, teaching systems and contextual forces. In educational contexts where knowledge transfer is the norm, the danger of seeing curriculum change initiatives as merely concerned with substituting current course content with new subject matter is not be underestimated. It would therefore also make sense to apply the design—reality gap model in risk analysis mode to identify some of the larger design—reality gaps and, hence, the main challenges for implementation.

In analysing the changes made to date, and also these recommendations, there is a uniformity to the changes which we should step back and recognise: they are always about changing Ethiopian reality to match curriculum re-design; not about changing the design to match Ethiopian reality.

Could that latter path have been considered? Put another way, are there particular gaps – hence, challenges – that have arisen due to adoption of a new computing curriculum deriving from Western professional associations and therefore incorporating Western design assumptions and requirements? Looked at from this perspective, it is arguable that almost all the gaps originate from this source; that the design is one fitting – say – a large US university, rather than a university in a developing country. We can see this in many of the dimensions: the values are those of Western education; the assumed availability of skilled staff and well-appointed computing labs and ready access to information draws from a Western level of resourcing; the approach to teaching and assessment is that which fits a Western (arguably North American) setting; and so on.

Suggesting a developing country-specific design for computing curricula is dangerous. It readily falls prey to accusations of giving developing countries second-best; of reducing the opportunities for international exchange. Students, in particular, may be wary of such qualifications since many have aspirations for international mobility. Yet, we have seen the difficulties faced in bringing a Western-inspired curriculum re-design into a developing country context, and there are not only arguments but also specific guidance for developing country-relevant curricula (Tedre *et al*, 2009b). We would also note that many Western universities currently seem busy developing curricula on computing-and-development or ICTs-and-development.

At the least, then, there are opportunities for international collaboration around curricula of particular relevance to developing countries (as reflected in just such an initiative led by the Association of Information Systems's GlobDev special interest group). At the most, universities in developing countries may have the confidence to not just adopt but adapt international curricula; customising curriculum designs more closely to their own realities; realities not just of resource constraints but also of different context, structures, systems and values.

Finally, what of the application of the design—reality gap model? Certainly there were some practical challenges. The OPTIMISM dimensions have been developed on the basis of information systems projects rather than curriculum change projects. As a result, it was not always easy to see which elements to assign to which dimensions. This was especially true of curriculum design and content which we ended splitting between the Objectives/values, and Information dimensions. But this sat alongside other elements in each dimension such as information flows between stakeholders in the latter case. It might therefore make sense for assessment of curriculum change to add a new dimension e.g. a COPTIMISM checklist that began with Curriculum design and content.

A second challenge lay in drawing out the assumptions and requirements within the design of curriculum change. Most of our interviewees had limited understanding of the design, so we were able to ask them about reality but could not get them to directly assess the design—reality gaps. And many of the design expectations were implicit; in some cases not having been surfaced by the Working Group. We were therefore left to expose these ourselves on the basis of knowledge of the curriculum change, knowledge of the guidance documents, and knowledge of the surrounding processes and structures.

Despite these challenges, we find that the design—reality gap model has been a valuable progress reporting framework; one that has enabled us to develop an in-depth evaluation of not just how far curriculum change has proceeded, but also what more needs to be done and what barriers exist to further implementation. We find three advantages compared to less formal approaches. The design—reality gap model has enabled us to systematically evaluate the curriculum change, understanding clearly what two things we are comparing and how they are to be compared. As Table 3 and Figure 4 demonstrate, it therefore allows findings to be readily summarised and communicated. Third, the checklist has pushed the evaluation to be comprehensive, exposing many issues that are important requirements for successful change to computing curricula in developing countries, but which might otherwise have remaining hidden.

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APPENDIX 1: THREE-YEAR (OLD) COMPUTER SCIENCE CURRICULUM (EXTRACT)

Objectives Of The Program

The primary objective of the program is to produce a high quality graduate with an entrepreneurial and problem-solving mindset. The specific objectives of the program are as follows:

- Educating and training students for the very dynamic and rapidly changing science and technology market.
- Educating and training students to become life-long learners by providing them with a sound knowledge in computer science, other basic sciences and with general education.
- Motivating students to face the present and future technology challenges.
- Laying a strong foundation for, and instilling confidence in students who may want to pursue post-graduate studies in the future.

Graduate Profile

The graduates of the program would be able to:

- Determine user information requirements;
- Design, develop and maintain application software;
- Design, set up and administer computer networks;
- Design, develop and administer databases.
- Manage computer-based information systems.
- Participate in research activities.
- Teach in schools and higher education institutions.
- Design web pages and administrating internet

Compulsory Courses

Course No.	Course Title	Credit Hours	Lecture Hours	Lab Hours
Comp 201	Introduction to Computer Science	3	2	3
Comp 211	Principles of Programming	4	3	3
Comp 218	Data Structures and Algorithms	3	2	3
Comp 232	Database Systems	3	2	3
Comp 311	Object Oriented Programming	3	2	3
Comp 313	Analysis of Algorithms	3	3	-
Comp 314	Operating Systems	3	2	3
Comp 316	Rapid Application Development	3	2	3
Comp 322	Internet Programming	3	2	3
Comp 324	Data Communications and Computer Networks	3	2	3
Comp 326	Computer Organization and Architecture	3	2	3
Comp 331	Systems Analysis and Design	3	3	-
Comp 400	Practical Attachment		-	-
Comp 401	Information and Society	3	3	-
Comp 403	Seminar in Computer Science	1	1	-
Comp 406	Selected Topics in Computer Science	3	3	-
Comp 408	Industrial Project	3	0	9

Compulsory Courses (contd.)

Course No.	Course Title	Cr. Hrs.	Lec. Hrs	Lab Hrs
Comp 413	Software Engineering	3	3	-
Comp 415	Introduction to Formal Language Theory	3	3	-
Comp 416	Principles of Compiler Design	3	2	3
Comp 425	Systems and Network Administration	3	2	3
Comp 444	Introduction to Artificial Intelligence	3	2	3

Elective Courses (At least six credits from the following)

Course No.	Course Title	Cr. Hrs.	Lec. Hrs	Lab Hrs
Comp 417	Computer Graphics	3	2	3
Comp 418	Software Reuse	3	3	-
Comp 419	Systems Simulation and Modeling	3	2	3
Comp 426	Computer Security	3	3	-
Comp 428	Interactive Multimedia	3	2	3
Comp 435	Advanced Database Systems	3	2	3
Comp 436	Information Retrieval	3	3	-

Supportive Courses

Course No.	Course Title	Cr. Hrs.	Lec. Hrs	Lab Hrs
EEng 204	Fundamental of Electricity & Electronic Devices	4	3	3
EEng 323	Digital Electronics	3	2	3
Math 223	First Course in Abstract Algebra	3	3	-
Math 231	Applied Mathematics I	4	4	-
Math 232	Applied Mathematics II	4	4	-
Math 293	Discrete Mathematics and Combinatorics	3	3	-
Math 330	Numerical Analysis I	3	3	-
Stat 274	Introduction to Probability and Statistics	3	3	-

General Education Courses

Course No.	Course Title	Cr. Hrs.	Lecture Hrs	Lab Hrs
CEED 201	Civics & Ethical Education	3	3	-
FlEn 201	Sophomore English	3	3	-
Phil 201	Logic	3	3	-
Mgmt 214	Business Communication	3	3	-
Mgmt 414	Entrepreneurship	3	3	-

APPENDIX 2: FOUR-YEAR (NEW) COMPUTER SCIENCE CURRICULUM (EXTRACT)

Objectives of the Program

The primary objective of the program is to produce a high quality graduate with an entrepreneurial and problem-solving mindset. The specific objectives of the program are:

- Educating and training students for the very dynamic and rapidly changing science and technology market.
- Educating and training students to become life-long learners by providing them with a sound base in computer science, basic sciences as well as general education.
- Motivating students to become innovators who can respond very positively to the challenges and opportunities presented by new ideas and technologies.
- Laying a strong foundation for, and instilling confidence in students who may want to pursue post-graduate studies later in life.

Graduate Profile

The graduates of the program would be able to:

- Have thorough understanding of theories, principles and methods in computer science
- Articulate & demonstrate effectively computer & transferable knowledge& skills on computer science practices, theories & principles
- Elicit user requirements for information system development
- Analyze, design, develop & maintain software (application & system software)
- Analyze, design, implement & administer computer networks
- Analyze, design, develop & administer database systems
- Maintain & administer computer based information systems
- Analyze, design, develop, maintain, and administer web based applications
- Apply the concept of professional practices and ethics
- Assist, participate and contribute in research activities in the area of computer science
- Design, analyze and implement computer algorithms

Quality Assurance - Maintaining the Quality of the Program

- Comprehensive examinations and colleague assessment of examination papers and teaching methods;
- Periodical workshops (with stakeholders, teachers and graduates);
- Assessments by using survey project works (researches), internships, and link programs;
- Graduates' evaluation of the program;
- Standardization of course offerings through preparation of general course outlines, exam contents, and external audit;
- Annual assessment of the program by the teaching staff;
- Establishing alumni of graduates as a mechanism to assess their career development;
- Working closely with the relevant professional associations to assess graduates' performance.

Teaching Methods

The following formats of teaching and learning are used in order to meet the program learning outcomes stated above.

- Lectures
- Practical classes / laboratories
- Independent learning

- Group or individual coursework assignments or projects
- Educational visits
- Student final project
- Automated learning tools

Teaching Materials

The teaching materials used include:

- Blackboards, whiteboards, chalks and whiteboard markers
- Projectors
- Computers and related peripherals like printers and scanners
- Network infrastructures
- Text and reference books
- Software tools

Core Courses

Course No.	Course Title	Credit Hours	Lecture Hours	Lab Hours
Comp 201	Introduction to Computer Science	4	3	3
Comp 211	Fundamentals of Programming I	3	2	3
Comp 212	Fundamentals of Programming II	3	2	3
Comp 324	Data Structures and Algorithms	4	3	3
Comp 342	Fundamentals of Database Systems	3	2	3
Comp 313	Object Oriented Programming	3	2	3
Comp 427	Analysis of Algorithms	3	3	0
Comp 352	Operating Systems	4	3	3
Comp 413	Internet Programming I	3	2	3
Comp 414	Internet Programming II	3	2	3
Comp 372	Data Communications and Computer Networks	4	3	3
Comp 351	Computer Organization and Architecture	3	3	0
Comp 461	Fundamentals of Software Engineering	3	3	0
Comp 462	Object Oriented Software Engineering	3	2	3
Comp 411	Advanced Programming	4	3	3
Comp 597	Industrial Project I	3	0	9
Comp 598	Industrial Project II	3	0	9
Comp 490	Research Methods & Technical Report Writing in CS	3	3	0
Comp 581	Introduction to Formal Language Theory	3	3	0
Comp 582	Principles of Compiler Design	4	3	3
Comp 574	Computer Security	2	2	0
InTc 476	Systems & Network Administration	3	2	3
Comp 301	Professional Practice & Ethics in Computing	2	2	0
Comp 476	Complexity Theory	3	3	0
Comp 354	Microprocessor & Assembly Language	3	2	3
Comp 484	Computer Graphics	3	2	3
Comp 449	Advanced Database Systems	3	2	3

Core Courses (contd.)

Course No.	Course Title	Cr. Hrs.	Lec. Hrs	Lab. Hrs
Comp 451	System Programming	3	2	3
Comp 531	Introduction to Artificial Intelligence	3	2	3
Comp 203	Logic in Comp. Sc.	3	3	0
Comp 576	Introduction to Distributed Systems	3	2	3
Comp305	Discrete Mathematics and Combinatory	3	2	3
Comp 509	Systems Simulation and Modeling	3	2	3

Elective Courses

Course No.	Course Title	Cr. Hrs.	Lec. Hrs	Lab. Hrs
InTc322	Multimedia Systems	3	2	3
Comp 501	Selected Topics in Computer Science	3	3	-
Comp 478	Wireless & Mobile Computing	3	2	3
InSt331	Information Storage & Retrieval	3	2	3
InSt512	Expert Systems	3	2	3

Supportive Courses

Course No.	Course Title	Cr. Hrs.	Lec.Hrs	Lab. Hrs
EEng 204	Fundamental of Electricity & Electronic Devices	4	3	3
EEng 323	Digital Electronics	3	2	3
Math 423	Fundamentals of Abstract Algebra	3	3	0
Math 233	Applied Mathematics for CS	4	3	0
Math 330	Numerical Analysis I	3	2	3
Stat 274	Introduction to Statistical Methods	3	3	0
Mgmt 214	Business Communication	3	3	0
FLEn 211	Sophomore English	3	3	0
FLEn 201	Communicative Skills for Computer Science	2	2	0

General Education Courses

Course No.	Course Title	Cr. Hrs.	Lec. Hrs	Lab. Hrs
CEED 201	Civics & Ethical Education	2	2	0
Mgmt 414	Entrepreneurship and Small Business Mgmt	3	3	0

APPENDIX 3: FOUR-YEAR (NEW) INFORMATION TECHNOLOGY CURRICULUM (EXTRACT)

General Objective
- To produce high quality IT graduates with entrepreneur and problem solving mind set.

Specific Objective
- To produce graduates who possess the right combination of knowledge and practical skills to take care of an organization's and people's need of technology and infrastructure.
- To produce professionals that take responsibilities for selecting hardware and software products appropriate for an organization, integrating those products with organizational needs and infrastructure.
- To produce graduates who installing, customizing and maintaining applications (network installation, network administration, Web site design, development of multimedia resources, installation of communication components and oversight of email system) for the organization.
- To produce professionals to work in organizations implementing and managing automated information systems for different scientific, educational, commercial and other purposes.
- To produce graduates that plan and manage the technology lifecycle by which an organization's technology is maintained, upgraded and replaced.

Goals of an IT Program
IT programs aim to provide IT graduates with the skills and knowledge to take on appropriate professional positions in Information Technology upon graduation and grow into leadership positions or pursue research or graduate studies in the field. Specifically, within five years of graduation a student must be able to:
- Explain and apply appropriate information technologies and employ appropriate methodologies to help an individual or organization achieve its goals and objectives;
- Manage the information technology resources of individuals or organizations;
- Anticipate the changing direction of information technology and evaluate and communicate the likely utility of new technologies to an individual or organization;
- Understand and contribute to the scientific, mathematical and theoretical foundations on which information technologies are built;
- Live and work as a contributing, well-rounded member of society.

Graduate Profile
In general, the graduates of the program will have the ability to:
- Use and apply current technical concepts and practice in the core information technologies;
- Analyze, identify and define the IT requirements that must be satisfied to address problems or opportunities faced by organizations or individuals.
- Design effective and usable IT-based solutions and integrate them into the user environment;
- Identify and evaluate current and emerging technologies and assess their applicability to address the user's needs;
- Analyze the impact of technology on individual, organization and society.
- Assist in the creation of an effective project plan.
- Analyze, adopt and demonstrate IT best practices, standards and their application.
- Demonstrate independent critical thinking and problem solving skill.

- Collaborate in teams to accomplish a common goal by integrating personal initiatives and group cooperation.
- Communicate effectively and efficiently with clients, users and peers both verbally and in writing, using appropriate terminology.
- Implement, maintain and manage information technologies and services.
- Implement, maintain and manage Web based systems and services.
- Implement, maintain and manage data and database systems.
- Implement, maintain and manage data communication and networks.
- Recognize the need for continued learning throughout their career.

Attitudes and Values
The graduates will be inspired:
- To have professionalism at the center of their mentality;
- To have a positive and responsive attitude towards the value of information resources and towards their profession (love, dedication, commitment, etc.);
- To have good personal confidence in their jobs and professional activities;
- To have the sense of co-operation, honesty, loyalty, etc.; and
- To be ethical.

Teaching Methods (Strategies)
Lectures, laboratory works, tutorials and practical exercises, reading assignments and term papers, computer programming, application projects and presentation; demonstration and discussions; research and report writing.

Quality Assurance - Maintaining the Quality of the Program
- Comprehensive examinations and colleague assessment of examination papers and teaching methods;
- Periodical workshops (with stakeholders, teachers and graduates);
- Assessments by using survey project works, internships, and link programs;
- Graduates' evaluation of the program;
- Standardization of course offerings through preparation of general course outlines, exam contents, and external audit;
- Annual assessment of the program by the teaching staff;
- Establishing Alumni of Graduates as a mechanism to assess their career development;
- Working closely with the relevant professional associations to assess graduates' performance.

Compulsory Courses

Code	Course Name or Title	Credit Hours	Lecture Hours	Lab. Hours
InTc201	Introduction to Information Technology	4	3	3
Comp351	Computer Organization and Architecture	3	2	3
Comp211	Fundamentals of Programming	4	3	3
InSt342	Systems Analysis and Design	3	3	0
Comp 332	Data Communications and Computer Networks	4	3	3
Comp314	Data Structure and Algorithms	4	3	3
Comp341	Fundamentals of Database Systems	3	2	3
Comp352	Operating Systems	4	3	3
Comp212	Object Oriented Programming	3	2	3
InTc437	Systems and Network Administration	3	2	3
InTc492	Project Management	3	3	0
Comp313	Advanced Programming	3	2	3
InTc401	IT Social, Professional and Ethical Issues	3	3	-
InTc501	Current Issues in Information Technology	2	2	0
InTc591	Industrial Project I	3	0	9
InTc592	Industrial Project II	3	0	9
InTc541	Introduction to Geographical Information System & Remote Sensing	3	2	3
InTc422	Multimedia Systems	3	2	3
InTc301	Basic Applications Management and Use	1	0	3
InTc252	Operating Systems Management and Use	2	0	6
InTc472	Computer Maintenance and Technical Support	3	1	6
InTc362	Internet Services	1	0	3
InTc532	Network Devices Configuration	2	0	6
InTc461	Internet Programming I	3	2	3
InTc462	Internet Programming II	3	2	3
InTc531	Information Assurance and Security	4	3	3
InTc402	Special Purpose Databases	2	1	3
InTc431	Integrative Programming and Technologies	3	2	3
InTc522	Human Computer Interaction	4	2	6
Comp449	Advanced Database Systems	3	2	3
Comp 576	Introduction to Distributed Systems	3	2	3
InTc302	Introduction to Telecom Technologies	2	2	0
InTc532	Wireless Networking and Mobile Computing	3	2	3
InTc206	IT and Economic Development	2	2	0
InSt483	E-commerce	2	1	3
InTc541	Data Mapping and Exchange	2	1	3
Comp203	Logic in Computer Science	3	3	-
InTc311	Rapid Application Development	3	2	3
InTc391	Research Methods & Technical Report Writing in Information Technology	3	3	0

Supportive Courses

Code	Course Name or Title	Cr. Hr	Lec. Hr	Lab. Hr
Mgmt201	Introduction to Management	3	3	-
Comp208	Discrete Mathematics and Combinatory	3	3	-
Stat374	Introduction to Probability and Statistics	3	3	-
Mgmt405	Business Communication	3	3	-
Mgmt414	Entrepreneurship	3	3	-
Math263	Applied Mathematics for Computer Science	4	4	-
EEng204	Fundamental of Electricity & Electronic Devices	4	3	3

Common Courses

Code	Course Name or Title	Cr. Hr	Lec. Hr	Lab. Hr
FLEn201	Communicative Skills for Information Technology	2	2	-
FLEN211	Sophomore English	3	3	-
CEED202	Civics and Ethical Education	2	2	-

Elective Courses (six credits total)

Code	Course Name or Title	Cr. Hr	Lec. Hr	Lab. Hr
Comp514	Computer Graphics	3	2	3
Comp519	System Simulation and Modeling	3	2	3
InSt517	Natural Language Processing	3	2	3