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A New ICT Maturity Model for Education Institutions in Developing Countries

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Abstract

There is increasing interest in the use of information and communication technologies (ICTs) in education institutions in low-income countries. Developing ICT infrastructure is disproportionately expensive in developing countries and sustainable interventions are difficult to achieve: in part because leaders of educational institutions and donors have often not had the opportunity to develop ICT infrastructure planning and implementation skills. There has been a lack of concrete guidance regarding the stages of development needed to make efficient use of resources and maximise the chances of sustainable investments.

To address these needs, a novel ICT Maturity Model is presented here that provides a developmental framework for education institutions in low-income countries. The Model is unique in defining the ICT infrastructure resource levels required to achieve primary organisational objectives expressed in the form of student learning outcomes. The Model consists of eight levels, with the lowest levels defining the infrastructure required to enable initial computer training. The highest level applies to institutions where e-research is widely practised across the curriculum. The levels in the Maturity Model show management, teaching and technical staff, and donors how to make most efficient use of ICT resources by maximising opportunities for student learning.

The Maturity Model has been derived from documentary sources and an analysis of selected schools, colleges and universities in Ethiopia. The surveyed institutions include five primary schools, one higher education preparatory school, six teacher education colleges and five public universities. The Maturity Model was used as a prescriptive, developmental tool in one of the teacher education colleges and one public university. In this mode, the Model was shown to prioritise capacity building and infrastructure development initiatives that contributed to improving student learning opportunities. Although developed and tested in the context of one country, it is hoped that the Model will be applicable across a range of developing countries.

Introduction

This paper considers the stages of development of ICT infrastructure in education institutions in developing countries. A novel Maturity Model is presented which has been used to develop ICT infrastructure for educational use at a college of teacher education and a new university over a two-year period. The purposes of the Maturity Model are to:-

- Provide a planning framework for stakeholders in educational institutions,
- Enable advocacy of a systematic series of developmental stages,
- Foster efficient and sustainable use of existing installed infrastructure resources, and to
- Guide investment in ICT resources so they are targeted to enhance student learning outcomes.

As will be shown in the following pages, the levels of the Maturity Model link ICT resources to student learning outcomes. Further, the levels have been selected to maximise the efficient use of available computing resources for the benefit of student learning opportunities.

ICT in Education in Developing Countries

There has been growing interest in the use of ICTs in educational settings in developing countries. Non-governmental initiatives have included the much publicised One Laptop Per Child initiative (Kraemer, 2009). Further, in recent years, several countries have attempted government-led initiatives to expand access to ICTs in schools. These initiatives have often been associated with a broader educational quality improvement agenda. Interventions have included investment in new computer classrooms, and schemes to provide teachers with laptops (Gülbahar, 2008).

Research evaluating the use of computers in education shows that ICTs can contribute to enhancing education in a development context in a number of ways (Wims & Lawler, 2007):

- Increasing the number of qualified teachers by accelerating teacher training,
- Improving achievement levels by helping to counter adverse factors such high student:teacher ratios, shortage of basic teaching materials and poor physical infrastructure,
- Reducing drop-out rates by making learning more interesting and stimulating,
- Overcoming geographical obstacles through distance learning, and
- Providing access to educational content and up to date resources.

Other student benefits may include greater opportunities for post-school employment, and greater motivation for ICT-related careers.

Despite these benefits, shortcomings have also been found. For example, Wims and Lawler (ibid) also report teachers having to share use of computers with other school staff. They show sometimes comparatively little educational use of the ICT resources is made in subjects other than computer skills training. And their research demonstrated the need for staff training and staff computer access to encourage the educational mainstreaming of ICT.

In an investigation of the obstacles to greater use of ICTs in African schools, Kessy et al (2006) report several reasons, which fall into two main camps. First, is the lack of tangible resources such as technology, money and power. These point to the need for effective planning in order to make best use of the few resources that can be brought to bear on education. Yet the second problem relates to human resource shortcomings around awareness, competencies and governance, which make such effective planning all the more difficult to achieve.

Among other issues, we can see that education institution managers, teachers and senior academics in developing countries lack ICT planning and infrastructure implementation knowledge. Guidance on this could help make better use of scarce resources, develop in-house skills and cope with rapid technological change by focusing on key organisational objectives. One form in which such guidance could come is a Maturity Model.

Maturity Models

Defining the ICT adoption of organisations as a series of clearly articulated developmental stages is intuitively attractive and was first posed as a hypothesis by Richard Nolan at Harvard University (Nolan, 1973). Nolan identified four stages:

- Stage I: Initiation (computer acquisition),
- Stage II: Contagion (intense system development),
- Stage III: Control (proliferation of controls), and
- Stage IV: Integration (user/service orientation).

In a subsequent paper Nolan (1979) adds two further stages of maturity:

- Stage V: Data Administration, and
- Stage VI: Maturity.

The initiation phase refers to the initial introduction of computers into the organisation. Computers are seen to be introduced because of some computational need or because the size of the organisation demands administrative automation. Computer introduction is seen as a powerful agent for change and to focus the organisation on rigour and efficiency. This, according to Nolan, causes a backlash with early proponents becoming alienated.

The contagion phase takes place when management implements policies and plans to improve utilisation of computer resources. The contagion phase is required to overcome alienation and hostility and to maximise use of computing resource investments already made. During contagion additional investment is required in order to support decentralised ICT projects. Sometimes planning is poorly executed during this phase because of lack of ICT project management experience.

The control phase usually follows a crisis of out-of-control computing expenditure and poorly planned and executed automation projects. During this phase the emphasis is on more formalised planning and budget controls of computing resources. A centralisation process is often used to review and evaluate proposed projects to ensure value for money.

The integration phase is focused on reassessing the role of computing resources in the achievement of organisational goals. This involves reconciling user needs with the

advantages of appropriate forms of computer automation. There is a trend during this phase towards mainstreaming computing solutions into functional departments.

In the data administration phase management is focused on information flows, storage and management. The emphasis shifts from computing resources to database systems (perhaps "information systems" in more modern terminology).

The final maturity phase is reached when the computing resources precisely mirror the information flows within the organisation. In this phase, there is a sense that the full range of applications required to support the work of the organisation has been implemented.

A stage model, such as that proposed by Nolan, is attractive for planning purposes and to enable institutions to assess their own maturity in respect of ICT adoption. In any stage model, the stages must be distinct and empirically testable and the relationship or transition between predecessor and successor stages must be well defined. A problem with the Nolan model is that he uses computing budget expenditure (rather broadly defined) as a surrogate measure for a wide range of ICT developmental infrastructure properties. The validity of using budget to represent organisational environment, management strategies and institutional skills-base has been questioned (King, 1984).

Budget expenditure is also an important driver in Nolan's model for the transition from Stage II to Stage III, the suggestion being that it is mushrooming ICT budgets that precipitate imposition of controls in the ICT environment. In recent years, the benefits of ICT policies and management plans have come to be seen as good practice in themselves and not necessarily motivated by any need to control ICT budgets. The Nolan plan has been important for identifying that the motivation for growth in computing use comes from factors both internal and external to organisations (King, 1984). Also, that there is a dialectical relationship between freedom and constraint in the control of computing that leads to certain states of equilibrium (King, 1984).

The primary contribution of the research presented in the following pages, is the development of a new Maturity Model that links the stages of an organisation's ICT development to the potential student learning outcomes made possible at each level. This new Maturity Model decouples budgets from being the major driving force propelling organisations through ICT development stages. Rather, the objective of creating new student learning outcome opportunities becomes the major driver for targeted investment to move from one developmental stage to another. The aim is to link ICT infrastructure investment to primary organisational objectives, expressed in the form of student learning outcomes.

A New ICT Maturity Model for Education Institutions

The new Maturity Model development was based on analysis of surveyed education institutions and was also informed by several documentary sources. The International Computer Driving License, ECDL/ICDL (2009) syllabus is aimed at computer users. The syllabus has seven units including concepts of IT, computer use and managing files, word processing, spreadsheets, databases, presentations, and information and communication (Internet use). From a computer user's point of view, the syllabus

provides a detailed breakdown of desirable skills. In a resource-constrained context, it can be observed that varying infrastructure is required to teach the units in the ECDL/ICDL syllabus. The introductory unit needs no computers at all (although they may be desirable to enliven teaching). The second unit requires only an operating system (to learn about file management tasks), while four units require standard office application software. The final unit requires an Internet connection with sufficient bandwidth to support a student group. This provides a basic foundation for the idea of linking infrastructure to learning outcomes.

University computing curricula are required in order to train a future generation of professionals. Detailed degree curricula guidelines have been produced by the Joint IEEE/ACM Computing Curriculum Task Force. Important work to establish the commonalities and distinctive features of five computing subject areas has been helpful: computer science, computer engineering, information systems, information technology and software engineering (IEEE/ACM, 2005). In particular, the broad scope and applied nature of the information technology curriculum is attractive in developing countries (Bass, 2008), and it therefore contributes further to learning outcome ideas in the new model.

The Skills Framework for the Information Age (SFIA) provides a detailed taxonomy of 86 specialist ICT practitioner skill areas and 290 tasks (SFIA, 2009). The three-dimensional SFIA reference model describes six categories of work on one axis, seven levels of responsibility on another and information resources/components on the third axis. The SFIA was not produced with developing countries in mind. However, merging the skill areas within categories can provide a useful model of desirable student learning outcomes and organisational support activities for a developing country context.

These documentary sources can thus be used to gain improved understanding of skills outcomes from the perspective of computers users, education curricula guidelines and ICT practitioners. They also offer the basic connection between those outcomes and both infrastructural resources and organisational stage. But this is just a background of ideas and structures, and with little specific developing country relevance. To take the idea of the new model further, fieldwork was required.

The next section of this paper, Section A, therefore discusses the research methodology used; in this case a practitioner-based action research approach. Section B illustrates the development of the new ICT Maturity Model using results of a survey of schools in the city of Debre Birhan and Colleges of Teacher Education predominantly located in the Amhara Region of northern Ethiopia. A survey of in-service and pre-service trainee teacher ICT skills is also presented. These surveys illustrate the lack of resources for ICT investment available in a low-income country. However, more interestingly, where an ICT infrastructure is available, the surveys reveal underutilisation of computing resources when considering student learning objectives.

Once developed, the new Maturity Model was then applied, as discussed in Section C, giving direction to ICT infrastructure development projects at two education institutions. Concluding remarks are presented in Section D.

A. Research Methodology

Action research is a form of practitioner-based enquiry which seeks to contribute both to current practice and to the generation of new knowledge (Schon, 1983). As traditionally envisaged in the social sciences, it sees a collaborative relationship between researcher and client over time aimed at both problem-solving and contributing to theory (Lewin, 1982). Educational action research frames the action research approach in an educational setting and recognises that the process is itself a learning experience (Carr & Kemmis, 1986). It was seen as particularly appropriate given the knowledge generation goal represented by the desire to develop and test a new Maturity Model, and given the long-term immersion of the author within an educational environment.

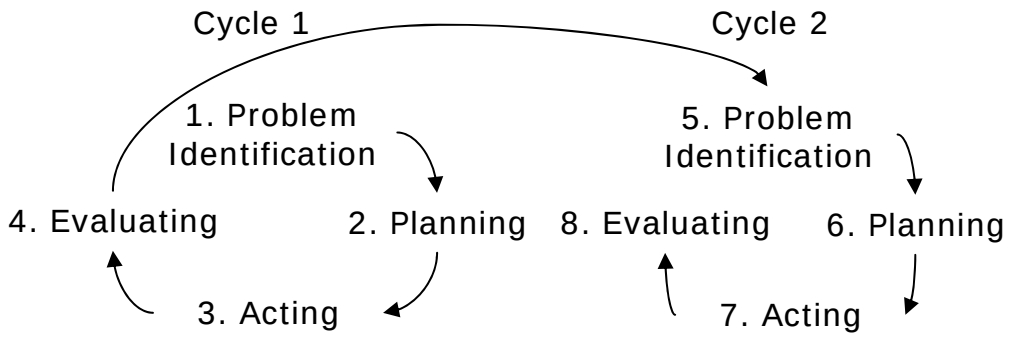
Action research is holistic, it is rooted in practice, and so it typically takes practical reality as its starting point (McNiff, 1988). It takes place in real time, with the research engaging with real events as they actually unfold. Increased use of action research has been advocated in developing country settings because it:

- enables research in resource-constrained environments,
- aims to make a specific contribution to the research setting, and
- can develop ideas that are crucial in changing attitudes (Walsham & Sahay, 2005).

Again, then, this was seen as a particularly appropriate to the aims of generating a new, practical and usable Maturity Model in a developing country.

Action research involves iterative cycles of identifying a problem, planning, acting and evaluating (Argyris, 1985). The research comprised two action research cycles each lasting about 18 months, as shown in Figure 1. The core of each cycle broadly corresponded to a one-year placement of the author, with the international NGO Voluntary Service Overseas (VSO), at an education institution in Ethiopia. The first year was spent at Debre Birhan College of Teacher Education. The second year was spent with the newly-established Debre Birhan University. Debre Birhan is the administrative centre of North Shoa Zone about 130km north east of Addis Ababa, the capital city of Ethiopia (see Figure 2 below).

FIGURE 1
ACTION RESEARCH PHASES AND CYCLES



There was some overlap and blurring between the two action research cycles because of the close geographical and institutional relationships between the two organisations. Staff from both organisations worked together for in-service professional development activities and infrastructure installation activities.

Likewise, the practicalities of working on a day-to-day basis with the institutions meant that the phases of each action research cycle were of unequal duration with blurring of the boundaries between phases. The practical realities impinging on the research included semester start dates, the need to establish new computer classrooms to support the teaching timetable, and so on. The emphasis of treatment in this article is on the problem identification, planning and evaluation phases of the first cycle and a more extended evaluation phase of the second cycle.

A1. Problem Identification Phase (Cycle 1)

During the problem identification phase, three information gathering studies were conducted; intended to provide some baseline information about skills and infrastructure components of the Maturity Model:

a) *ICT Status in Six Colleges of Teacher Education.* This information gathering activity was designed to answer the following questions:

- How do Colleges of Teacher Education in Ethiopia compare with each other in terms of ICT infrastructure?
- How many computers do they have for teacher education?
- What internet connectivity do they have? Do students have Internet access?

A survey of ICT status in selected Colleges of Teacher Education (CTEs) was conducted, using a network of volunteers from VSO during December 2006 and January 2007. The six CTEs surveyed are mostly in the Amhara Region (Debre Birhan, Debre Marcos, Dessie and Gondar) but also with one each in Southern Nations, Nationalities and Peoples Region (Dilla) and Tigray (Abbiye Addi). The approximate location of these institutions is shown in Figure 2.

FIGURE 2
LOCATION MAP SHOWING APPROXIMATE INSTITUTION LOCATIONS IN ETHIOPIA

The institutions were opportunistically selected based on the availability of volunteers willing to gather and submit the survey information. Resources were not available to conduct a survey of all institutions, and lack of telecommunications and large geographical distances presented insurmountable logistical challenges to such a wider study. Knowledge of other institutions, obtained subsequently, such as Harar CTE and Arba Minch CTE (see Figure 2), showed consistency with the surveyed institutions.

b) *ICT Status in Six Debre Birhan Schools*. This information-gathering activity was designed to explore the following research questions:

- What ICT infrastructure can be expected when College of Teacher Education graduates are employed in local schools?
- What ICT skills could CTE graduates usefully bring with them into schools now and in the future?

A survey of ICT provision in schools in Debre Birhan was conducted between May and July 2007. The survey questions were based on those advocated by UNESCO (2006) for international school surveys. The criteria were selected to enable comparison with other countries, such as those elsewhere in sub-Saharan Africa. This form of survey (like all research approaches) has strengths and weaknesses. There are a number of reasons why respondents might under- or over-represent their access to ICT resources or levels of skill. However, the respondents were either practicing teachers or trainee teachers and felt to have the maturity to answer questions with honesty and integrity.

c) *Trainee Teacher ICT Skills Survey*. A survey of trainee teacher ICT skills at Debre Birhan CTE was conducted in June 2007. This survey was designed to answer the following questions:-

- What ICT competencies are trainee teachers currently acquiring?
- What prevents trainee teachers from acquiring additional skills?

To ensure a consistent approach, the same survey questions, based on those advocated by UNESCO (2006) for international school surveys, were used.

A2. Planning Phase (Cycle 1)

During the planning phase the Maturity Model, described in Section B in the following pages, was developed. The model was derived from analysis of the results from the information-gathering studies. It was iteratively developed and applied to practitioner-based activities such as meetings with senior college staff, and preparation of technical plans, funding proposals and purchasing specifications. The emphasis of these planning activities was the prioritisation of capacity building and infrastructure development projects that would have a positive impact on the professional development of academic staff and student learning outcomes. This in particular helped spotlight the organisational maturity elements of the model.

A3. Action Phase (Cycle 1)

The action phase included equipment purchasing, installation and commissioning following from the plans, proposals and specifications developed during the planning phase. The Maturity Model had been used to identify capacity building and ICT infrastructure developments that would contribute to student learning outcomes. This prioritisation meant a sacrifice of some ICT service improvements designed to benefit staff only, although some in-service staff development training was conducted. Details of the specific projects conducted are beyond the scope of this article but have been described in more detail elsewhere (Bass, 2009).

A4. Evaluation Phase (Cycle 1)

Research during the evaluation phase was designed to answer three main questions:-

- Did the capacity building and ICT infrastructure development activity in the action phase contribute to enhanced learning outcomes?
- Did the Maturity Model continue to reflect the ICT infrastructure found in institutions? and
- Had the action research cycle addressed the issues raised during the problem identification phase?

Structured interviews with college and university staff were conducted to assess the availability of ICT infrastructure, resources and the types of classroom activity. Qualitative methods eloquently described by Patton (2002) were in the form of one-to-one open-ended interviews which were used to gain detailed insights into the

perspectives of stakeholders. Classroom observations at Debre Birhan College of Teacher Education were used to investigate use of technology during teaching sessions.

A placement review was conducted involving senior officers of the College and teaching staff. The review found that obtaining budget approval from the Amhara Regional Education Bureau and purchasing processes had caused implementation delays in the project. The transition to the new University for the second placement afforded an opportunity for reflection on the first action research cycle and the Maturity Model that it had produced.

A5. Problem Identification and Planning Phases (Cycle 2)

Experience of the placement at the College and the lack of any infrastructure in the new University meant that the problem identification and planning phases followed in quick succession during the early stage of the placement. Reputation developed by the implementation team, based on work in the nearby college, assisted rapid approval for plans. Those plans again used the new Maturity Model to prioritise projects that would bring benefits in terms of student learning opportunities.

A6. Action Phase (Cycle 2)

The access to funding from within University budget shortened the decision making process and enabled rapid acceptance of initial plans to develop computer classroom capacity and Internet access for staff. This allowed equipment purchasing and installation to proceed relatively rapidly to establish a computer classroom infrastructure and embryonic campus network.

A7. Evaluation Phase (Cycle 2)

At the end of the University placement an evaluation was conducted with teaching staff and senior officials regarding the relevance of capacity building and infrastructure development initiatives undertaken. However, the evaluation phase in cycle 2 actually extended beyond the end of the placement with the University. Subsequent investigations were conducted on other educational institutions (see Section B4) further clarifying the Maturity Model.

Classroom observations at Debre Birhan University established use of technology during teaching sessions. Focus group meetings with students, for example at Dilla University (which was a College of Teacher Education until 2007) were used to triangulate statements from faculty members and technical staff about ICT infrastructure.

B. Maturity Model Development

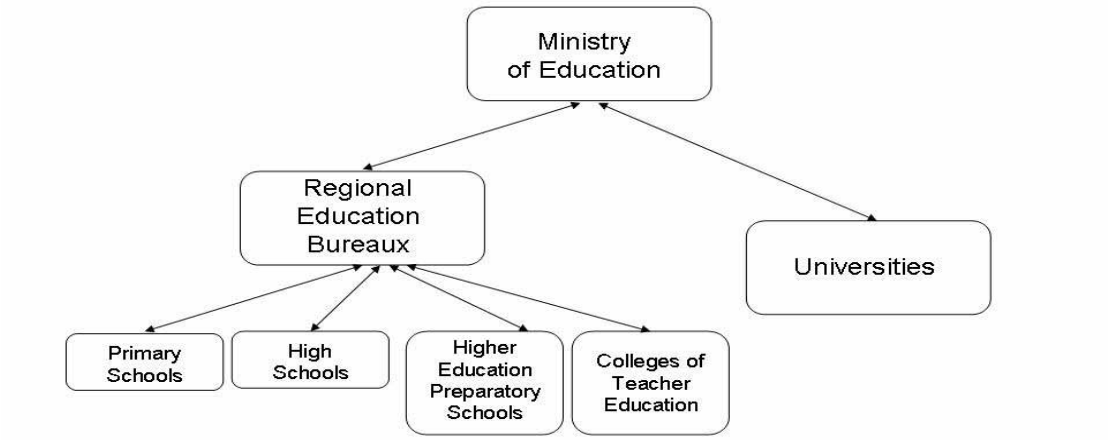
B1. Background: Public Education in Ethiopia

Before describing the survey data that helped form the Maturity Model, it is necessary to understand Ethiopia's public education system.

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 (FDRE, 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 support.

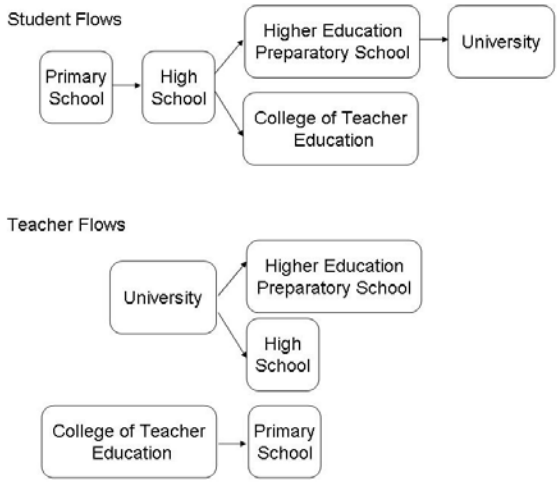
Management of education institutions in Ethiopia is partially decentralised, as shown in Figure 3. The Figure shows that Regional Education Bureaux have responsibility for financing and supervising schools and the College of Teacher Education sector. Both the Regional Education Bureaux and public universities are responsible to the Ministry of Education.

FIGURE 3
MANAGEMENT OF EDUCATION INSTITUTIONS IN ETHIOPIA



School student progression in Ethiopia is based on a system of national examinations at Grades 8, 10 and 12. Children have entitlement to free education up to Grade 8, after which it 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. Figure 4 shows how students progress from institution to institution and might eventually gain employment as teachers, or elsewhere.

FIGURE 4
STUDENT AND TEACHER FLOWS THROUGH EDUCATION INSTITUTIONS



In an effort to drive up the quality of education, since 2006, Ethiopia has imposed a requirement for all primary school teachers to qualify with a two-year Diploma. Those teaching in higher schools require a Bachelors degree from a university. The country also has ambitious university expansion plans. The number of universities was more than doubled in 2007, from nine to 22. A further ten universities are planned over the next four years, though there have been warnings about the difficulty of maintaining quality during a period of such rapid expansion (Saint, 2004).

B2. Primary and Secondary Schools

The city of Debre Birhan is administrative centre of the North Shoa Zone, within the Amhara Region of highland Ethiopia 130km north east of the capital Addis Ababa (see Figure 2). The buildings housing "first cycle", Grades 1 to 4, primary schools in the rural hinterland of Debre Birhan use very basic construction techniques and locally available materials (such as timber and mud). Even larger first and second cycle, Grades 1 to 8, rural schools are typically constructed using simple concrete blocks and tin sheet roofing. In common with many rural African schools (UNESCO, 2006), these do not have access to piped water or electricity. For these rural schools the prospects of installing computers in classrooms is currently very remote. Their first priority, from an infrastructure point of view, is to establish running water, sanitation and a reliable electricity supply.

A survey of school directors at primary and secondary schools in Debre Birhan itself showed that none had an ICT infrastructure used to support teaching and learning. The urban schools have both electricity and telephone access, so in principle the pre-requisite infrastructure is in place. However, resource limitations mean that none of the surveyed schools actually have computing resources available to support teaching. They have not even been able to purchase sufficient computers to conduct in-service training to further develop ICT skills of teaching staff. An overview of results, based

on questionnaire feedback from staff in five urban schools serving 3,802 pupils, is shown in Table 1.

TABLE 1
OVERVIEW OF PRIMARY AND SECONDARY SCHOOLS IN DEBRE BIRHAN

School Name and Status	Grades	Teachers	ICT Certified Teachers	Pupils	Pupil to ICT Teacher Ratio	Educational Use of Computers	
						Computers	Classrooms
Blanc Mesnie Academy (Private)	1-6	20	3	142	47:1	0	0
Soressa (Private)	1-6	30	15	479	32:1	0	0
Model 1 (Public)	1-6	16	0	492	N/A	0	0
Tebassie Primary (Public)	1-8	39	5	1424	285:1	0	0
Baso General Secondary (Public)	9-10	19	0	1265	N/A	0	0
Totals and Average		124	23	3802	165:1	0	0

The schools shown in Table 1 have yet to acquire computers to support educational objectives or outcomes. An introductory stage in the Maturity Model can be created to accommodate these institutions, as shown in Table 2. The schools in this level are able to teach ICT in theory only and are unable to teach practical computer use skills, since they are without mouse and keyboard hardware.

TABLE 2
EDUCATION INSTITUTION ICT MATURITY MODEL SUMMARY

	Institutional Maturity Levels	Resource Milestones	Potential Learning Outcomes
Level 1	Aspirant	Built environment	Theory only

B3. Tertiary Education Institutions

School leavers progressing from Grade 10 have two options, depending upon their national exam results, as shown in Figure 4. Students with the best exam results can enter the Higher Education Preparatory School system, and study Grades 11 and 12. Good students who do not score a high-enough grade for Grade 11, may have the chance to join the Teacher Education College sector. All these institutions typically

do have some level of ICT infrastructure used for teaching and learning in Ethiopia. First, let us consider the College of Teacher Education sector.

A) Initial ICT Infrastructure in the Tertiary Education Sector

There are about 22 Colleges of Teacher Education (CTEs) in Ethiopia, responsible for awarding Diplomas to primary education teachers. An overview of the survey results from six institutions is shown in Table 3 (see Figure 2 for approximate locations). The shortage of resources, relatively few computers and qualified staff available for ICT teaching, is evident from the Table.

TABLE 3
COLLEGE OF TEACHER EDUCATION ICT SURVEY OVERVIEW

College	Region	Student Population	ICT Teachers	ICT Technicians	Internet Bandwidth	Student to Computer Ratio
Abbiye Addi	Tigray	970	2	0	56kbps	42:1
Debre Birhan	Amhara	1,115	2	1	56kbps	65:1
Debre Marcos	Amhara	1,500	1	0	2 x 56kbps	30:1
Dessie	Amhara	-*	2	0	128kbps	-
Dilla**	SNNP	1,300	4	2	128kbps	16:1
Gondar	Amhara	650	2	2	2 x 56kbps	13:1

* Student population information not available
** Dilla was upgraded to university status in 2007

These institutions show a diversity of ICT infrastructures. In Table 4 the colleges are categorised along two axes: Internet connectivity and helpdesk technician provision. The diversity in this Table reflects a lack of clarity regarding the use of technology to support the core purpose of teaching and learning.

TABLE 4
ICT CATEGORISATION OF COLLEGE OF TEACHER EDUCATION SECTOR

		Helpdesk Technician Support	
		NO	YES
Internet access	Dial-up	Abbiye Addi	Debre Birhan
	Broadband (128kbps or better)	Debre Marcos Dessie	Dilla Gondar

Consider Abbiye Addi, a college in Tigray, that has neither high-speed Internet nor helpdesk technician support. We can create a level in the Maturity Model, Level 2, to accommodate such institutions that have electrical power, where computers are installed and used for teaching purposes, as shown in Table 5. Two distinctive features of institutions in Level 2 are the absence of helpdesk technician support or high-speed Internet connectivity. This is a maturity level required for institutions using computers for any education purpose (e.g. for education, health or agriculture).

Basic computer use and manipulative skills must be acquired by students before any unsupervised usage of a computer is advisable.

TABLE 5
EDUCATION INSTITUTION ICT MATURITY MODEL SUMMARY

	Institutional Maturity Levels	Resource Milestones	Potential Learning Outcomes
Level 2	Generic Hardware and Software	Electrical power Computers installed	Computer operation Mouse and keyboard manipulation
		Application software	Courseware development Course delivery
Level 3	Teaching and Learning Administration (Early Adopters)	Technician support	Backup and restore Archiving Data security

Institutions, such as Debre Birhan CTE, that have the resources to provide a helpdesk technician support service are in Level 3 of the Maturity Model, as shown in Table 5. The services that are provided at this level of maturity include equipment repair and fault-finding, ensuring data integrity and security procedures such as virus protection. These helpdesk service skill areas are described in SFIA (2009). The model also encourages the use of technicians to provide user support and in-service staff development training.

ICT training is compulsory for the government-sponsored regular (daytime) programme trainee teachers. There is considerable enthusiasm for the subject among the student body, evidenced anecdotally by the queues that form outside the classroom prior to classes. A survey of 179 3rd year diploma students was conducted to obtain a snapshot of usage patterns and ICT skills at the Debre Birhan College of Teacher Education. The results of the computer usage survey are shown in Table 6. The survey shows that trainee teachers do not use the computational power of computers to enrich their own learning. They are not conducting computer-based simulations or experiments. They are rarely using e-books or the Internet for information gathering either.

TABLE 6
FREQUENCY OF ICT USAGE BY 3RD YEAR DIPLOMA STUDENTS

	Everyday or Almost Everyday	**Once or Twice a Week**	**Once or Twice a Month**	**Never or Almost Never**	**Overall Usage Score [1]**
How often do you watch movies, videos or television to obtain information?	34%	6%	1%	60%	250
How often do you use the computer to practice skills and procedures?	12%	79%	8%	2%	205
How often do you use computer technology at school/college?	0%	100%	0%	0%	150
How often do you compare material presented in different media?	0%	6%	56%	38%	28
How often do you use computer technology to find information (Internet, CD-ROM)?	3%	0%	6%	91%	27
How often do you use computer technology outside school/college?	1%	1%	12%	80%	16
How often do you use the computer to do scientific procedures or experiments?	0%	0%	0%	100%	5
How often do you use the computer to study natural phenomena through simulations?	0%	0%	0%	100%	5

A self-assessment of 3rd year diploma student ICT skills is shown in Table 7. These results show students demonstrating basic computer use skills (mouse operations to navigate and managing files). However, students are ill-equipped to prepare a multimedia presentation, which might enrich their own learning and enliven classes for their pupils.

[1] The overall usage score is calculated using the formula:
$score = \sum (Column2 * 7) + (Column3 * 1.5) + (Column4 * 0.3) + (Column5 * 0.05)$

TABLE 7
STUDENT SELF-ASSESSMENT OF ICT SKILLS

	Performed the task many times	**Have performed the task alone**	**Might need a little help to perform the task**	**Need help to perform this task**	**Overall Task Frequency Score [2]**
Scroll a document up and down the screen?	170	4	5	0	702
Save a computer document or file?	120	45	3	11	632
Use a database to produce a list of addresses?	100	40	5	34	564
Open a file?	120	5	3	51	552
Start and shutdown the computer?	21	145	13	0	545
Draw pictures using a mouse?	100	0	51	28	530
Create/edit a document?	105	7	5	62	513
Copy a file from a floppy disk or flash drive (USB memory stick)?	50	49	0	80	427
Move files from one place to another on the computer?	50	49	0	80	427
Delete a computer document or file?	70	0	50	9	389
Start a game?	55	5	0	119	354
Play computer games?	50	0	0	129	329
Create a multimedia presentation (with sound, pictures and video)?	5	5	5	164	209

It can also be seen from Table 7 that, while basic computer use skills are acquired, little use is made of computers for broader educational objectives or deeper student learning outcomes. These results confirm the findings of other studies conducted in sub-Saharan Africa (e.g. Wims & Lawler, 2007).

A prescriptive element in Level 3 of the Maturity Model, shown in Table 5, is introduced to encourage the application of newly acquired computer use skills to educational tasks and processes (in the case of a College of Teacher Education), rather than teaching computer use as an end in itself. Preparation of presentation materials, learning support materials, using spreadsheets to manage assessment results are ways

[2] The overall task frequency score is calculated using the formula:
$score = \sum (Column2 * 4) + (Column3 * 3) + (Column4 * 2) + (Column5 * 1)$

that teachers can enliven the learning process and make efficient use of their time for teaching administration tasks.

The preparation of multimedia learning resources and use of computers for simulations and experiments using CD-ROM and DVD-based resources becomes a reality for Level 3 institutions, even though they do not at that stage have high-speed Internet access. In this way institutions can make better and more efficient use of resources they already have, before making additional purchases of further expensive infrastructure.

Institutions, such as Gondar CTE and Dilla, that have both a helpdesk technician service and high-speed Internet access are in Level 4, as shown in Table 8. The Internet access enables classroom teaching of Internet browsing, use of online email services and the use of search engines. These user skills are described in Unit 7 of the ECDL/ICDL syllabus (ECDL/ICDL, 2009). They should be applied to enhancing the learning experience of students, by accessing external information sources or subject experts.

TABLE 8
MAPPING COLLEGES TO THE ICT MATURITY MODEL

	Institutional Maturity Levels	Resource Milestones	Potential Learning Outcomes
Level 4	Generic Internet (Early Adopters)	High-speed internet	Web searching Web-based email accounts

B) Hailemariam Mamo Higher Education Preparatory School

It is now possible to consider an example institution from the preparatory school sector. Preparatory schools in Ethiopia (see Figure 4) are used to teach Grades 11 and 12 to students expected to achieve good enough grades to go on to the public university sector.

The Hailemariam Mamo Higher Education Preparatory School was the only school surveyed in Debre Birhan that had an ICT infrastructure used for educational purposes (see Table 9). A UNDP programme installed V-Sat high-speed Internet access into Higher Education Preparatory schools throughout Ethiopia. However, the Preparatory Schools were not provided any technical support staff or support infrastructure. There have been periods where service was unavailable sometimes for some months, due to technical problems. Even when the Internet service is functioning, our survey showed it is only used by 5% of staff for teaching students.

TABLE 9
OVERVIEW OF HAILEMARIAM MAMO PREPARATORY SCHOOL

School Name and Status	Grades	Teachers	ICT Certified Teachers	Pupils	Pupil to ICT Teacher Ratio	Educational Use of Computers	
						Computers	Classrooms
Hailemariam Mamo Higher Education Preparatory (Public)	11-12	53	4	1603	401:1	30	1

The use of the ICT infrastructure in the school for teaching and learning raises questions about the ways the computers are being used. These questions include:

- How often do staff members use computers?
- What do staff use computing resources for?
- How often are computers used for teaching?
- What are computers used for in the classroom?

The frequency of ICT use by the teachers at Hailemariam Mamo Higher Education Preparatory school, shown in Table 10, is based on responses received from 22 of the 53 teachers in the school. The results in Table 10 show that Internet access was contributing little to the quality of teaching. Staff did not use the communication technology available to interact with teachers in other schools, or institutions of higher learning. The computational power available was rarely used to perform simulations or experiments, and little used to develop teachers' own professional skills.

TABLE 10
FREQUENCY OF ICT USAGE BY PREPARATORY SCHOOL TEACHERS

	Everyday or Almost Everyday	**Once or Twice a Week**	**Once or Twice a Month**	**Never or Almost Never**	**Overall Usage Score [3]**
How often do you watch movies, videos or television to obtain information?	59%	27%	0%	0%	454
How often do you compare material presented in different media?	18%	23%	27%	9%	169
How often do you use the computer to practice skills and procedures?	18%	14%	41%	14%	160
How often do you use computer technology at school?	14%	27%	41%	5%	151
How often do you use computer technology to find information (Internet, CD-ROM)?	9%	9%	27%	41%	87
How often do you read stories, reports or other texts on the computer?	9%	5%	36%	36%	83
How often do you write stories, reports or other texts on the computer?	5%	14%	32%	36%	67
How often do you use computer technology outside school?	5%	14%	18%	50%	64
How often do you use the computer to do scientific procedures or experiments?	5%	5%	9%	68%	49
How often do you use the computer to process and analyse data?	0%	18%	41%	23%	40
How often do you read emails and web pages because you want to?	0%	14%	41%	32%	35
How often do you use the computer to study natural phenomena through simulations?	0%	9%	9%	68%	20
How often do you use the computer to communicate with or do projects with students in other schools, colleges or countries?	0%	0%	14%	73%	8

The survey found that only ICT subject teachers use computers in the classroom. The very low scores in Table 11 show that ICT classroom use is in a limited range of activities mainly involving teaching of ICT skills themselves. In fact, over 75% of teachers hardly ever use computers for teaching at all. The computers are rarely used to enliven or enhance student learning though experiments or simulations, and thus this School is still at Level 4 of the Maturity Model.

[3] The overall usage score is calculated using the formula:
$score = \sum (Column2 * 7) + (Column3 * 1.5) + (Column4 * 0.3) + (Column5 * 0.05)$

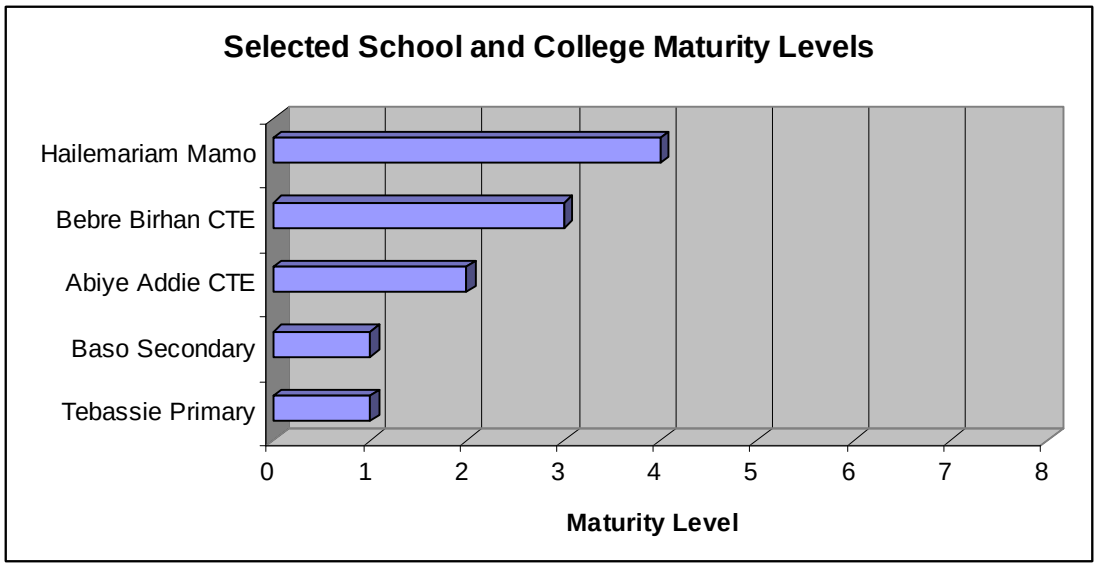
TABLE 11
CLASSROOM USE OF ICT BY PREPARATORY SCHOOL TEACHERS

	Everyday or Almost Everyday	**Once or Twice a Week**	**Once or Twice a Month**	**Never or Almost Never**	**Overall Usage Score** [4]
How often do you have students use computer technology to find information?	4.5%	14%	4.5%	77%	58
How often do you have students write stories or other texts on the computer?	5%	9%	0%	86%	53
How often do you have students read stories or other texts on the computer?	4.5%	9%	4.5%	82%	50
How often do you have students use instructional software to develop reading skills and strategies?	4.5%	4.5%	9%	82%	45
How often do you have students use the computer to look up information?	4.5%	4.5%	9%	82%	45
When you have reading instruction and/or do reading activities with the students, how often do you use reading material on the Internet (Web Pages)?	5%	0%	9%	86%	42
How often do you have students use the computer to communicate with or do projects with students in other schools or countries?	5%	0%	0%	95%	40
How often do you have students use the computer to study natural phenomena through simulations?	5%	0%	0%	95%	40
How often do you have students use the computer to do scientific procedures or experiments?	4.5%	0%	4.5%	91%	37
How often do you have students use the computer to practice skills and procedures?	0%	18%	5%	77%	32
How often do you have students use the computer to look up ideas and information?	0%	18%	5%	77%	32
How often do you have students use the computer to process and analyse data?	0%	14%	5%	82%	27
How often do you have students use the computer to write reports?	0%	14%	0%	86%	25
How often do you have students watch movies, videos or television to obtain information?	0%	5%	9%	86%	15
How often do you have students compare material presented in different media?	0%	5%	9%	86%	15
When you have reading instruction and/or do reading activities with the students, how often do you use computer software for reading instruction (e.g. a CD-ROM)?	0%	0%	5%	95%	6

[4] The overall usage score is calculated using the formula:
$score = \sum (Column2 * 7) + (Column3 * 1.5) + (Column4 * 0.3) + (Column5 * 0.05)$

The Maturity Levels observed at selected schools and colleges are summarised in Figure 5.

FIGURE 5
MATURITY LEVELS AT SELECTED SCHOOLS AND COLLEGES



B4. Higher Education (Public University) Sector

A survey of ICT status in public universities was conducted for the Higher Education Strategy Centre of the Ministry of Education, covering five institutions, as shown in Table 12.

Two of the universities surveyed were under construction on green-field sites, Debre Marcos and Wolaita Sodo. These universities have technician support but no high-speed Internet. This places these institutions at Level 3 in the Maturity Model. However, the ICT teaching was predominantly generic computer user training (Level 2) in the form of common courses given by specialist ICT teachers to students of other subjects.

TABLE 12
SUMMARY OF PUBLIC UNIVERSITY SECTOR ICT STATUS

University	Foundation Date	Student Population	Computers for Classroom Use	Student to Computer Ratio
Addis Ababa	~1955	50,492	1,608	31:1
Dilla*	2007	7,153	134	53:1
Debre Marcos	2007	6,462	58	111:1
Hawassa**	April 2000	15,420	242	64:1
Wolaita Sodo	March 2007	3,653	52	69:1

* Previously Dilla CTE
** Formerly known as Debub University

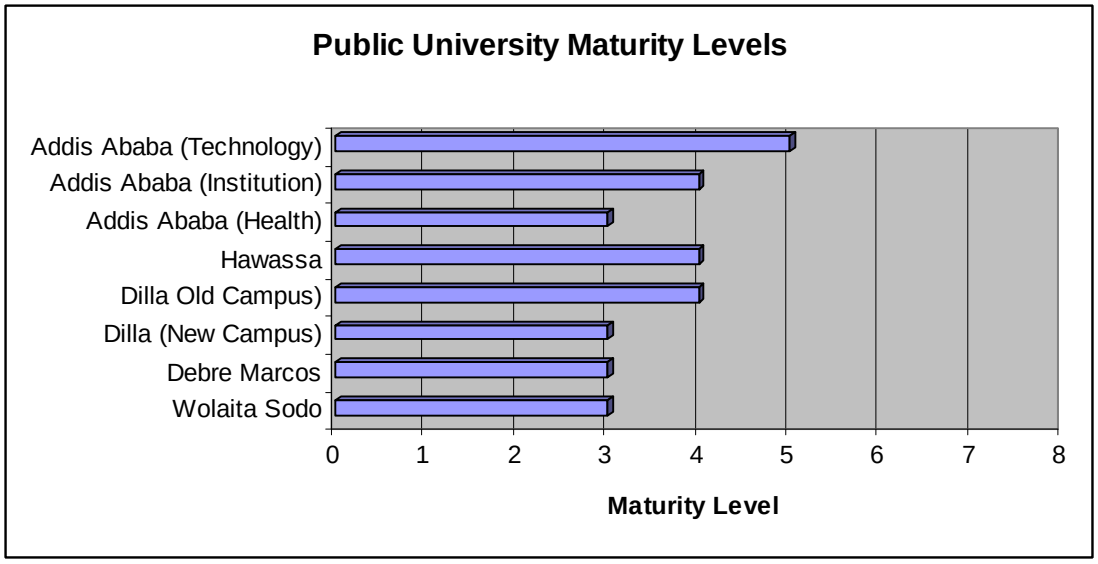
On the basis of the other universities, though, higher levels of the Maturity Model were developed: see Table 13.

TABLE 13
MAPPING UNIVERSITIES TO THE ICT MATURITY MODEL

	Institutional Maturity Levels	Resource Milestones	Potential Learning Outcomes
Level 5	Critical Pedagogy (Early Adopters)	Higher learning support	Broad, high-level ICT education knowledge
Level 6	Teaching and Learning Administration (Mainstreaming)	Mainstreaming support	Mainstreaming backup and restore, archiving and data security.

Dilla had a new campus under construction on a green-field site but also a well-established older campus and so benefited from some previously-installed infrastructure. The old campus did have a high-speed Internet connection (Level 4), although there was a lack of connectivity on the new campus (see Figure 6). There was no evidence of institutional support for use of the ICT for critical pedagogy, and no learning support group providing e-Library or e-Learning infrastructure support (Level 5). Despite the more advanced infrastructure at Dilla, there is also no evidence of institutional support for mainstreaming (Level 6).

FIGURE 6
MATURITY LEVELS AT PUBLIC UNIVERSITIES



Addis Ababa and Hawassa Universities both have a longer history of development. Addis Ababa has an ICT Development Office (which is rather more focused on infrastructure than pedagogy) and has some examples of using ICT to support teaching and learning, but confined to Faculties such as Technology and Informatics. Students in the Addis Ababa University Medical Faculty are relatively underserved in terms of computer access, as shown in Figure 6.

Students outside the Computer Science Department at Hawassa had very limited computer access. Open access computers, such as those in libraries, were almost exclusively for use by postgraduate students. New classrooms were under construction, but these will primarily be used by ICT teachers to teach computer use skills to students of other subjects.

In the Informatics and Technology faculties at Addis Ababa University ICT resources to support teaching and learning correspond to Level 5 of the Maturity Model. Postgraduate (Masters Level) provision benefits from use of specialist computing classrooms to support specific subject areas. In addition, there is access to e-journal, e-library and e-learning resources. Masters students undertake dissertation project work that, at some level, engages with the international body of published literature in their chosen field.

The universities surveyed in Ethiopia have not established support processes or a staff development team dedicated to assisting staff in ICT for learning adoption. This lack of support processes makes it difficult for staff outside early adopter faculties to learn about the benefits of supplementing face-to-face teaching with electronic learning resources. The lack of any organised learning technology mainstreaming effort goes some way to explaining the wide variations between ICT provision in faculties at Addis Ababa University. The provision of mainstreaming support is characteristic of Level 6 of the Maturity Model, as summarised in Table 13.

B5. Review of Maturity Stages (Levels)

The analysis of the results of information gathering conducted during the survey of education institutions revealed several important observations:

- Teaching staff under-utilised computing resources from the viewpoint of improving student learning opportunities,
- Internet access did not contribute much to enhancing learning outcomes,
- The importance of a helpdesk support technician was not fully appreciated, and
- Opportunities to use existing installed infrastructure for in-service staff development were overlooked.

The Maturity Model was developed to highlight the importance of ICT support for student learning (the main mission of all learning establishments) and the benefits of obtaining technician support, before Internet access is emphasised.

A summary of the Maturity Model is shown in Table 14. Development of Levels 1 to 6 in the model has been described above, while development of the final two levels was drawn from scholarly visits to two well-established universities in India (IIT-B and IIIT-B) and a series of professional body accreditation visits to UK universities. The specific components within the model are drawn from the background presented above, and are a development of those first presented in Bass (2007). The training skill areas in the third column of Table 14 may be supplemented with specific example skills as shown in Appendix 1.

TABLE 14
EDUCATION INSTITUTION ICT MATURITY MODEL SUMMARY

	Institutional Maturity Levels	**Resource Milestones**	**Potential Learning Outcomes**
Level 1	Aspirant	Built environment	Theory only
Level 2	Generic Hardware and Software	Electrical power Computers installed	Computer operation Mouse and keyboard manipulation
		Application software	Courseware development Course delivery Operating systems skills Application software skills
Level 3	Teaching and Learning Administration (Early Adopters)	Technician support	Backup and restore Archiving Data security In-service staff training
Level 4	Generic Internet (Early Adopters)	High-speed Internet	Web searching Web-based email accounts
Level 5	Critical Pedagogy (Early Adopters)	Higher-learning support	Broad, high-level ICT education knowledge (up to postgraduate)
Level 6	Teaching and Learning Administration (Mainstreaming)	Mainstreaming support	Backup and restore Archiving Data security
Level 7	Generic Internet (Mainstreaming)		Web searching Web-based email accounts
Level 8	Critical Pedagogy (Mainstreaming)	Higher-learning mainstreaming support	Deep subject domain knowledge (up to postgraduate)

The rows in Table 14 represent maturity stages within an education institution. Maturity levels build upon each other from Level 1 to Level 8. So, each row is dependent on achieving the level of maturity described in the rows above.
The resource milestone column represents ICT infrastructure required to achieve institutional objectives expressed in the form of potential learning outcomes at each maturity level. The full Maturity Model shown in Appendix 2 includes additional columns that describe infrastructure installation and technical support skills. A review of the eight maturity levels in the model is presented below.

a) Level 1 Aspirant
Institutions that have yet to obtain installed computers map to this level of the Maturity Model. Such institutions are restricted to teaching ICT from a theoretical perspective only. A detailed breakdown of potential learning outcomes in this level is presented in the ECDL/ICDL Unit 1 syllabus (ECDL/ICDL, 2009).

b) Level 2 Generic Hardware and Software
Access to electricity, a power distribution infrastructure and the installation of computers with standard office application software enables transition from Level 1 to Level 2 in the model. This transition enables teaching of file management, word processing, spreadsheet and presentation application skills. At this level of maturity

these are generic user skills, such as the basic skills described in Units 2-6 of the ECDL/ICDL syllabus (ECDL/ICDL, 2009).

c) Level 3 Teaching and Learning Administration (Early Adopters)
The key mechanism defining progression from Level 2 to Level 3 is the establishment of a technical support service within the institution. The need for technical support becomes more pressing as the number of computers increases and the institutional dependency on computing resources grows. The helpdesk technician support skills map to basic service provision skills in SFIA (2009) and to the Information Technology subject emphasis in the joint IEEE/ACM Computing Curriculum (IEEE/ACM, 2005).

There are opportunities at this level of the Maturity Model in a teacher training college for students that are pre-service trainee teachers to acquire ICT skills that directly relate to their role as teachers. This is particularly important prior to any practical training component providing classroom experience (Clarke, 2007). In addition all types of education institutions at Level 3 have the infrastructure and in-house skills to undertake in-service staff development training.

This is the level of maturity at which an institution starts to apply basic office application software to the management and process of education. Administrative tasks are conducted using computers, and locally-available information sources (whose quality and timeliness may be questioned) are used to assist in the development of learning materials. Early adopters may include technology subject specialists or senior managers at an institution that may have undertaken private study to acquire specialist ICT skills.

d) Level 4 Generic Internet (Early Adopters)
Provision of Internet access with sufficient bandwidth to enable institutional use enables access to a wide range of online learning resources. With this resource, for example, pre-service trainee teachers have the opportunity to learn generic browser use and web navigation skills. The use of English keywords, for those for whom English is not their first language, is a particular challenge.

These basic skills can be used to facilitate personal communication, for example with friends and family abroad. The skills are also used to support personal professional development, for example through applications for scholarships.

e) Level 5 Critical Pedagogy (Early Adopters)
At this maturity level experienced learners are able to participate in the global online community in their discipline. Experienced learners communicate with peers of national and international standing. They have knowledge of authoritative online sources of information. They are able to critically assess the quality of information sources and select only high-quality sources that suit the needs of their own learning and support production of quality learning materials.

f) Level 6 Teaching and Learning Administration (Mainstreaming)
The mechanism for defining migration from Level 5 to Level 6 is establishment of a staff development support service to encourage adoption of office application software by teaching staff. At this maturity level institutions can support a wide range

of staff to integrate the use of technology in their professional life. This implies a widespread knowledge of the use of office applications among teaching staff and their routine application to support teaching and learning activity.

g) Level 7 Generic Internet (Mainstreaming)

Institutional support is provided for a wide range of staff to use tools such as web-browsers and email. However, the skills are not sufficiently well developed to be routinely harnessed to support development of teaching materials.

h) Level 8 Critical Pedagogy Mainstreaming

At this maturity level a broad range of teaching materials across the spectrum of curricula is influenced by high-quality online resources from national and international sources.

C. Maturity Model Application and Discussion

The Maturity Model, derived from documentary sources and the survey data summarised in Section B, was used in the second action research cycle to guide capacity building and infrastructure development priorities at two institutions.

C1. Debre Birhan College of Teacher Education

At Debre Birhan CTE the Maturity Model was an important instrument to support institutional change. The model was used for advocacy and to support focused investment targeted on improving student learning opportunities. In 2006 the College had two small computer classrooms, each with around 18 computers. One of these classrooms also served to provide Internet access for staff using a shared dial-up connection (the staff ICT resource centre). ICT teachers were temporarily seconded from the Education Department and an ICT technician was employed on a temporary contract. The presence of the computer classrooms (Level 2 in the Maturity Model) and the ICT technician meant the college was observed to be at Level 3 in the Maturity Model. However, the use of secondments and temporary contracts meant this infrastructure level was fragile.

The Maturity Model, in conjunction with survey data from other colleges and stakeholders, was used to develop an ICT strategy and implementation plan. The strategy envisaged consolidation of existing Level 2 infrastructure and a staged progression through the Maturity Model levels prioritising student learning outcomes:-

- Maturity Model Level 2 Infrastructure
    - Installation of new expanded computer classrooms to enable one computer per student during classes,
    - Moving the computer classroom and staff ICT resource centre into separate rooms, and
    - Recruitment of dedicated ICT teachers,
- Maturity Model Level 3 Infrastructure
    - Recruitment of an ICT technician on a permanent contract,
- Maturity Model Level 4 Infrastructure
    - Purchase of a broadband (high-speed) Internet connection,
    - Purchase and installation of server computers to support a campus intranet, and
    - Purchase and installation of intranet networking hardware and software.

College of Teacher Education survey findings were presented to teaching staff at a research day and a proposal was made to the College Management Committee. Budget allocation for a broadband Internet connection was formally requested from the Amhara Regional Education Bureau and subsequently approved. The budget allocation represented a considerable investment, equivalent to teachers' salaries for an entire academic department. This Internet connection was designed to provide students the opportunity to learn about Internet browsing, searching and email use.

A review of the ICT status at the College, conducted 18 months after the initial application of the Maturity Model, showed that the two new computer classrooms had been installed. The larger of the two classrooms had 50 computers, allowing every student in a class individual access to a computer. A server room had been established and two newly-purchased server computers installed, in anticipation of improved Internet bandwidth. The larger computer classroom had a network installed allowing access to an e-library installed on one of the server computers.

The institution had upgraded technician helpdesk support from a temporary contact to a permanent post (securing Level 3 in the Maturity Model). This helped build the skills base within the organisation by improving job security and skills retention. Two suitably qualified ICT teachers were employed (previously ICT teachers had been early adopters seconded from the Education Department). A separate staff resource centre with shared access to a dial-up Internet account was created with six computers. Several in-service staff development training sessions had been conducted.

However, a major component of the infrastructure upgrade had not been implemented. The monopoly Internet provider, the state-run Ethiopian Telecommunications Corporation, had not been able to provide the College with a high-speed Internet connection. This was due to shortcomings in the telecommunications infrastructure in the city. This means the college could not achieve Level 4 in the Maturity Model.

The prioritisation of infrastructure investment to support student learning outcomes was at the expense of expansion of a local area network to departmental and senior staff offices. In fact, moving to the large computer classroom and establishing a server room nearby, meant that part of the previously-existing campus network was disconnected. This resulted in a degradation of network service to some staff users.

C2. Debre Birhan University

The Maturity Model was used to guide the planning and initial implementation of a campus network at Debre Birhan University. The University was founded in February 2007 using classrooms in Debre Birhan College, and moved onto its own campus in June 2007. At founding the University was at Level 1 of the Maturity Model, without its own computer classrooms. Construction on the campus was ongoing and initially programmes were taught using a small subset of the buildings scheduled for Phase 1 construction.

The Maturity Model was used to prioritise infrastructure in support of primary organisational objectives, in the form of student learning opportunities. Plans were developed in discussion with stakeholders. The plans followed a similar trajectory to that of the College, developing infrastructure in a staged manner:-

- Maturity Model Level 2 Infrastructure
    - Installation of computer classrooms, and
    - Provision of a staff ICT resource centre
- Maturity Model Level 3 Infrastructure
    - Recruitment of a ICT technicians,

- Maturity Model Level 4 Infrastructure
    - Purchase of a broadband (high-speed) Internet connection,
    - Purchase and installation of server computers to support a campus intranet, and
    - Purchase and installation of intranet networking hardware and software.

Two computer classrooms were established, each with about 24 computers. This allowed the University to achieve Level 2 in the Maturity Model. Subsequently, ICT technicians were recruited achieving Level 3 of the Maturity Model.

The Maturity Model was then used to prepare an initial ICT infrastructure strategy document for the University. This gave direction to the initial infrastructure development including campus network design, purchasing and installation. ICT technical staff and computing subject faculty members were consulted during the initial strategy preparation. A server room was established and shared access to a dial-up Internet connection made available to staff in a room of one of the library buildings. This networking infrastructure was in readiness for obtaining a high-speed Internet connection to be provided by the monopoly Internet Service Provider, that would allow achievement of Level 4 in the Maturity Model.

The model was used to discourage demand from some elements of University management to install MIS systems and a promotional Web presence. The Maturity Model was used to argue that installing administrative information systems was high risk while not having a proper ICT support infrastructure. Instead it was suggested that investment be focused on resources that had a direct impact on student learning. This prioritisation was popular with ICT teaching staff members (who were being criticised by students for the lack of ICT infrastructure) and was formally endorsed and supported from budget allocation by the senior officers of the University.

The administrative staff and teaching staff from other faculties were not sufficiently consulted during the development of the strategy, although some in-service staff development training sessions were conducted. There was criticism from some administrative managers over the lack of automation of some onerous manual university processes.

C3. Maturity Model Evaluation and Discussion

Stage theories are based on the assumption that distinct phases can be identified that institutions move through over time. Two guidelines for a stage theory have been proposed

1. the characteristics of each stage should be distinct and empirically testable, and
2. the relationship of any stage to its predecessor or successor stage should be well defined (Kuznets, 1965 quoted in Nolan, 1973).

It is argued that the levels identified in this new Maturity Model fulfil the criteria for being distinct and measurable.

Another aspect of the ICT Maturity Model is that the stages are not *evolutionist*, which would define a uni-directional progression, from one level to the next (King, 1984). Rather, the model is *evolutionary* and does not preclude an organisation from regressing through the levels, perhaps through declining availability of resources. Progression through the Maturity Model levels is not a natural or pre-ordained process over time.

The Maturity Model links ICT infrastructure to the primary organisational objectives of an education institution expressed in the form of student learning outcomes. The model is intended to be prescriptive, advocating best practice in ICT infrastructure development in an education institution. Within Level 2 of the Model there is a tendency, also observed by Wims and Lawler (2007), for teaching to focus on computer use as an end in itself. The Maturity Model can be used to advocate application of computer use skills to support subject specific learning. For example, trainee teachers should be encouraged to apply their computer use skills to the preparation of engaging teaching materials, assessments and so on.

A key question facing managers of institutions at Level 2 is how to further develop their ICT maturity. This dilemma is illustrated in Table 15. In what sequence should a college attempt to set up a helpdesk technician resource and purchase a higher-speed Internet connection? Resource constraints rarely allow a college to do both in a given financial year. So which one should come first?

TABLE 15
MATURITY EVOLUTION CHOICES

		Helpdesk Technician Support	
		NO	YES
Internet access	Dial-up	Level 2 ⇨	?
	Broadband (128kbps or better)	⇩ ?	Level 4

Two of the Colleges, Debre Marcos and Dessie, have broadband Internet access without any helpdesk technician support. These colleges are characterised by large numbers of computers that are broken and not in use or are infected with numerous viruses. Teaching staff typically do not have the skills or resources to repair broken machines.

The access to a higher-speed Internet connection at the Hailemariam Mamo Preparatory School represents a significant advantage over the Debre Birhan College. However, comparison of Tables 10 and 11 from the Preparatory School and Tables 6 and 7 from Debre Birhan College show strikingly similar results. Computing resources are, by and large, not used to conduct scientific experiments or simulations at either institution. The presence of the broadband Internet connection at the Preparatory School is not being used to facilitate communication with staff or students at other institutions. The Internet connection at the Preparatory School has been

observed to suffer long periods of service outages. These situations might be improved by a support infrastructure at the school.

Putting together these experiences, we can answer the question posed above to say that the Maturity Model should be used to advocate helpdesk technician provision before purchase of broadband Internet connection. This is to improve the chances of sustainable use of the servers and network infrastructure associated with the higher-speed Internet service.

More generally, prioritisation – driven by the model – of institutional objectives in the form of student learning outcomes can be used to de-emphasise support for management information systems or organisational promotion through Web sites. As seen in the Debre Birhan University case above, this may lead to criticism, for example from administrative officers such as registrars. But the model can be used to argue that automation of manual processes can only be undertaken when a sustainable support infrastructure is in place. Anecdotal evidence of major data loss incidents, for example resulting from virus infections, suggests that reliance on computers for storage of mission-critical data without a support infrastructure would be premature.

The higher levels of the Maturity Model (Levels 6 through to 8) focus on mainstreaming of ICT for teaching and learning support across the full range of subjects taught. None of the institutions surveyed so far are attempting to undertake the mainstreaming of ICT in teaching. This was because Ethiopia is a low-income country where many institutions are at a formative stage of their ICT infrastructure development.

Applying the Maturity Model to larger and more complex institutions, such as major high schools or universities, is problematic. It is inevitably something of an over-simplification to condense diverse examples of practice into a single level of the Maturity Model. However, neither Addis Ababa nor Hawassa universities can demonstrate any institution-wide effort to support the use of ICT for teaching and learning. This lack of mainstreaming restricts these institutions to Maturity Model Level 5, at best. They do however have high-speed Internet and are teaching web navigation skills and so have achieved Level 4. Some faculties are supporting staff who use technology to support higher learning (Level 5) and yet some departments are still only teaching students generic computer use skills, not linked to any subject-specific pedagogy (Level 2). The diversity observed suggests that the Maturity Model may be better used at a sub-institutional rather than institutional level for larger organisations.

D. Concluding Remarks

A new ICT Maturity Model for education institutions in low-income countries has been developed. The model has eight levels describing the most basic physical infrastructure with which only theory can be taught (Level 1) through to the infrastructure required to mainstream e-research and the teaching of advanced (up to postgraduate) critical thinking and reasoning skills (Level 8).

The model has been derived from documentary sources and the observation of ICT status in educational institutions ranging from primary schools which are yet to have the resource infrastructure to undertake any ICT-related teaching and learning, through to universities with tens of thousands of students.

The model links the stages of development of an institution's ICT infrastructure to the organisation's primary objectives expressed in terms of the student learning outcome opportunities created, and the full version of the Maturity Model includes:

- Resource milestones of the institution,
- ICT infrastructure installation skills (for creating computer classrooms, etc.),
- Technical support skills (to sustain the ICT infrastructure), and
- Student learning outcomes (enabled by a particular level of infrastructure maturity).

Derivation and application of the model in Ethiopia revealed that:

- There is a tendency to teach computer use skills as an end in themselves, rather than applying them to any subject-specific pedagogy,
- Insufficient use is made of computing resources for in-service staff development,
- The benefits of helpdesk technician support are not fully appreciated, and
- Learning outcomes were not being significantly enhanced by Internet access.

To address these structural weaknesses the model supports advocacy to prioritise ICT investment towards student learning outcomes. Level 2 of the model highlights the development of computer use skills, but also the application of those skills to the student's field of study. For example, trainee teachers should have the opportunity to use computers to prepare learning resource materials. Infrastructure available at Level 2 enables teaching staff to use subject-specific multimedia resources to enrich and enliven learning experiences. Level 3 of the Maturity Model emphasises the benefits of helpdesk technician support to resolve technical problems and provide user-support to teaching staff. Employment of technicians helps retain and develop in-house skills, improving sustainability of infrastructure investment. Technician support enables greater institutional reliance on ICT for mission-critical purposes. Institutions at Level 3 are also encouraged to maximise the use of existing resources for the purpose of in-service staff training. These measures can usefully be instituted prior to obtaining scarce and expensive Internet access. Level 4 of the model, in turn, links access to high-speed Internet to browsing, searching and communication. Here skills described in Unit 7 of the ECDL/ICDL (2009) syllabus are developed to support communication with external information sources and subject specialists for the purpose of enhanced student learning.

Thus, each of the levels of the Maturity Model emphasises developmental stages that focus on different student learning opportunities. This unique aspect of the model encourages staff and management to make efficient use of available resources to maximise student learning.

The Maturity Model has been used to discourage some poor practice, for example installing high-speed Internet infrastructure without a proper support environment, or underusing installed infrastructure by not linking technology use to subject-specific pedagogy.

Further research is required to assess the applicability of the model in other countries. An investigation of the model in other low-income countries would enhance confidence in its applicability. Examining the model in the context of institutions in middle-income countries would be expected to shed more light on the process of mainstreaming ICT in teaching across the full range of subjects taught. The Maturity Model does not currently pay sufficient attention to learning support technologies such as e-libraries and e-learning software applications. A revision to the model in this area would thus be helpful, particularly for institutions that have already achieved Level 3.

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Appendices

Appendix 1. Institutional Maturity Levels and Example Skills

Example learning outcome skills associated with each institutional Maturity level are shown in Table A1.1.

TABLE A1.1
INSTITUTIONAL MATURITY LEVELS AND EXAMPLE SKILLS

Institutional Maturity Level	Skill Area	Example Skills
Level 1 Aspirant	Theory Only	Concepts of Information and Communication Technology (ECDL/ICDL (2009) Unit 1)
Level 2 Generic Hardware and Software	Computer Power	Usage of un-interruptible power supplies
		Switching on and shutting down the computer
	Mouse Usage	Mouse manipulation
		Mouse and screen pointer coordination
		Mouse button presses and uses of buttons
	Keyboard Usage	Typing skills (for those for whom English is not their first language)
		Names and meaning of special symbols (for example @, / and *)
	File Management	Copying files from one place to another
		Saving and deleting files
	Word Processing	Creating a document
		Formatting text
		Editing text, correcting mistakes
	Spreadsheets	Entering numerical values and text into cells
		Performing calculations using formulas
	Presentations	Create a presentation
		Add and format slides
Level 3 Teaching and Learning Administration (Early Adopter)	Data Integrity and Security	Archiving mission critical data. Backup and restore service for learning materials, course descriptions, assignments and examinations.
		Anti-virus and anti-malware installation, updates and scanning
	Staff Development	User support helpdesk provision
Level 4 Generic Internet (Early Adopter)	Web Browser Usage	Opening web pages
		Navigating web links
		Saving favourite web pages
	Web-based Email	Creating an online email account
		Opening and deleting messages

TABLE A1.1 (CONT.)
INSTITUTIONAL MATURITY LEVELS AND EXAMPLE SKILLS

Institutional Learning Outcome Level	Skill Area	Example Skills
Level 5 Critical Pedagogy (Early Adopter)	Web Searching	Opening a search engine
		Using keywords to drive searches
		Assessing the quality of sites found in search results
	Learning Materials Preparation	Identifying internationally validated information sources
		Selecting relevant and appropriate materials
		Downloading
		Awareness of copyright and citation issues
Level 6 Teaching and Learning Administration (Mainstreaming)	Data Integrity and Security	Archiving mission critical data. Backup and restore service for learning materials, course descriptions, assignments and examinations.
		Anti-virus and anti-malware installation, updates and scanning
	Staff Development	User support helpdesk provision
Level 7 Generic Internet (Mainstreaming)	Web Browser Usage	Opening web pages
		Navigating web links
		Saving favourite web pages
	Web-based Email	Creating an online email account
		Opening and deleting messages
Level 8 Critical Pedagogy (Mainstreaming)	Web Searching	Opening a search engine
		Using keywords to drive searches
		Assessing the quality of sites found in search results
	Learning Materials Preparation	Identifying internationally validated information sources
		Selecting relevant and appropriate materials
		Downloading
		Awareness of copyright and citation issues

Appendix 2. Full Maturity Model

The full Maturity Model including infrastructure installation skills and technical support skills is shown in Table A2.1. The installation skills are required by those building or enhancing campus ICT infrastructures. The technical support skills are needed by technicians. The skills are derived from analysis of campus infrastructure development projects and in-service professional development training provided at the surveyed institutions.

TABLE A2.1
MATURITY MODEL INCLUDING INSTALLATION AND TECHNICAL SUPPORT SKILLS

	Institutional Maturity Levels	**Resource Milestones**	**Design, Installation and Commissioning Skills**	**Technical Support Skills**	**Learning Outcomes**
Level 1	Aspirant	Built environment			
Level 2	Generic Hardware and Software	Electrical power	Power distribution Uninterruptible power supplies Voltage regulators		
		Computers installed	Air conditioning	Hardware troubleshooting	
		Application software	Classroom network	Operating system Application software	Courseware development Course delivery Operating systems skills Application software skills
Level 3	Teaching and Learning Administration (Early Adopters)	Helpdesk technician support	Office network File server Print server	Data security and integrity Anti-virus, anti-malware	Backup and restore Archiving Data security In-service staff development
Level 4	Generic Internet (Early Adopters)	High-speed Internet	Firewall Internet security	Internet connectivity and access distribution Bandwidth management	Web searching Web-based email accounts
Level 5	Critical Pedagogy (Early Adopters)	Higher-learning support			Broad, high-level ICT education knowledge (up to postgraduate)
Level 6	Teaching and Learning Administration (Mainstreaming)	Mainstreaming support	Campus network Email server	Large network management	Backup and restore Archiving Data security
Level 7	Generic Internet (Mainstreaming)		(Intranet) Web server Information systems	Internet programming	Web searching Web-based email accounts
Level 8	Critical Pedagogy (Mainstreaming)				Deep subject domain knowledge (up to postgraduate)