global e-schools and communities initiative

transforming education, empowering communities, promoting development

Deploying ICTs in Schools:

A framework for identifying and assessing technology options, their benefits, feasibility and total cost of ownership

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The latest version of the TCO tool and manual can be downloaded from:

http://www.gesci.org/ict-infrastructure-connectivity-and-accessibility.html

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If you have any comments or suggestions please write to tco.tool@gesci.org

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Chapter 1: The framework

Introduction

This series of documents and tools are intended to help in deploying Information Communication Technologies (ICTs) in schools.

The Framework document helps in identifying the range of possible ICT solutions and making a selection informed by an assessment of the benefits and costs of the different options.

The tool demonstrates the use of the framework through an Excel Spreadsheet. It reports on key findings from an analysis of data from real projects in four locations in Jordan, Colombia, India and Namibia. The analysis and finding are meant to provide an insight into some of the critical issues facing the deployment of ICTs in schools.

1.1.1 What this document is not

This document focuses on the capabilities and costs of ICTs and does not deal in detail with many of the broader questions that must be answered when developing a policy towards the use of ICT in education. It also does not directly address the even broader question of how spending on ICT compares with other investments towards achieving educational goals.

ICTs in schools today

Planning and deployment of ICTs in schools today suffers from several major problems:

- Planning officials, school principals and other decision makers do not emphasize or in some cases even consider the educational objectives at all. ICTs are acquired without any due consideration for what purpose they will actually serve.
- Decision makers often focus purchase decisions on the ICT hardware and software. There is often no consideration given to acquiring the appropriate

content, training of teachers, support and maintenance, which together form the "system-wide" approach discussed in detail later in this chapter.

- Budgets only consider the immediate costs and seldom, if ever, consider the long term costs of purchasing, deploying and maintaining ICTs. For example, costs for replacements, disposal or even operating costs for refresher training, maintenance and technical support are often ignored. The sum of all this costs is called the TCO (Total Cost of Ownership).

- ICTs are equated with personal computers usually in computer laboratories. There is no consideration given to other alternative technologies. Even where there is some awareness, decision makers are still faced with a myriad of questions and complex decisions on almost a daily basis: adopt laptops or desktops? Are thin-client computers better than networked desktops? Open Source or proprietary software? Whether to have the computers networked or connected to the Internet?

- Even when there are computers available for students, there are few or no incentives to use the computer in class. Sometimes the equipment has been installed but it is seldom used outside of specific "ICT classes". This might be due to the teachers not being adequately trained or not having enough time to dedicate to preparing the classes to incorporate the use of these new resources. Also, school calendaring issues (teacher timetables and exam schedules) complicate the adequate use of the devices even more.

- Inattention to monitoring and evaluation, that do not allow the benefits being obtained and the mistakes incurred in when introducing ICTs in schools.

Common Disconnects

The five major issues hindering effective deployment of ICTs in schools today are

1. Lack of focus on educational objectives
2. Considering ICTs a 'solution' for which the problem is not clearly defined.
3. Failure to consider all the elements of the system-wide approach
4. Failure to consider short term as well as long term costs (Total Cost of ownership or TCO)

5. Failure to consider the human factors related to teachers, headmasters and students.

These problems manifest themselves in many ways but the classic and often seen cases include:

- The computers sent to the school never leave their boxes because school personnel are afraid to break them!
- A school equipped with computers does not use the computers because the teachers have not been trained. While a few miles away, another school has had all their teachers attend an ICT training program but the school lacks any computers.
- Computer labs seem to have most of their computers broken all the time.
- The ministry of education draws up plans to equip every school with computer labs connected to the Internet and shelves the plan because it is too expensive.

This Report is intended to provide relief for people who plan and make decisions of acquiring and deploying ICTs in schools, and to avoid the problems highlighted above. It describes a framework for thinking about ICT acquisition and deployment and an approach that can be used to identify and assess different technology platform options, judging them in terms of the benefits they bring, how feasible they are, and the costs they impose. The report is meant to be used in conjunction with a set of electronic tools that calculate the total cost of ownership (TCO) and benefits of a given approach to deploying ICTs in a particular environment.

The System-wide approach

The effective deployment of ICTs in schools and indeed in any setting is a complex affair that goes beyond purchasing hardware and software. GeSCI has identified several key elements (see Figure 1) that must be considered if the deployment of ICTs is to have meaningful impact. These components must all co-exist; none is optional and together form a system. This system should be comprehensive, demand driven, capable and efficient and well coordinated.

Figure 1- GeSCI system-wide approach

Deployment of ICT Platform

This is the component that most people focus on. It involves the acquisition and installation of hardware and software. It is also the focus of this report. There are so many various ICTs that a school can choose from. To simplify the process of choosing among them, the decision is broken down into five main choices: the access device; the software; the display device; to-school connectivity; and in-school connectivity (*See* Figure 2). All these are supported by new or modified physical infrastructure and power backup systems. More detailed descriptions of each of the choices are given in Chapter 3.

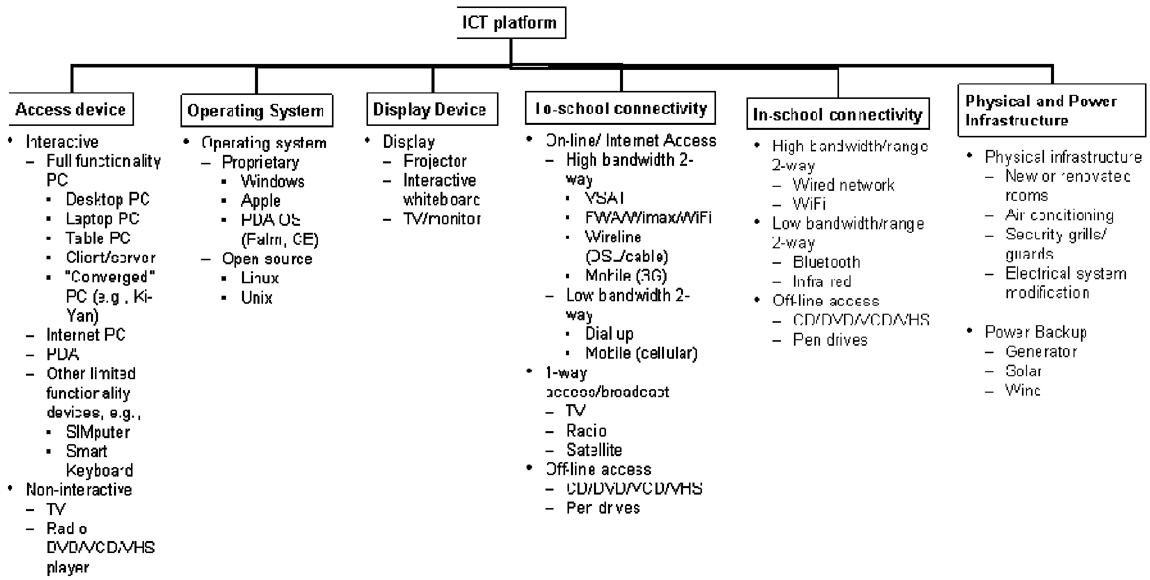

Figure 2- Components of ICT platform

A combination of these 5 choices is termed the "ICT platform". There are also various ways of deploying any particular platform (termed the "ICT deployment model") which are discussed in detail in chapter 2.

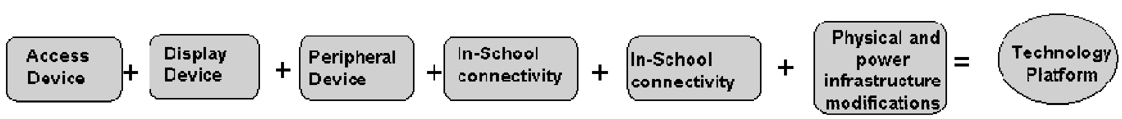

Figure 3- ICT Platform

Educational Content and Applications

Deploying ICTs without the appropriate content, software and applications is like buying a car without fuel. There are several types of content and applications some of which depend on the subject or class addressed. They can all be broadly classified under 4 categories:

- Basic software, comprising of productivity software such as word processors, spreadsheet programs, presentation software and Internet browsers. This also extends to server applications such as email.
- School Administration Applications, school administration tools such as accounting and time tabling applications and Educational Management Information Systems (EMIS).
- Educational applications, which include multimedia development tools, programming tools for children, simulation software and virtual labs, and quizzes and assessment applications.
- Electronic Content, which includes e-books, journals, e-lesson plans, dictionaries, encyclopaedias, teaching guides and multimedia content.

User Training and Support

This involves equipping school principals, administrative staff, teachers and students (the users) with the appropriate ICTs skills and advising principals and teachers on pedagogical issues in the use of ICTs. All users should also be provided with on-going support in using the technology platforms, content and applications. Training can be broadly categorized under training for teachers and administrators and training for students.

Training for teachers should cater for basic computing skills (introduction to computers and operating systems, typing, use of devices like printers and scanners); productivity software and the Internet; specialist applications; pedagogical aspects of effectively using ICTs in teaching and learning and technical training to enable teachers provide a first line of technical support and maintenance. Students should acquire basic computing skills, use productivity and specialist applications such as programming applications. Training of the students is conducted by teachers.

Types of teacher training

It is widely acknowledged that provision of teacher training is a critical element in capturing the full benefits of ICTs in schools. There are many ways to conduct such training and they cover a broad range of skills that can be taught to the teachers. A useful framework can be gathered from World Links for Development (https://www.world-links.org), who has developed a set of teacher professional development workshops for developing countries, delivered primarily face-to-face in five phases:

1. *Basic Concept of Information Technology* – introduce the fundamentals of computer technology

and help teachers acquire basic computer literacy knowledge and skills

2. *Introduction to the Internet for Teaching and Learning* – introduce fundamental concepts, technologies, and skills necessary to for introducing networked technology and the Internet to teaching and learning; initiate discussion of new possibilities, generate basic email projects

3. *Introduction to Tele-collaborative Learning Projects* – introduce educational telecollaboration – from activity structures to the creation, design, implementation and dissemination of original projects

4. *Curriculum and Technology Integration* – develop skills and understanding of how to create, incorporate and facilitate innovative classroom practices that integrate networked technology and curricula

5. *Innovations: Pedagogy, Technology, and Professional Development* – develop skills and understanding of how to evaluate and diffuse innovative classroom practices while addressing social and ethical concerns

Source: World-Links website, "ICT in Education" by Victoria L. Tinio, APDIP

Support for both teachers and students is critical. Support involves advising teachers on how best to integrate and use the technologies, advising students on how to use the technologies and providing a contact point for any questions and queries the users may have. Support can be provided through one or a combination of the following methods:

- On site- in the school by a trained teacher or by a technician
- Off site- through a helpdesk, dial-in system or online

Maintenance and Technical Support

Maintenance involves actions taken on equipment and systems e.g. repair, upgrades and can be diagnostic or preventive. Technical Support on the other hand involves actions taken on behalf of users to keep them working or help them get more out of the ICT systems e.g. help desk, initial technical training, and provision of Frequently Asked Questions (FAQ).

Maintenance and support can be either proactive or reactive:

- Proactive maintenance is aimed at stopping any breakages or problems from occurring in the first place. It involves providing preventive maintenance and technical training to a small group or for all teachers to enable them to maintain and clean the equipment and fix small problems before they degenerate into big problems.

- Reactive maintenance usually involves trouble shooting and repairing hardware and software breakages. This is usually provided through an external annual contract, for example four visits a year (quarterly), or a case by case basis as repairs are needed. Technical support involves responding to user's technical queries. Maintenance can be provided by the equipment supplier/ vendor, a third party company that specializes in maintenance and repair or well trained teachers and technicians in the school. Technical support can be provided through the use of a help desk, an internal teacher trained to do maintenance, a shared technician or a full time dedicated technician, or a combination of these methods.

Management, Monitoring and Reporting

This encompasses strategic planning, project management, financial and sustainability planning, setting impact measurement criteria and monitoring and evaluation of programs to ensure that the stated goals and objectives are being met.

A new approach

Once a country – or a school district or even an individual school – has decided to invest in ICTs, it must choose how to go about it. Choosing a technology platform is like making any other major investment, such as buying a home or a car. You decide what you would like, work out what it takes to supply that, and see whether you can afford it. If you can, you go ahead, if not, you adjust your plan.

The framework and corresponding approach is based on 3 key considerations that arise directly out of some of the major problems facing the deployment of ICTs in schools today discussed at the beginning of this chapter:

- **Focus on educational objectives**

  ICTs are a tool and not an end in themselves. What tools one chooses to use for any given task depends on the task and anticipated outcomes and not the capabilities of the tool. In the same regard, choosing and deploying ICTs for education must stem from the desired educational objective and outcome.

- **Target system-wide approach**

  Purchasing and installing the ICT platform in schools is not the end of the story but rather a part of an integrated (wide) system that requires that a plan be developed in advance, ICTs purchased and installed, training conducted, provisions for user support, technical support and maintenance made and continuous assessment and evaluation conducted to ensure that educational objectives are being met.

While GeSCI advocates the use of a system-wide approach designed to extract full impact from deploying ICTs in schools, this document focuses on the benefits, feasibility and costs associated with the deployment of ICT platform. It does explore in some detail and assesses the types and options of education content, initial and ongoing user training and support of teachers, technical support and maintenance. It does not however discuss management, monitoring and support in any detail. The Total Cost of Ownership (TCO) tools however capture all the components of the system-wide approach.

It is important to recognize that there are relationships between the various components and the educational objectives as shown in Figure 4. These relationships have an impact on making choices of ICT platforms and are explored in detail in the next few chapters.

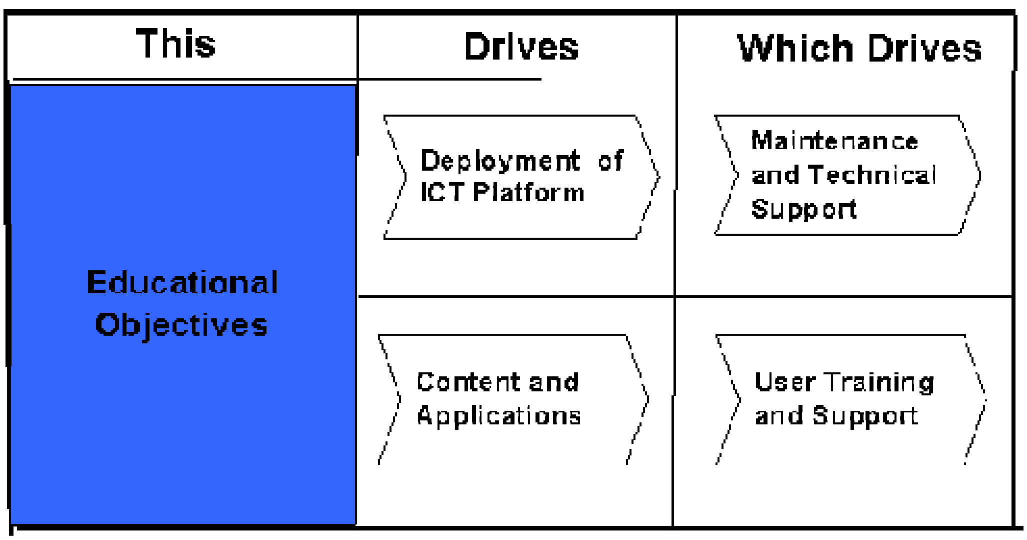

Figure 4- Relationship between system-wide components

- **Consider benefits, feasibility and long term costs**

Benefits and feasibility of both the technology selected and the overall approach to deployment should be considered along with the long term costs of introducing ICTs in schools. It is dangerous to focus on the immediate or initial costs such as those for buying and installing computers in a school lab without considering the long term recurring costs, which are usually much higher than the initial or immediate costs.

The feasibility of any given ICT is important to determine whether that particular ICT is applicable in a given context irrespective of the inherent benefits. Feasibility is usually influenced by local conditions. For example, the lack of wired telecommunications infrastructure at a remote village may mean that the only connectivity options are satellite or none at all. Or, cultural considerations such as teachers' lack of readiness to use technology in the classroom may mean a deployment of technology in teacher offices only.

The Strategy

Drawing from the considerations above, a strategy to select and deploy ICTs in schools has 5 key steps as depicted in Figure 5:

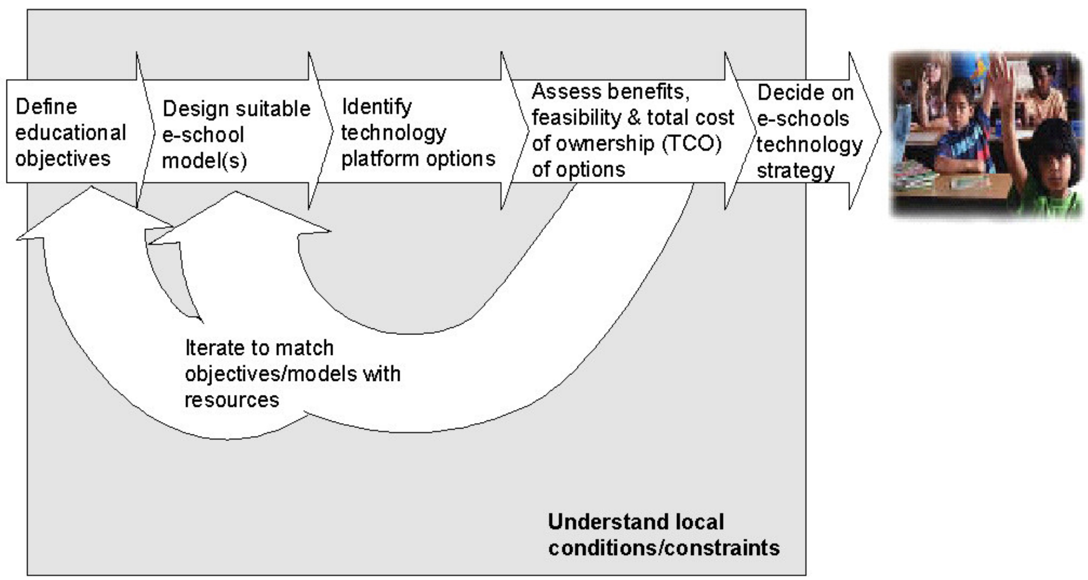

Figure 5- The approach

1. Define the educational objectives: what are you trying to achieve with the technology?
2. Design suitable "e-school model(s)" that best achieves these objectives: who uses/ will use the ICTs, where do they use it, how many devices are

deployed, what basic functionalities should it have and what content and applications accompany the devices? Note that a school may implement more than one e-school model to achieve its objectives.

3. Pick the specific technology platform (what hardware, software, connectivity and services to buy?) along with the necessary content and applications, user training and support and maintenance and technical support that suit this model and the educational objectives to be achieved.

4. Work out how much this technology will cost, not merely to buy in the first place, but throughout the life of the project. In addition to the initial purchase of the equipment and other costs such as telecommunications and modifications to physical school infrastructure, this TCO should include all the accompanying components of the system-wide approach: content and applications, user training and support and maintenance and technical support.

5. Compare this TCO to the budget. If it is within the budget, you can move forward to design a strategy around the chosen technology platform. If it is too expensive, you must go back and review the earlier choices, starting off with your selected technology platform and then the e-school model. Finally, if the cost is still too high, you must go all the way back to your educational objectives, and make compromises until the TCO falls to an acceptable level.

Remember that every stage of this process will be shaped by local conditions and constraints, which could influence or limit the choices at any point of the approach.

As you will have undoubtedly have noted, the approach to choosing an e-school technology strategy is a complicated one and does not necessarily have a "right" answer. In fact, the reader may well have come across numerous other frameworks that strive to achieve the same goal. Therefore the approach described above in Figure 5 is not meant to be a definitive one, but merely one that we have found to be useful in guiding our thinking.

We will now consider each of these steps in more detail in the succeeding chapters. Chapter 2 considers each of the 5 steps in the strategy in more detail. Chapter 3 provides a detailed assessment of the possible e-schools models and technology options and Chapter 4 presents the electronic tools that accompany the framework and discusses how they can be used in the selection of technology options.

Chapter 2: The approach

The approach to selecting technology platform options, or simply the technology options, has been introduced in Chapter 1 and it involves 5 steps. This chapter discusses the steps in further detail. As Figure 5 clearly depicts, the process is iterative and aims to match the educational objectives with the available resources and to achieve an efficient and effective deployment within the constraints set by local conditions.

Step 1: Define educational objectives

Information and communication technology offers a wide range of potential benefits for teachers and for students. The first step of forging an ICT strategy for your school(s) is to decide which of these educational objectives to pursue.

The range of possible objectives divides into four broad categories: administration, teacher development, student learning resources, and ICT skills training as a subject in its own right. In all there are eleven distinct objectives within these four categories, which are summarized in the table and described below.

Category	Objectives
Administration = better school management	Enhancing School productivity
	Enhancing data flow for policy making
Teacher Development = better teaching and learning	Developing teacher skills and knowledge
	Assisting effective lesson planning
Student learning resources = more tools for an improved educational system	Accessing information (by students)
	Improving conceptual understanding
	Developing constructivist skills
	Facilitating collaboration
	Providing testing and feedback

ICT skills training = creating skills for a brighter future	Developing basic ICT skills: obtaining the minimum abilities required to operate computers and its peripherals and to allow for further learning, for example typing, the operating system, using computer devices, basic tools.
	Developing advanced ICT skills like using the Internet, email systems, graphic software and image processing, sound and music, programming, advance office tools, etc.

Table - summary of possible education objectives

Possible administrative objectives

- **Enhancing school productivity**: Freeing up teacher and administrator time, and improving data storage and flow, through use of ICT for administrative tasks and communications
- **Enhancing data flow for policy making**: Collecting and managing data for planning purposes (monitoring results, assessing needs, allocating resources, etc.). Data is usually collected at the school level and aggregated regionally or nationally to facilitate policy changes to enhance overall education effectiveness

Possible teacher-development objectives

- **Developing teacher skills and knowledge**: Using ICT to improve teacher's subject knowledge, train new pedagogical practices, and motivate and connect teachers
- **Assisting effective lesson planning**: Assisting teachers with planning objectives, structure and content of lessons, especially for teaching new or unfamiliar subjects

Possible learning resources objectives

- **Accessing information (by students):** Students accessing local content, Intranet, or Internet for information beyond what is available in textbooks and library collection
- **Improving conceptual understanding:** Explaining concepts and information to students through dynamic audio-visual representations.

- **Developing constructivist skills**: Actively constructing knowledge by searching for information, interacting with simulations, designing products, and presenting work.
- **Facilitating collaboration**: Using ICT for group project work and communication between students in order to improve motivation and understanding.
- **Providing testing and feedback**: Opportunities to rapidly apply learning and get feedback through tests

Possible ICT skills objectives

- **Developing basic ICT skills**: Familiarizing students with ICTs and developing basic usage skills
- **Developing advanced ICT skills**: Learning advanced ICT skills (e.g., programming, multimedia) under teacher instruction

It is possible to pursue several of these objectives at the same time, but in doing so, policy-makers should be clear that they are distinct, and that the model best adapted to providing one kind of desired benefit may not be the best way to achieve another. Policy-makers should be clear which objectives they give the highest priority to, and which they are prepared not to pursue, or to trade off, before moving on to consider the different kinds of e-school model available.

STEP 2: Design Suitable E-School model(S)

Once your educational objectives are clear, you must decide which of several distinct "e-school models" will best serve them. Chapter 3, following this, analyses this issue in detail, and sets out clear guidelines for choosing an e-school model(s) depending on your objectives. There is no standard definition for what an e-school model is and school ICT deployments across the world adopt numerous models. For example, the Enlaces program in Chile has dedicated

NEPAD E-Schools

The New Partnership for Africa's Development (NEPAD) defines an e-school as one which:

- Will produce young Africans with skills to participate in the knowledge economy;
- Is equipped with apparatus of the knowledge economy;
- Is connected to the Internet;
- Has teachers trained to teach ICT skills;
- Allows teachers to use ICT to deliver their lessons;
- Uses ICT for administration of the school;
- Has a "health point".

computer labs where students use PCs with broadband connectivity. In another example, in the Philippines BRIDGEit initiative, teachers use their mobile phones to send text messages on what content they would like, and the content is sent via satellite to video recorders in schools. TVs in classrooms are then used to display the content. A desk review of these different models across the world undertaken by GeSCI suggests there are six key questions, grouped into 4 elements that help define those models:

1. Usage approach:
   - Who uses the equipment: administrators, teachers, students?
   - Where do they use it: office, classroom, lab, open access, school and home (1:1 models)?
2. Functionality:
   - How interactive is the equipment?
   - Is it connected in a Local Area Network (LAN)?
   - Is it connected to the Internet?
3. Numbers:
   - What is the ratio of devices to users? (students per computer)
4. Content and Applications used:
   - What content and applications are required for the educational objectives set?

The combination of only the usage approach and functionality forms the "technology deployment model". In this document, we defer to an e-school model as a distinct combination of these four elements (Figure 6):

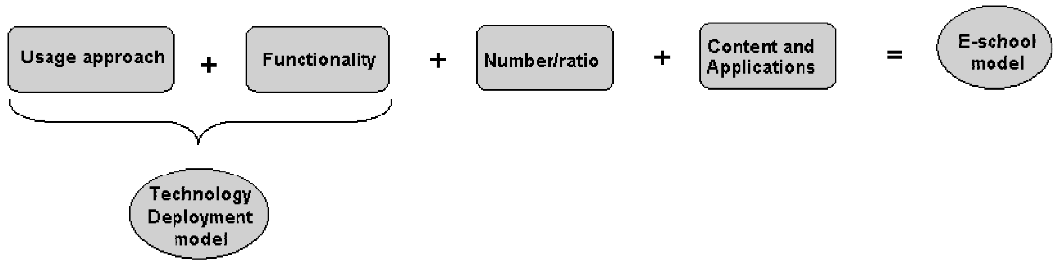

Figure 6- E-School model and Technology deployment model

By combining each possible set of answers to the questions making up each element, we can build up a number of distinct e-school models. It is important to emphasize here again that a particular school may choose to deploy more than one e-school model to achieve its educational objectives.

Taking each of these elements in turn, the detailed range of possibilities is listed below:

Usage approaches

There are several distinct approaches to usage, depending on who uses the equipment and where they use it. They are described here:

1. Teacher/admin office use

- The equipment is used only by teachers and administrators
- ICT is used for administrative tasks such as records storage, grade calculation, communication, e-mail, scheduling, budgeting, etc.
- Teachers can use ICTs to increase pedagogy expertise, subject knowledge and professional development, to become familiar with using technology, create their lesson plans, etc.

2. Mobile device (laptop) assigned to teacher

- The teacher will use the equipment in office for admin tasks, lesson planning and professional development
- The teacher can also bring equipment to teach students in class through presenting ready-made/tailored course-ware, incorporating multi-media into the lesson and gain access to information on the internet or CDs while in the classroom

- The teacher can also take the equipment home and use it off school

3. In-classroom single device mainly used by teacher

- The teacher will use the equipment to teach students in class through presenting ready-made/tailored course-ware, incorporating multi-media into the lesson and gaining access to information on the internet or CDs while in the classroom
- In some cases, students can access device when teacher is not using it

4. In-classroom multiple devices used by teacher and students

- Allows spontaneous use of technology in class, where students can do group exercises and have more interactive classes while the teacher guides the class
- With only a few devices in class, the teacher can use the equipment to instruct the class and a few students can use the devices in their own time (or during class, with teacher's instructions)

5. Computer lab with multiple devices used by teacher and students

- Similar to classroom multiple devices, but with the computers situated in a shared facility. The lab could be a general computer lab or a lab for a specific subject (e.g., Math lab)
- Students can use the devices when the computer lab is not being used to schedule classes (e.g., during lunch or after school)
- A special derivative of the lab or in-classroom multiple device approach is the use of "mobile" labs. These consist of laptop or handheld computers on a mobile cart and connected to a WIFI network. The cart can be wheeled into any free room and a lab setup instantaneously and is a great way to share a few computers if you have no space for a dedicated computer lab.

> The Hole in the Wall project of India is considered a radical new solution to complement the framework of traditional schooling, a solution that uses the power of collaboration and the natural curiosity of children to catalyze learning. To find out more about the solution see http://www.hole-in-the-wall.com/

6. Shared unsupervised access

- Students can use the equipment located in the library/shared areas to gain familiarity with the technology, to use the Internet, or to gain access to information or course-ware available outside the classroom setting
- Students can conduct assigned project work in their own time, without direct supervision of teachers
- Since these are shared resources, some method must exist to assign time slots to students and or classes, so that everyone has the chance to use them.

7. One-to-one (1:1)

- A recently proposed model where each student "owns" a portable computer and carries it to classes and home. The device becomes a personalized learning tool[1].
- Students can conduct assigned project work in their own time, without direct supervision of teachers, even at home, using the same personal device.

8. School based Telecenters

- As a unified solution to access both for the educational system and the community, school based telecenters consist of equipment connected to the Internet that are used by students during school hours and by community members for the rest of the day. A model that works better in small communities, it is being deployed in several developing countries as a way of finding new ways to reduce costs and guarantee sustainability over time.
- Students can use the telecenter as a computer room during assigned classes, and on their free time sharing it with other community members.

[1] More on this model available in "1:1 Technologies/Computing in the Developing World - Challenging the Digital Divide by M. Hooker, "http://www.gesci.org/index.php?option=com_content&task=view&id=35&Itemid=41

Functionality

There are three distinct levels of functionality, which offer differing levels of ability to run sophisticated interactive software and efficient real-time sharing and communication. These are described below:

1. Non-interactive

- One-way delivery of content, typically via TV or radio programming, but could also include playing CD/DVD on TV

2. Interactive un-networked

- Run computer applications that are held locally or delivered via physical media such as CD-ROM or DVD
    - Basic computer applications, e.g., word processor, spreadsheet, presentation or simple custom applications for special uses, e.g., administrative applications
    - Sophisticated applications specifically developed for educational purposes, and can include
        - Interactive content (e-curricula)
        - Assessment tool
        - ICT training tool

3. Interactive with network and/or Internet

- In addition to functionalities in Interactive un-networked:
    - Ability to access the Internet for content download or general information search
    - Ability to connect to an Intranet (private closed network) to access content or information stored on central server in national center or school district
- Local devices could be directly connected to the Internet, or to a centralized server which then administers the Internet privilege
- Connectivity to Internet also allows administrative and student records from different schools to be standardized on a single platform, and allow centrally hosted e-curricula content to be accessed by schools.

This can be accomplished either through direct Internet access with VPN, or schools connected via intranet to central server

Numbers

Different usage approaches demand different numbers of devices. For example, for office-based, teacher-only use, a single computer shared by several teachers could be valuable. But in a computer laboratory, the educational benefit may be greater if there is at least one device to every two to three students during a session. This topic is discussed in much more detail in Chapter 3: "**Benefits of different device to users ratio**".

Content and Applications

As detailed in Chapter 1, there are four categories of content and applications that you can choose to deploy with any ICT: basic software, school administration applications, educational applications and electronic content. For instance, video content broadcast over a TV system is an example of electronic content and would demand a TV whereas a piece of simulation software is a stand alone educational application that requires an interactive device to run.

Step 3: Identify Technology Platform and other system-wide Component Options

Once the e-school model(s) are chosen based on the educational objectives in Step 2, the next step is to identify amongst the many different technology options those that might support the model(s) chosen. Along with this, selection must also be made of options in the other system components. Remember that some components of the system are related (as described in Chapter 1 above) and this must be factored into the decision making so as to make intelligent and feasible choices. Chapter 3 details the various technology platforms and other component options.

Step 4: Assess Benefits, Feasibility and TCO of Options

Benefits

Benefits should be assessed for the technology deployment models, the entire e-school model and each of the individual technology platform selections. Benefits for each of the various options are explored in detail in Chapter 3 which follows.

Feasibility

The feasibility of any technology deployment model, e-school model and technology platform option is determined by a set of local conditions of the environment under consideration. These are referred to as the local conditions or constraints. Some technology options will simply not be locally available, for example, or may have to be scaled back to reflect constraints of different kinds. Computer servers that require a constant, steady electricity supply, for example, are unlikely to work in a remote rural region with at best intermittent power supplies, and teachers who are themselves uncomfortable with high technology are unlikely to apply complex networking successfully to either administration or teaching.

The main relevant categories of local conditions that are most likely to impose constraints on and therefore determine the feasibility of ICT decisions are described below.

1. ICT infrastructure

Existing ICT infrastructure such as computer equipment and telecommunications infrastructure

2. Electricity

Availability of sufficient and reliable electricity for ICT usage.

Good quality and risk-free internal electrical installation in the classrooms or labs (including surge protection).

3. Physical school infrastructure

Adequate Size and shapes of classrooms

Security: window bars, secure doors where equipment is stored

Adecquate furniture for the use of computers in class or in a lab

Lighting conditions; ventilation, access…etc.

4. Teacher skills

Educator's technology skills and comfort in integrating technology into teaching

5. Access to developed local ICT industry

Distance from services; capability of local ICT service industry; ease of procurement, technical centre close enough for repairs and replacements

6. Other

Calendaring / exam timetables allowing for computer usage, alignment with curricula

Incentive schemes for teachers

Every one of the steps in the technology options selection strategy, and the iterative process of arriving at a final satisfactory approach, will be affected by the local constraints.

Total Cost of Ownership

The Total Cost of Ownership or TCO is a concept that captures all the costs of a particular purchase from "cradle to grave" i.e. from making the decision to purchase, through the useful life of the purchase to retirement or end of life.

TCO differs from a regular budget because the budget usually focuses on the immediate (or initial) costs, encompassing one time purchases and the more obvious operating costs. TCO is therefore vital to understanding the full implications of any purchase one makes. The TCO of the technology platform options selected in Step 3 must take account of all the five main categories of spending, aligned with the GeSCI system-wide approach.

Each of these categories involves initial capital expenditure and then ongoing operating expenditure as depicted in Figure 7.

End-to-end system	Deployment of ICT platform	Content and Applications	User training and support	Maintenance and Technical support	Management, Monitoring and reporting
Upfront/capex	• Initial purchase, delivery and setup of equipment: – Access device – Display device – Connectivity – Software OS and apps – Peripherals – Physical infrastructure – Electrical system	• Off-the-shelf content • Custom-developed content – Development/ customization – Distribution	• Initial administrator, teacher and student training	• Setup of support infrastructure (if not outsourced) – Maintenance – Technical support call center – Etc	• Setup of organization (e.g., PMO)
Ongoing/opex	• To-school connectivity • Electricity • Security • Insurance	• Upgrades in content	• Recurring training for select admin and teachers • ICT training for students • Pedagogical support	• Maintenance and upgrades of all components of ICT platform • Technical support • Insurance	• Ongoing personnel for monitoring, evaluating and reporting

Figure 7- Initial and Ongoing costs

The components making up these categories are in turn made up of sub-components. To simplify the calculation of the TCO, this document is accompanied by an electronic technology assessment tool that automates the detailed calculations required to arrive at the overall TCO. This tool is described in detail in Chapter 4.

When the cost calculator has provided TCO values for the technology platform options that are under consideration, decision makers must weigh them against their budget and other constraints. Technology platform options with TCOs higher than available budget are dropped, and the remaining options are assessed and compared based on TCO and perceived benefits and feasibility. A decision on the technology platform thus depends on the decision maker's quantification of certain additional benefits that are associated with higher cost technology platforms. For instance, if the additional benefits are deemed to be "worth" the incremental cost, then the decision maker may well choose the higher cost technology platform and look for additional sources of founding.

Step 5: Iterate To Match Objectives/Models with Resources

If the TCOs for all the technology platform options under consideration are higher than the available budget, decision makers can start modifying their plans in a systematic way, by retracing the steps above and choosing different options.

Thus the first response to an excessive TCO should be to re-examine the e-school model chosen in Step 2: can the desired educational objectives be served by a less complex e-school model? Once again, the calculation tool will generate a new TCO based on a different e-school model. This process can be repeated until a suitable e-school model(s) is identified.

If the TCOs for all relevant e-school models are still too high, it is time to go all the way back to Step 1 and re-examine the educational objectives: would a more modest range of objectives be nonetheless worth pursuing?

This iterative process will not only yield useful estimates of TCO for different approaches, but will also be instructive in showing how changing different elements of the approach affects overall cost.

Chapter 3: Assessment of Technology Deployment models in Schools

Different e-school models and technology options are likely to produce different educational results. To achieve a particular objective, policy-makers need to know which e-school models and technologies are most suitable.

This chapter analyses the benefits of different usage approaches, functionalities, device ratios, particular technologies and content and application types, by showing to what extent they help achieve the eleven possible e-school objectives. Data on each option is presented, as well as a brief introduction to current debate over certain "hot topics" (e.g., deployment of computers in labs vs. in classrooms, use of proprietary vs. open source operating systems). A fuller treatment of the hot topics is presented in Part 2 of the report.

The exact choice of technologies will depend on the decision maker's interpretation and selection of educational objectives and local conditions, which are discussed in this chapter in greater detail. But this report will act as a useful guide to inform strategy formulation. It should be used in conjunction with the electronic TCO calculator, which will help the decision maker assess the costs of particular e-school models and technology platforms.

The analysis takes place in distinct stages. First, eighteen possible technology deployment models are assessed in terms of their suitability to achieving each of the eleven educational objectives. (These models are driven by a combination of the seven usage approaches with the three technology functionalities.) Second, the benefits of different device-to-user ratios are discussed. Third, the different technology options suitable for each technology deployment model are shown and assessed in terms of functionality, feasibility and total cost of ownership. It will be seen that many permutations of technologies are possible for each technology deployment model – the exact configuration or platform will depend on local cost and feasibility factors.

Part 2 of this report uses the framework to conduct analysis of all the technology deployment models using example technology platform options. The analysis is based on real data from technology deployments in schools in Jordan, Colombia, Namibia and India. This analysis is meant to gain and communicate insights into the cost effective deployment of ICTs in schools.

Suitability of Technology Deployment Models to Achieving Objectives (Guide to Step 2)

This section focuses on the technology deployment model as a major part of an e-school model. Because there are eight different usage approaches and three different levels of functionality, twenty-four technology deployment models are theoretically possible. However, of these technology deployment models, six are not in fact meaningful, since they combine a functionality (non-interactive) with usage approaches that would not make sense together. Specifically, it does not make sense to consider use of non-interactive technology (e.g., TV, radio) only in office administration, or as a mobile device assigned to teacher, or as multiple devices in a classroom or a computer lab. The only meaningful ways to utilize non-interactive technology are as single device in classroom (e.g., teacher using TV with broadcasted materials) or in a shared unsupervised access environment (e.g., TVs or radios in library's language section). This is illustrated in Figure 8 below:

Usage Approach	**Functionality**		
	Non interactive	Interactive Un-networked	Interactive with Internet
Teacher and admin office use	NO	YES	YES
Mobile device (laptop) assigned to teacher	NO	YES	YES
In-classroom single device mainly used by teacher	YES	YES	YES
In-classroom multiple devices used by teacher and students	NO	YES	YES
Computer lab with multiple devices used by teacher and	NO	YES	YES

Usage Approach	**Functionality**		
	Non interactive	Interactive Un-networked	Interactive with Internet
students			
Shared unsupervised access	YES	YES	YES
One-to-one (1:1)	NO	YES	YES
School based Telecenters	NO	YES	YES

Figure 8- Types of technology deployment models

Each of the relevant eighteen technology deployment models can help achieve a number of educational objectives to varying degrees. The suitability analysis is given in detail below, but is summarised, for assessment purposes, on a five point scale, from zero suitability to maximum suitability. "Suitability" in this particular case is based on a combination of the benefits rendered and the feasibility of the given model. These are helpfully represented in a table that summarises each stage of the analysis as "circles" – a blank circle represents zero suitability and a completely filled-in circle represents maximum suitability. Mounting degrees of suitability are represented by quarter-, half-, and three-quarter-filled circles. See Figure 9 for an overview of 14 technology deployment models and their relevance to achieving educational objectives.

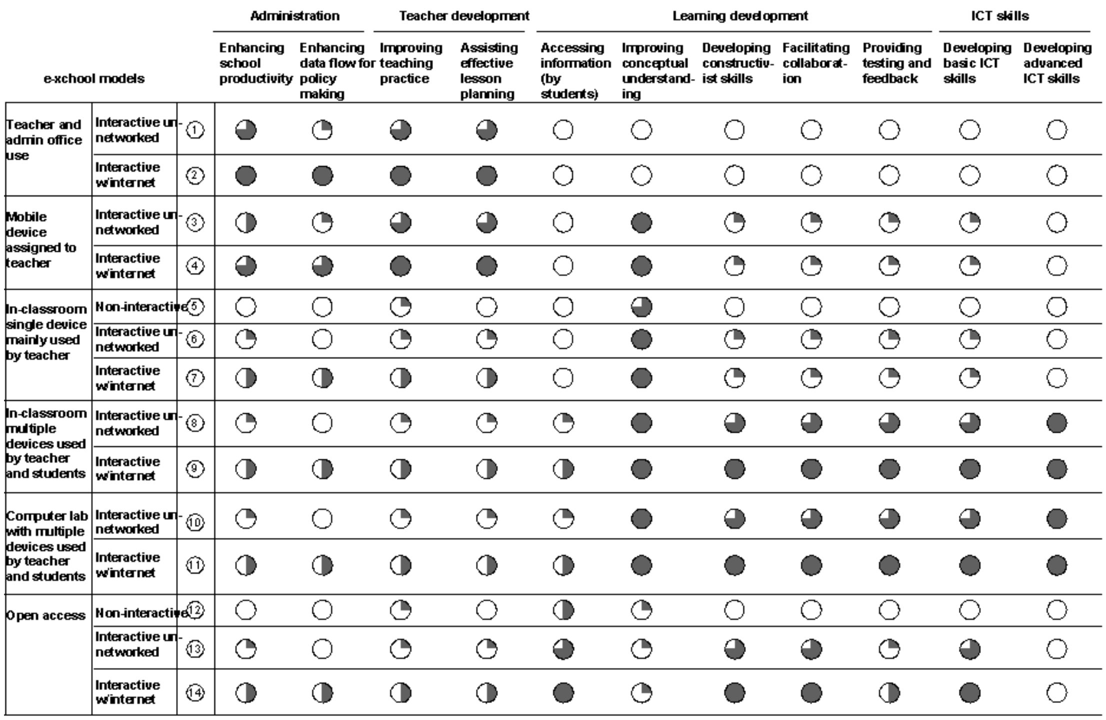

Figure 9- Technology deployment model vs. educational objectives

Note that the usage approaches 'in-class multiple devices' and 'computer lab with multiple devices' are equally suitable in achieving educational objectives. In this case, a final selection would require a more in-depth analysis of the benefits, feasibility and costs of each model. While it is very difficult to quantify the "amount" of benefit any model is likely to offer, it is clear that some measures such as the amount of ICT contact or exposure time per student or the frequency of use per student (both determined by the student device ratio) will impact the extent to which the benefit is realized. The cost of each model is a more straight forward quantity to determine and this is usually used as the deciding factor.

In the specific case of computers in labs vs. computers in classrooms, the debate has been inconclusive so far but seems to favour computers in the classroom as a good approach as this is more likely to lead to spontaneous use during lessons and integration into the curriculum and teaching. On the other hand, computers in a lab are considered a less costly approach and one that makes it easier to provide access to the community.

FEASIBILITY OF GIVEN DEPLOYMENT MODEL

✓ suitable
✗ Not suitable

e-xchool models			Poor ICT infrastructure e.g. telecom	No or unreliable Electricity	Poor Physical school infrastructure e.g. no security, lack of space	Low Teacher skills	No Access to developed local ICT industry (service difficult to obtain)
Teacher and admin office use	Interactive un-networked	1	✓			✓	
	Interactive w/internet	2	✗			✓	
Mobile device assigned to teacher	Interactive un-networked	3	✓		✓	✗	✗
	Interactive w/internet	4	✗		✓	✗	✗
In-classroom single device mainly used by teacher	Non-interactive	5	✓		✓	✓	✓
	Interactive un-networked	6	✓		✓	✗	
	Interactive w/internet	7	✗		✓	✗	
In-classroom multiple devices used by teacher and students	Interactive un-networked	8	✓		✓	✗	
	Interactive w/internet	9	✗		✓	✗	
Computer lab with multiple devices used by teacher and students	Interactive un-networked	10	✓		✓	✗	
	Interactive w/internet	11	✗		✓	✗	
Open access	Non-interactive	12	✓		✓	✓	
	Interactive un-networked	13	✓			✓	
	Interactive w/internet	14	✗		✓	✓	

Figure 10- Feasibility of deployment models

Figure 10 above details the feasibility of the deployment models as determined by the local conditions or constraints. The table below explains how some of the constraints limit feasibility.

Technology Deployment model	Most suitable for areas with	But not suitable for areas with or where
Model 1- Teacher and admin office use, interactive un-networked	• low teacher skills (to restrict use to teacher office only) • lack of telecommunications infrastructure	
Model 2- Teacher and admin office use, interactive w/	• low teacher skills (to restrict use to teacher	

Technology Deployment model	**Most suitable for areas with**	**But not suitable for areas with or where**
Internet	office only)	
Model 3- Mobile device assigned to teacher, interactive un-networked	• lack of telecommunications infrastructure • security concerns (teacher can keep custody of equipment at all times),	• Teacher skills are low • where technical service is difficult to obtain (since laptop is less robust than desktop)
Model 4- Mobile device assigned to teacher, interactive with Internet	• security concerns (teacher can keep custody of equipment at all times),	• Teacher skills are low and where technical service is difficult to obtain (since laptop is less robust than desktop)
Model 5- In-classroom single device mainly used by teacher, non-interactive	• low teacher skills (non-interactive is easier for teacher to teach with than interactive device), • lack of space for computer labs, • lack of telecom infrastructure and • where service is difficult to obtain (since TV/radio rarely break down)	
Model 6- In-classroom single device mainly used by teacher, interactive un-networked	• lack of space for computer labs, • lack of telecom infrastructure,	• Teacher skills are low
Model 7- In-classroom single device mainly used by teacher, interactive with internet	• lack of space for computer labs,	• teacher skills are low
Model 8- In-classroom multiple devices used by teacher and students, interactive un-networked	• lack of space for computer labs, • lack of telecommunications	• teacher skills are low

Technology Deployment model	**Most suitable for areas with**	**But not suitable for areas with or where**
	infrastructure	
Model 9- In-classroom multiple devices used by teacher and students, interactive with Internet	• lack of space for computer labs,	• teacher skills are low
Model 10- Computer lab with multiple devices used by teacher and students, interactive un-networked	• lack of room in classroom for equipment, • lack of telecommunications infrastructure	• teacher skills are low
Model 11- Computer lab with multiple devices used by teacher and students, interactive with internet	• lack of room in classroom for equipment,	• teacher skills are low
Model 12- Open access, non-interactive	• low teacher skills, • lack of room in classroom for equipment, • lack of telecommunications infrastructure	
Model 13- E-school model 13: Open access, interactive un-networked	• low teacher skills, • lack of room in classroom for equipment, • lack of telecommunications infrastructure	
Model 14- Open access, interactive with Internet	• low teacher skills, • lack of room in classroom for equipment, or classrooms not adequately equipped (furniture, security, roofs, electricity)	

Benefits of Different Device-To-User Ratios

The number devices in the school or ratios of ICT devices to students or teachers will determine the degree to which educational objectives are achieved. This has two effects: on the *frequency* with which users can interact with ICTs, and the intensity or quality of their interaction. For resource constrained environments, it also depends on the trade-off between costs and benefits. The key numbers are different depending on the usage approach. Figure 11 sets out the ratios that a planner must specify when designing an e-school strategy and the impact this has on achievement of educational objectives. Note however that the quantity of a given type of device in a given context does not alter its basic suitability for a given purpose.

Usage approach	Key ratios	Impact
Teacher/office use	• # of devices per teacher	• Frequency with which each teacher can access ICTs for administrative or professional development purposes
Mobile device assigned to teacher	• # of devices per teacher	• Proportion of teachers who can use ICTs for administrative or professional development purposes • Proportion of classes where ICTs are used as learning resource
In classroom single device mainly used by teacher	• # of devices per classroom	• Proportion of classes where ICTs are used as learning resource (especially for conceptual understanding)
In classroom multiple devices used by students and teachers	• # of classes where ICTs are deployed • # of devices per student in each class	• Proportion of classes where ICTs are used as learning resource • Amount of time each student has to directly access ICTs (to build constructivist skills, collaboration, ICT skills, and provide testing/feedback)
Computer lab multiple devices used by teacher and students	• # of labs per school • # of devices in each lab	• Number of hours of tuition per week for each student in computer lab • Amount of time each student has to directly access ICTs (to build constructivist skills, collaboration, ICT skills, and provide testing/feedback)
Open access	• # of devices per school • [hours per day that devices are accessible]	• Number of hours/minutes that each student can access device per week

Figure 11- Implications of device to user ratio

Numerous studies have been carried out on the "ideal" PC to student ratio. The studies clearly indicate that the debate on the optimum student computer ratio for schools is still unresolved. Student to computer ratio seems to be driven purely by financial resource availability. According to Russell et al[2], the optimum ratio that schools should aim for is 1:1.

According to the US National Center for Educational Statistics[3], quoting from President's Committee of Advisors on Science and Technology 1997, p. 14, a reasonable ratio according to most experts is at least 1:5. A UNESCO/IIEP report in 2003 discusses student-computer ratio issues and notes that at the end of the 90's many developed countries had set themselves the goal of a student computer ratio of at most 10:1[4]. In Many OECD countries, the student computer ratio is less than 5:1. When countries of Eastern Europe are included, the average student to computer ratio is about 10:1[5]. Student computers ratios can also be determined by "proportion of curriculum time dedicated to the use of ICT". Thus Singapore and Korea have targets of 10-30% of curriculum time to integrate use of ICTs which translates to student computer ratios of 6:1 and 2:1 respectively[6].

Also note that according to the UNESCO/IIEP report:

- Students with limited access to computers performed below the OECD average, particularly those with no access to computers at home even after accounting for socio-economic background of students
- Students with the shortest duration of computer usage (less than 1 year) scored below those with 1-3 years usage but those with more than 3 years usage scored only slightly better than those with 1-3 years usage
- For School usage, the most frequent users of computer perform below moderate users but moderate users perform better than low users

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2 Russell, M., Bebell, D., Cowan, J., & Corbelli, M. (2002). *An AlphaSmart for each student: Does teaching and learning change with full access to word processors?* Technology and Study Collaborative, Boston College. Retrieved August 26, 2002, from http://www.bc.edu/research/intasc/studies/AlphaSmartEachStudent/description.shtml.

3 http://nces.ed.gov/pubs2001/InternetAccess/3.asp

4 http://unesdoc.unesco.org/images/0013/001362/136281e.pdf

5 *ECD, 2003, PISA 2003, Are Students Ready for Technology Rich World? http://www.pisa.oecd.org/document/31/0,3343,en_32252351_32236173_35995743_1_1_1_1,00.html*

6 *UNESCO Schoolnet Toolkit http://www.unescobkk.org/education/ict/online-resources/e-library/elibrary-themes/teaching-and-learning/schoolnet-toolkit/*

- Students with higher confidence in using computers also score more highly in mathematics

These ratios will obviously be different for different deployment models and may have an impact on the technology platform selection to. A computer lab or in-classroom multiple device deployment model, for instance could do with a 1:5 ratio. A 1:1 ratio on the other hand may require the deployment of mobile devices for each student. Interestingly, ratios of device to teacher are seldom, if ever, discussed. Part 2 of this report discuses this topic further.

Also, the device to user ratios might affect the number of servers needed. See next section for more information.

CHAPTER 4: SELECTING SUITABLE TECHNOLOGY OPTIONS AND OTHER SYSTEM-WIDE COMPONENTS (GUIDE TO STEP 3)

Armed with the technology deployment model(s) that best suit a chosen set of educational objectives, the next step is to decide what technology to purchase. The technology deployment models themselves somewhat limit the number of suitable technologies – for example, a choice of model #6 of In-classroom single device + interactive un-networked immediately rules out the use of non-interactive devices such as TVs and radios. However, a review of the full range of technology options presented in Chapter 1 suggests many are still possible. For example, should desktop or laptop be used? Should they be new or used? Running Windows or Linux? How about a thin client-server solution?

We will now consider some of these choices in more detail.

4.1 Access devices:

The access device is in many ways the centrepiece of the technology platform. It receives input from the user (e.g., via keyboard, remote control), processes applications and/or content (stored locally, accessed via Internet or broadcasted), and outputs the information to a built-in screen or external display device.

The range of possible access devices divides into two broad categories: interactive and non-interactive, as mentioned in the e-school model functionality discussion. Interactive devices can be further broken down into two major categories: full functionality PCs and limited functionality devices. The latter includes PDAs, internet PCs, and other limited functionality devices such as SIMputer or the Smart Keyboard. These are described below.

Full functionality PCs: Desktop PC, laptop PC, tablet PC, or other "converged" devices that contain one of the above devices (e.g., Ki-Yan compact projector box). A client/server set up is also included in this category since from the user's perspective, full functionality is achieved at the client level even though most processing is done at the server level. These PCs can run a full array of productivity applications and specialized educational software, and are equally suitable for achieving the educational objectives under given usage approaches, with the exception of laptop and table PCs, whose mobility allows for use in more than one usage approach. Thus selection of one over another is mainly driven by feasibility and cost considerations, which are set out in Figure 12.

One variation of this option is the personal device of the one-to-one model, where a sort of simplified portable computer is assigned to each student. For a list of the different devices available produced by vendors worldwide, developed by Infodev, please refer to: http://infodev.org/en/Publication.107.html

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	Benefits			
Technology	Key features	Implications for objectives	Feasibility	Indicative TCO*
Desktop PC	• Fully compatible with common productivity and specialized educational applications • Supports most connectivity and output options • Large data storage and processing power • Suitable for group use	• Depending on usage approach, facilitates all major educational objectives • Particularly suitable for developing ICT skills due to prevalence in society	• Well-supported by local services industry (both procurement and maintenance) • Most robust and less likely to break	$$
Laptop PC	• All key features of desktop PC • Mobility of device allows fulfillment of multiple usage approaches as teacher can use laptop in office, then bring it to class	• Same as desktop, with additional benefit of fulfilling multiple usage approaches, which facilitates more educational objectives	• Well-supported by local services industry (both procurement and maintenance) • Less robust than a desktop and is more likely to break during heavy use	$$$
Tablet PC	• All key features of laptop PC • Handwriting recognition allows quicker/more instantaneous user input	• Same as laptop	• Not well-supported by local services industry (both procurement and maintenance) • Less robust than a desktop and is more likely to break during heavy use	$$$$
Client/server	• All key features of desktop PC	• Same as desktop	• Not as well-supported by local services industry (both procurement and maintenance) as desktop • More robust than a desktop as main processor (server) could be placed out of reach of students	$$
Converged device	• All key features of desktop PC, with display built-in	• Same as desktop	• Not well-supported by local services industry (both procurement and maintenance) outside of India • Robustness uncertain as device is not widely used yet	$$$$

* TCO indicative since it is not in the context of a complete technology platform, it varies across countries, and the data used in this assessment are preliminary and in some cases incomplete. $ = <US$750, $$ = <US$1500, $$$ = <US$2500, $$$$ = >US$2500

Figure 12- Comparison of access devices

Limited functionality devices:

Internet PCs: Sometimes called network PCs. These are low cost PCs designed to primarily allow users to access the internet and have limited processing power and storage capacity, which restricts range of applications that can be run. For example, AMD's Personal Internet Computer (PIC) uses a PDA-grade processor, runs Windows CE and comes with a minimal set of software, including a browser, email client, word processor, spreadsheet, and viewers for images, multimedia files and standard format documents such as PowerPoint files

PDAs: Personal digital assistants. The main types of PDAs are categorized by operating system – Palm devices, which run Palm OS, and Pocket PC devices, which run Windows based operating systems such as Windows Mobile. Both types of PDAs are characterized by a large support base of custom applications and ability to synchronize with PCs. Most support viewing of popular file formats (e.g., Word, Excel, PowerPoint) but are ineffective in creating/editing them

Other limited functionality devices: There are several devices on the market that are designed with lower levels of functionality than a full functionality PC, and in many cases, designed specifically for educational use. These are sometimes collectively called "low cost computing devices". Going forward, as processing and memory prices continue to plummet, and wireless becomes more prevalent, these will become more and more relevant. Below is an illustrative non-exhaustive list of such devices:

SIMputer – handheld device developed by PicoPeta Simputers (http://amidasimputer.com), which contains a 206 MHz processor, 64MB of RAM, 32MB of storage. Runs Linux and has proprietary applications for basic personal assistance (address book, calendar, calculator, MP3 player…etc.) and limited options to connect to internet (dialup or through selected mobile phones)

Smart Keyboard – handheld devices such as those developed by AlphaSmart (http://www.alphasmart.com), which are sophisticated word processor devices with built-in features such as dictionary and thesaurus

Other devices like interactive whiteboards, calculators, sensors, microscopes, etc.

An overview of these devices' functionalities in terms of key features that contribute to achieving educational objectives, feasibility and indicative TCO are presented below in Figure 13:

	Benefits			
Technology	Key features	Implications for objectives	Feasibility	Indicative TCO*
Full functionality PC (desktop, laptop, tablet, client/server, converged device)	• Fully compatible with common productivity and specialized educational applications • Supports most connectivity and output options • Large data storage and processing power • Suitable for group use • Laptop & tablet allows fulfillment of multiple usage approaches	• Depending on usage approach, facilitates all major educational objectives • Particularly suitable for developing ICT skills due to prevalence in society	• Mostly well-supported by local services industry (both procurement and maintenance) except for tablet PC and converged device • Mostly robust (laptop and tablet less so) • Least foreign to teachers	$$ - $$$$
Internet PC	• Supports most connectivity and output options • Suitable for group use • Limited ability to create work and run specialized applications due to small processing power • Limited data storage	• Can be used by teacher/admin for simple administrative tasks, in-class single device for conceptual understanding with limited applications, by students in open access for email and for ICT skills development • Limited benefit in terms of developing advanced ICT skills, etc.	• Limited support by local services industry (both procurement and maintenance) • Robust • May be less familiar to teachers, although easy to overcome (same interface as desktop PC)	$
PDA	• Can output to display device, but wireless connectivity only • Limited ability to run specialized applications due to small processing power • Difficult to create work although can view files • Minimal data storage	• Can be used as in-class single device for conceptual understanding with limited applications, by students for testing/feedback, for email, and for limited ICT skills development • Limited benefit in terms of constructivist skills, collaborative work, access to information, etc.	• Moderately well-supported by local services industry (both procurement and maintenance) • Less robust and is more likely to break with heavy use • Requires little physical infrastructure changes • May be less familiar to teachers	$
Other limited functionality devices	• Very limited ability to run specialized applications due to small processing power and incompatibility with common applications • Limited output to display device and connectivity options • Can create simple work • Minimal data storage	• Can be used by students for limited ICT skills development and limited constructivist skills (by creating work) • Limited benefit in terms collaborative work, access to information, developing advanced ICT skills, etc.	• Limited support by local services industry (both procurement and maintenance) • Less robust and is more likely to break with heavy use • Requires little physical infrastructure changes • May be less familiar to teachers	$

* TCO indicative since it is not in the context of a complete technology platform, it varies across countries, and the data used in this assessment are preliminary and in some cases incomplete. $ = <US$750, $$ = <US$1500, $$$ = <US$2500, $$$$ = >US$2500

Figure 13- Functionalities of access devices

Non-interactive devices consist of televisions, radios and DVD/VCD/VHS players which allow basic storage and playback of audiovisual materials. An overview of these devices' functionalities in terms of key features that contribute to achieving educational objectives, feasibility and indicative TCO are presented below in Figure 14:

Technology	Benefits: Key features	Benefits: Implications for objectives	Feasibility	Indicative TCO*
TV	• Can receive and display visual and audio broadcast of content • Suitable for group use	• Can be used by teacher to improve conceptual understanding	• Mostly well-supported by local services industry (both procurement and maintenance) • Robust and has long life span • Least foreign to teachers	$
Radio	• Can receive and display audio broadcast of content • Suitable for group use	• Can be used by teacher to improve conceptual understanding, although in a very limited way since no visual	• Mostly well-supported by local services industry (both procurement and maintenance) • Robust and has long life span • Least foreign to teachers	$
DVD/VCD/VHS player (requires display)	• Can playback pre-recorded visual and audio content at any time • Allows sharing of content between devices within school and across schools • Suitable for group use (with appropriate display) • If matched with video camera or digital camera, allows playback and sharing of self-created content	• Can be used by teacher to improve conceptual understanding	• Mostly well-supported by local services industry (both procurement and maintenance), especially VHS player • May be slightly foreign to teachers, but teachers can be easily trained to work with equipment	$

* TCO indicative since it is not in the context of a complete technology platform, it varies across countries, and the data used in this assessment are preliminary and in some cases incomplete. $ = <US$750, $$ = <US$1500, $$$ = <US$2500, $$$$ = >US$2500

Figure 14- Comparison of non interactive devices

There is a broad spectrum of other devices that could serve as access devices in an educational setting, albeit in a limited sense. These are not discussed in detail in this document due to their very limited use, although they should not be ruled out completely as they may be relevant in certain settings. These include advanced calculators (especially ones with infra-red capability), mobile phones (e.g., smart phones) and game consoles (increasing connectivity options and processing power, especially for graphics).

Other decisions to make on Access Devices

Whatever the access device chosen, you will still be faced with two critical decisions to make in addition to choosing the device. These decisions relate to whether to choose new or refurbished devices (applies to all devices) and whether to adopt thick or thin-clients (applies to full functionality PCs).

New or Refurbished

❖ Refurbished devices are devices that have previously been used or reached their useful end of life and have been given a new useful lease through replacement or upgrade of some device components. There is a raging debate on whether refurbished devices are useful for schools especially in developing countries. Those against refurbished computers argue that they are not useful as they have almost reached their "end of life", can not run newer software and are more expensive than new PCs in the long run due to frequent breakdown and hence need for support and maintenance[7]. Developing regions also claim that refurbished PCs are an environmental risk (transferred by the richer countries) and stifle growth of local computer manufacturing or assembly industries. Those for refurbished computers argue that refurbished PCs are important and sometimes the only way to introduce ICT in schools and that they are also an important source of computers even in developed countries. Canada's Schoolnet used computer program provides about 25% of all school computers[8]. As Becta[9] argues, it is only human to "seek the newest, fastest and best equipment" but we should give appropriate attention to alternatives to new equipment. If we live with and indeed thrive on many used goods such as cars and clothes- what's special about computers? According to Schoolnet Africa[10], no conclusive data exists and opines that "Until it can be proven beyond doubt that the total cost of ownership of a new PC is less than that of a refurbished PC, most schoolnets are committed to continuing to use refurbished PCs in schools". We shall discuss and attempt to shed more light on this topic in Part 2 of the report.

Thick vs. Thin Clients

- There are two main types of thin clients:
    - Network Computers or dumb terminals- these are considered the "true" thin clients. A small piece of software is downloaded from the server for control purposes only and all the other software and applications are run on the server
    - Windows based terminals- software is downloaded from the server and then run off the clients as it were a fat client. The client runs only the very processor and memory intensive applications from the server.
- The debate revolves around which option has a lower TCO. Most studies claim thin clients have lower TCO because of lower terminal price and lower support and management costs as support and management is

[7] See BBC article on software compatibility issues of using refurbs- http://news.bbc.co.uk/1/hi/world/africa/2989567.stm

[8] *Islands in the Wastestream: Baseline Study of Noncommercial Computer Reuse in the United States- http://www.compumentor.org/recycle/baseline-report/*

[9] British Educational Communications and Technology Agency (BECTA)- information sheet on recycled/ refurbished computers- http://www.becta.org.uk

[10] Framework On Refurbished Computers For African Schools- http://www.schoolnetafrica.net/fileadmin/resources/USED_IT_Meeting_(FINAL_REPO.pdf

centralized. However, opponents like Intel claim the cost advantage has been eclipsed by recent lower standard PC costs and better PC central management and control systems such as those that come with windows server products and Linux operating systems making the TCO for thin clients and "managed or smart PC" about the same. This topic is also discussed and analysed in more detail in Part 2 of the report.

Server considerations

- Irrespective of the client solution to be adopted you will probably need one or more server machines at school. The servers perform several functions, and they can range from standard PCs to large costly equipment.
- One server can perform several functions at the same time. Some of the uses for a server are:
  - As file storage: since it will have more storage space, be in a protected environment, have a UPS and be backed up regularly.
  - As a proxy server/cache for Internet access: thus allowing the connection to be optimized by storing the most frequently accessed files locally, and also filtering unwanted content like porn or music files.
  - As part of the administration of the local network structure as domain controller (user access and rights), connectivity gateway, DHCP and DNS server
  - As a firewall protecting the school resources from unauthorized outside access.
  - As a way of sharing expensive resources like printers, scanners and storage among the network's users.
  - As a local email server, including antivirus protection for outgoing and incoming email.
  - As a local web server for storing locally developed content
- Exactly how many servers are needed depends mainly on the tasks that the servers will perform, the number of simultaneous users, and the operating software and applications in use. There is no simple "rule of thumb" to estimate the servers needed.

4.2 Display technology

Use by a teacher of an in-classroom single device will require a display device that all students can view. There are 3 main options available: a projector, a large TV monitor, or an interactive whiteboard. There are benefits and costs for each as shown in Figure 15.

	Benefits			
Technology	Key features	Implications for objectives	Feasibility	Indicative TCO*
Projector	• Can display image to a very large size for all students to view • Mobility facilitates sharing	• Can be used by teacher to improve conceptual understanding	• Moderately well-supported by local services industry (both procurement and maintenance) • Bulbs need to be replaced every 1-3 years depending on usage, which are very expensive • Depending on the configuration of the room, may be difficult to have a clear path of projection from projector to screen/wall	$$ - $$$
Interactive whiteboard	• Allows user to make changes on whiteboard, which is recognized by the application • Requires internal or external projector	• Can be used by teacher to improve conceptual understanding in a highly interactive way (students can draw on board)	• Not well-supported by local services industry (both procurement and maintenance) in developing countries • May not be appropriate for teachers with lower ICT skills	$$-$$$
TV/monitor	• Can display image to a size up to 36" for CRT TV, or up to 60" on plasma TV/monitor. Computer monitor typically up to 21"	• Can be used by teacher to improve conceptual understanding	• Well-supported by local services industry (both procurement and maintenance) • Least foreign to teachers • TV displays to a larger screen size than CRT monitor, but at lower resolution and not all TVs support PC input • LCD/plasma supports largest screen size but expensive	$ (TV) $-$$ (monitor) $$$$ (LCD/plasma)

* TCO indicative since it is not in the context of a complete technology platform, it varies across countries, and the data used in this assessment are preliminary and in some cases incomplete. $ = <US$750, $$ = <US$1500, $$$ = <US$2500, $$$$ = >US$2500

Figure 15- Comparison of display devices

All display devices are used to display an image to a large size for viewing by students and can be used by the teacher to improve conceptual understanding by, for example, displaying a simulation in class. Televisions and Projectors are the better known display devices available and are relatively well supported by the local service industry (both procurement and maintenance). While the older and more common Cathode Ray Tube (CRT) TVs are relatively cheap, new plasma and Liquid Crystal Displays (LCD) TVs are much more expensive but can support larger screen sizes, take up less space and consume less electricity. The cost of the projectors should not be under-estimated as they require regular (every 2 years on average) replacement of the lamps which can be expensive. Interactive White Boards are a newer and emerging technology whose best point is the ability to make interactive presentations and displays. However, they cost a lot more than televisions or projectors and are not yet well supported by local ICT service industries in many developing countries.

4.3 Operating system and software

The choice of an operating system is a key decision for the policymakers that will not only affect the cost of the technology platform but also the reliability, scalability, customizability and availability of applications that can be run on the system. Figure 16 describes some of the benefits and feasibility issues with the two most common operating systems available on the PC platform today – Microsoft Windows and Linux. Note that this document will not provide details on other operating systems that are less common or on non-PC platforms, such as Palm OS and other proprietary operating systems for limited functionality devices.

	Benefits			
Technology	Key features	Implications for objectives	Feasibility	Indicative TCO*
Microsoft	• Ability to run a wide variety of off-the-shelf productivity and specialized educational software • User friendly • Particularly suitable for developing ICT skills due to prevalence in society	• Depending on usage approach, facilitates all major educational objectives	• Mostly well-supported by local services industry (both procurement and support) • Least foreign to teachers who have had exposure to ICT previously	N/A
Linux	• Free/low cost** • Customizable (source code available for modification) • More secure, reliable and scalable • Teachers and students can use software at home without cost • Encourages innovation because of open and available source code	• Depending on usage approach, facilitates all major educational objectives	• Well supported in terms of procurement (can download for free) • Depending on country, support may be less accessible • High retraining cost if teachers already used to Windows platform	N/A

* TCO comparison difficult due to availability of several programs by Microsoft that offer Windows (initial purchase and/or upgrades) under certain contracts for substantially reduced prices. Upgrades are essentially free with Linux
** Linux is free. However, users can choose too purchase Linux packages from companies (e.g., RedHat) that come with documentation and support

Figure 16- Comparison of Operating Systems

No other debate seems to stir up raw emotions in the ICT in Education arena such as that of Free and Open Source (FOSS) vs. Proprietary and specifically Microsoft software. The issue is whether FOSS is cheaper and offers more benefits to the community than proprietary software. Few studies exist and are almost all inconclusive. There is no consensus on this issue as far as application in schools is concerned. A recent Bridges[11] publication concludes that the focus and debate should shift to how the software and applications can best be put to use.

In fact, a preliminary analysis reveals that both operating systems will facilitate all major educational objectives depending on the usage approach. Windows in all its varieties, the Microsoft operating system, supports more off-the-shelf applications, is more user-friendly and prevalent and therefore more suited for skills training as it is likely to be most encountered outside the school. Linux has become a catch all phrase for most FOSS operating systems and is a derivative of Unix. Linux comes in many "flavors," each promoted by a different organization. The more common Linux flavors are Redhat and Suse. Linux is freely available (although there exists commercial or enterprise variants where users are expected to pay for support and upgrades), easily customizable as the source code is freely available for modification, more secure, reliable and scalable, can be used at home by teachers and students without incurring extra costs and encourages innovation because of open and available source code.

Windows is usually more likely to be widely supported by local service industry and be least foreign to teachers who have had previous exposure to ICTs. Linux, is increasingly becoming available and supported by local service industry although this may be less so in some countries. It is also believed that adopting Linux may increase re-training costs where teachers have previously been exposed to Windows.

We hope to shed more light on the realities of FOSS and Proprietary software in Part 2 of this report.

4.4 To-school connectivity

Discussions of to-school connectivity usually revolve around providing access to the Internet. However, there are other methods of connecting the school to the outside world usually termed "offline methods" to differentiate them from "online" or Internet connections. Offline solutions include use of portable storage media such as diskettes and broadcast systems such as TV and radio. The various methods are compared in Figure 17 below.

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11 {add reference - Bridges}

Technology	Benefits: Key features	Benefits: Implications for objectives	Feasibility	Indicative TCO*
Broadband • Wireline (xDSL, cable) • VSAT • Wimax/FWA/ Wifi • 3G	• Fast connection speed (256k or above) • Faster connections (e.g., 1.5Mbps or above) ideal for bandwidth intensive applications such as multimedia or streaming video applications • 2-way connection (except for certain one-way VSAT) • Facilitates real-time access to content located on central server (easily updated) • Wireless technologies address last-mile issue (VSAT, Wimax/FWA/Wifi, 3G) at lower cost than laying wires	• Depending on usage approach and functionality, helps facilitate all major educational objectives	• Coverage highly dependent on country's telecom infrastructure – wireline coverage likely to be low in rural or remote areas in developing countries • VSAT covers most of the world but expensive • Wimax/FWA/Wifi and 3G yet to take off in most countries	$$
Narrowband • Dialup • Cellular • ISDN	• Slow connection speed (256k or below) allows download of content but ineffective real-time access to internet • 2-way connection • Cellular addresses last-mile issue	• Depending on usage approach and functionality, helps facilitate all major educational objectives	• Coverage highly dependent on country's telecom infrastructure • Though typically lower cost than broadband connection, cost could become prohibitively high if metered usage is high (especially cellular)	$
Portable storage media • CD/DVD/VCD • VHS • USB storage device (pen drive)	• Allows non-time sensitive content or data to be communicated and/or distributed • Does not facilitate applications that require real-time communication to another device or source • 2-way connection	• Depending on usage approach and functionality, helps facilitate all major educational objectives except for access to information, although at a much lower effectiveness than broadband or narrowband connection	• Can be used with any device that has the appropriate peripheral (CD/DVD/VCD, VHS or USB port) • Depends on local mail service reliability and effeciency	$
Broadcast • TV • Radio • Satellite	• Receive scheduled/pre-recorded broadcast • One-way connection only, therefore only suitable for subjects that do not require 2-way (e.g., languages)	• Helps improve conceptual understanding	• Can be used anywhere that receives broadcast signal • Dependent on suitable content being broadcasted at convenient times	$**

* TCO indicative since it is not in the context of a complete technology platform, it varies across countries, and the data used in this assessment are preliminary and in some cases incomplete. $ = <US$750, $$ = <US$1500, $$$ = <US$2500, $$$$ = >US$2500
** Does not take into account cost of broadcasting, which is incurred at the national or regional level (if applicable)

Figure 17- Comparison of connectivity options

The choice of any connectivity method is dictated by 5 key factors:

- Availability of technology- for example, Digital Subscriber Line (DSL), Integrated Services Digital Network (ISDN) and Cable Modem not are widely available outside major cities and depend on the quality of the local telecommunications infrastructure.
- Cost- generally VSAT costs much more than any of the other technologies, while the broadcast systems are most cost effective for simultaneous coverage of many schools (broadcast refers to one-to-many sites transmission).
- Bandwidth required- Broadband solutions offer much more bandwidth (or rate of information flow) than narrowband solutions and are therefore more suited for downloading multimedia content from the Internet.

- Interactivity- Only “online” or Internet connections (broadband and narrowband) offer interactivity or two-way connections in real (synchronous) or delayed (asynchronous) time.

Generally, the interactive or two-way connections help facilitate all major educational objectives depending on usage. Narrowband solutions, though typically lower cost than broadband connections, can be very expensive if cost is based on metered usage and usage is high. Portable media storage and broadcast systems are generally ideal in areas where telecommunications infrastructure is non existent, very poor, unreliable or extremely expensive. Portable media helps facilitate all major objectives except access to information while broadcast systems are best for improving conceptual understanding. The former also requires an appropriate peripheral device and its usage depends on local mail service reliability and efficiency. The latter can be used anywhere that receives a broadcast signal and is also dependant on suitable content being broadcast at convenient times.

4.5 In-school connectivity

In-school connectivity usually comprises of a combination of:

- ***Computer labs***- usually a single room housing a number of computers connected to each other. Physical connection can be achieved by:
    - Wireline solutions (typically Ethernet Category 5 cable)
    - Wireless solutions (typically Wireless Fidelity or WIFI)
- ***School widenetworks***- networks connecting computer labs, computers in classrooms and offices. Physical connections here can be achieved by:
    - Wireline solutions, usually Ethernet Cat 5 cable and Fiber optic
    - WIFI or WIMAX, or microwaves
    - Mix of wired and wireless

A kind of limited in-school connectivity can also be achieved with portable storage media.

The various methods of achieving an in-school network are summarized below in Figure 18.

Generally, the in-school connection, regardless of type, facilitates sharing of information amongst users. It also generally helps facilitate all major educational objectives depending on usage approach and functionality except for short range wireless which only facilitates collaborative work and portable media which can only support access to information at a much lower effectiveness than other faster and real-time options. Generally, wireline solutions are the most expensive but provide the highest bandwidth (usually at least 10 Mbps) closely followed by wireless solutions in cost and bandwidth capacity. Both wireline and wireless are usually well supported by local service industry. Portable storage media require peripheral devices. Short range wireless is only really useful at very short distances and is only useful for connecting peripheral and other devices such as keyboards and mice to computers.

	Benefits			
Technology	Key features	Implications for objectives	Feasibility	Indicative TCO*
Wifi (802.11)	• High bandwidth (11 Mbps for 802.11b and 54 Mbps for 802.11g) • Theoretical range of 50-100m, but depends on building infrastructure • Flexible access anywhere • Wifi potentially lower cost and faster rollout than wireline infrastructure • Can be used to set up temporary networks (e.g., for special occasions like parents day) • Works well in combination with to-school connectivity	• Depending on usage approach and functionality, helps facilitate all major educational objectives	• Moderately well-supported by local services industry (both procurement and support) in developing countries • May not be appropriate for teachers with low ICT skills	$-$$
Short range wireless (e.g., infra-red, bluetooth)	• Facilitates sharing of information amongst users with wireless capability built-in (e.g., transferring files between laptops) • Could be used in conjunction with to-school connectivity but less effective and at much lower bandwidth (e.g., PDA with bluetooth connect with cellular)	• Facilitates collaborative work	• Only useful for short-range communication (e.g., bluetooth has 10m range) • May require line-of-sight (e.g., infra-red)	$
Wireline	• Very high bandwidth (10/100/1000 Mbps) • Long range (100m) • More secured than wireless (especially if wireless security not configured properly) • Works well in combination with to-school connectivity	• Depending on usage approach and functionality, helps facilitate all major educational objectives	• Moderately well-supported by local services industry (both procurement and support) in developing countries • Rollout could be costly and more time consuming than wireless option	$$-$$$
Portable storage media (e.g., CD/DVD/VCD, USB storage device)	• Facilitates sharing of information amongst users with the appropriate peripheral (CD/DVD/VCD drive, USB port) • Does not work with to-school connectivity if real-time access is desired	• Depending on usage approach and functionality, helps facilitate all major educational objectives except access to information, although at a much lower effectiveness than other fast and real-time options	• Can be used with any device that has the appropriate peripheral (CD/DVD/VCD, VHS or USB port)	$

* TCO indicative since it is not in the context of a complete technology platform, it varies across countries, and the data used in this assessment are preliminary and in some cases incomplete. $ = <US$750, $$ = <US$1500, $$$ = <US$2500, $$$$ = >US$2500

Figure 18- In school networks

4.6 Power Backup and Alternate Power Sources

The majority of schools in many parts of the developing world still lack grid electricity and those that are connected to the electricity grid often experience frequent and long electricity outages. This lack or unreliability of grid electricity is a serious impediment to the deployment of ICTs in Education and indeed, in any other sector in these less developed countries. Any plan to introduce and deploy ICTs in Education on a regional or national scale in these countries must include a careful consideration of alternative power sources or power backup sources. An assessment of the major alternate power and power backup sources is presented in Figure 19 below.

Technology	Benefits: Key features	Benefits: Implications for ICT Deployment	Feasibility	Indicative TCO*
Universal Power Supply (UPS)	▪ Can be centralized or decentralized with each device having own UPS ▪ No pollution- Clean and environmentally friendly ▪ Requires alternate power source for charging ▪ Limited backup duration, typically < 4 hrs ▪ Can be configured to automatically and cleanly shut down devices at end of backup period	▪ Centralized UPS systems require extensive wiring and specialized power sockets and plug for effectiveness ▪ Decentralized systems do not require any specialized wiring	▪ Central UPS systems expensive and not well supported (procurement and maintenance) ▪ Decentralized UPS systems can also be expensive if provided for every device ▪ Small UPS to protect server highly desirable and well supported by local vendors	$ (server only) $$$- $$$$ (Centralized)
Generator	▪ Can be configured for automatic start upon power loss ▪ Independent power supply, ideal for places with no grid at all ▪ Noisy and not environmentally friendly (smoke)	▪ Requires some specialized wiring for installation ▪ May require separate room with hardened foundation for housing	▪ Well supported by local industry ▪ High running costs because of fuel requirements ▪ Requires fuel stocking for remote areas	$$$$
Solar	▪ Clean and environmentally friendly ▪ Independent power supply, ideal for places with no grid at all ▪ Low running costs	▪ When used as backup supply, requires specialized wiring for installation	▪ Sometimes not well supported by local industry ▪ Very expensive to acquire and install ▪ Solar panels are vulnerable to theft	$$$$
Wind	▪ Clean and environmentally friendly ▪ Independent power supply, ideal for places with no grid at all ▪ Low running costs	▪ N/A	▪ Not supported by local industry in many developoing countries ▪ Very expensive to acquire ▪ Requires specialized installation skills	$$$$

* TCO indicative since it is not in the context of a complete technology platform, and the data used in this assessment are preliminary.
$ = <$1,000, $$ = <$5,000, $$$ = <$20,000, $$$$ = >$20,000

Figure 19- Comparison of power backup options

No matter which power source exists, it is important to try to acquire equipment that consumes as little electricity as possible (also called "green"). Even though it might cost more initially, it will save money over time.

4.7 Supporting Physical Infrastructure

ICTs do require supporting physical infrastructure to be in place before they can be deployed. The first and most obvious requirement should be a suitable room with the necessary security and electrical modifications. For countries with extremely high temperatures, it is also necessary to install air-conditioning systems in the room(s) that will house the ICTs. In particular, the computer lab deployment model poses particular challenges to schools simply because it requires a free room with significant security and electrical system modifications. For many schools in developing countries, there is seldom a free room and in some schools, no suitable building at all. For these schools, the introduction of ICTs and in particular a computer lab often requires the construction of "special" ICT room which can be costly. Educational planners should therefore consider the issue of available rooms for ICTs in the schools carefully when planning for the deployment of ICTs.

Physical infrastructure	Requirement	Implications for ICT deployment
Rooms •Renovate •Build	▪ Room (s) large enough to comfortably accommodate at least 15 access devices, server, projector screen, teacher/ technician work desk and students working on the devices ▪ Students using access devices in the computer lab must be at least 1 meter apart. ▪ Preference is renovation rather than build new rooms because of high cost of construction	▪ Depending on institution, renovations might be necessary. ▪ A few schools might require construction of new computer rooms
Air conditioning	▪ Recommended in regions where temperatures top 35 degrees Centigrade ▪ Ceiling fans recommended for all schools	▪ Computer labs will require installation of ceiling fans or air extractors or air-conditioning units
Security • Security grills •Guards	▪ Students must be secure when using ICTs especially after hours ▪ ICT systems must be secured against theft and vandalism ▪ Solar panels must be secured	▪ Rooms hosting ICTs will be outfitted with metallic grills on all windows and a metallic door installed ▪ Meshing in ceiling can be considered whenever possible ▪ Web cams attached to server can be considered ▪ Solar panels could be welded onto metal frame where used
Electrical system modifications	▪ Every 3-4 computers connected to a 20 A dedicated circuit breaker and dedicated branch wiring to the socket point(s) ▪ Lighting should be on own separate dedicated circuit breaker ▪ Additional circuit breakers sized to take other loads e.g. for copiers, scanners, printers, Interactive White Boards, Projectors etc ▪ Cater for future expansion on the Circuit Breaker Board ▪ Wiring and installation must meet existing national electrical standards or codes	▪ Most schools will require modification of Circuit Breaker Boards and introduction of new plug points
Furniture •Chairs •Tables	▪ Tables should accommodate access devices with space between learners for two chairs per workstation (to be determined by actual chair size) ▪ Chairs should be provided for all students	▪ Re-use broken tables to hold access devices ▪ Schools will require additional tables and chairs

Figure 20- Physical Infrastructure requirements

The deployment of ICT usually also calls for the purchase of new, and sometimes, specialized furniture. This should also be taken into account. In Namibia, Schoolnet Namibia has pioneered a cost effective model for making computer desks out of old and broken furniture. SNN collects old and broken desks and simply replaces the worktops with cheap blocks of wood. This prolongs the life of the broken desks and reduces the costs of acquiring new furniture for ICTs.

4.8 Content and Applications

Content and applications can be broadly categorized into seven categories presented below:

1. Operating system and related tools
    - Computer operating system use
    - Document/ File Manager and tools to search for stored data
    - Document exchange software
    - Compression software

2. Basic applications, comprising of:
    - Word Processor
    - Spreadsheet
    - Presentation software
    - Web browser
    - Email Client
    - Internet Relay Chat, I Seek You (ICQ) or equivalent chat tool
    - Drawing tool for picture creation, viewing and editing

3. Multimedia applications (creation, editing, publishing, playback), comprising of:
    - Audio
    - Video
    - Flash and Shockwave
    - Other Multimedia development applications

4. Electronic content, comprising of:
    - E-Curriculum content specifically developed according to local curricula

5. Content development tools, comprising of:
    - Database software

- o Web development software
- o Application development/ programming software

6. School Management software, comprising of:
   - o Education Management Information Systems (EMIS):
   - o Financial Management System
   - o Human Resource Management System
   - o Time tabling software
   - o Library Management software
   - o Content Management Systems (CMS)
   - o Learning Management Systems (LMS)
   - o Document Management Systems (DMS)
   - o Virtual Learning Environments (VLE)

7. Server and network management software, comprising of:
   - o Network management applications, i.e. user and access right management
   - o Backup and Archiving
   - o Antivirus / Antispam
   - o Firewall and security applications
   - o Web filtering software and proxy (also to filter access to unwanted content like pornography, etc)
   - o Web server
   - o Email server

Content and Applications are operating system specific. Examples of both proprietary and Open source/freeware or shareware options are included in the following table.

Application Type	Proprietary or commercial	Open Source, freeware or shareware
Operating systems and related tools		
OS for desktops	Windows, Macintosh OS	Linux (several distributions)
OS for servers	Windows server, Unix	Linux (several

Application Type	Proprietary or commercial	Open Source, freeware or shareware
	(several brands)	distributions)
Compression software	WinZip	Zip, tar, arK
Basic Applications		
Word Processor	Microsoft Word 2002/XP	Openoffice 2 Writer
Spreadsheet	Microsoft Excel 2002/XP	Openoffice 2 Calc
Presentation software	Microsoft PowerPoint 2002/XP	Openoffice 2 Impress
Web Browser		Microsoft Internet Explorer, Firefox, Opera
Email Client	Microsoft Outlook, Lotus Notes	Web browser based, Pegasus, Eudora, MS Outlook Express
Document exchange	Word	PDF- Adobe Acrobat Reader 7. , Kpdf, Kghostview
Graphics application	Photoshop	Openoffice 2 Draw
IRC, ICQ or equivalent	IRC	IRC
Picture creation, viewing and editing	Paint	Kpaint, GIMP
Multimedia applications		
Audio	Microsoft Windows Media Player 9.0	Mplayer, noatun
Video	Microsoft Windows Media Player 9.0	Mplayer, kmplayer, kaffeine
Flash and Shockwave		

Application Type	Proprietary or commercial	Open Source, freeware or shareware
Multimedia development applications		
Content development tools		
Database software	Client- Access Server- SQL Server	Client- Mysql Sever- Mysql
Web development software	Front page- with ASP support, Dreamweaver	Quanta+, NVU
Application development	C++ Java ASP	C++ Java PHP

The two tables below present the correlation between the types of software needed and the educational objectives and also between the objectives and the training for students, teachers and admin personnel.

CORRELATION BETWEEN APPLICATION AND CONTENT AND EDUCATIONAL OBJECTIVE

Objectives	Basic Software	Specialist software	Educational Applications	Content	Acquisition Approach: Once off license	Acquisition Approach: Annual Subscription	Acquisition Approach: Build or Develop
	Productivity Software plus Internet/ Emai	Programming software, accounting, EMIS, multimedia dev tools	Distance learning, simulations, virtual labs, assessment	E-books, lesson plans, teaching guides, multimedia content	✓		
Enhancing school productivity	●	◕ (Accounting)	○	○	✓	✓ (EMIS)	
Enhancing data flow for policymaking	●	◕ (EMIS)	○	○	✓	✓ (DE)	✓
Developing teacher skills and knowledge	●	○	◕ (DE)	◕	✓		
Assisting effective lesson planning	●	○	○	●	✓		
Accessing information (by students)	●	○	○	◑	✓		✓
Improving conceptual understanding	○	◔ (MM dev tools)	◑	◕	✓		
Developing constructivist skills	◕	◑	◕	◕	✓		
Facilitating collaboration	●	◑ (MM devtools)	◔	◔	✓		
Providing testing and feedback	◑	○	●	○		✓	
Developing basic ICT skills	●	○	○	◔	✓		
Developing advanced ICT skills	●	● (MM devtools + programming)	○	◔	✓		

Must Haves: ● =Critical (Objective not achievable without); ◕ = essential (Central to achieving Objective)

◑ = important (Great benefit to achieving objective)

◔ = Useful but not important (Can support achieving objective)

○ = not necessary (Doesn't impact much on objective)

Figure 21- Applications and educational objectives

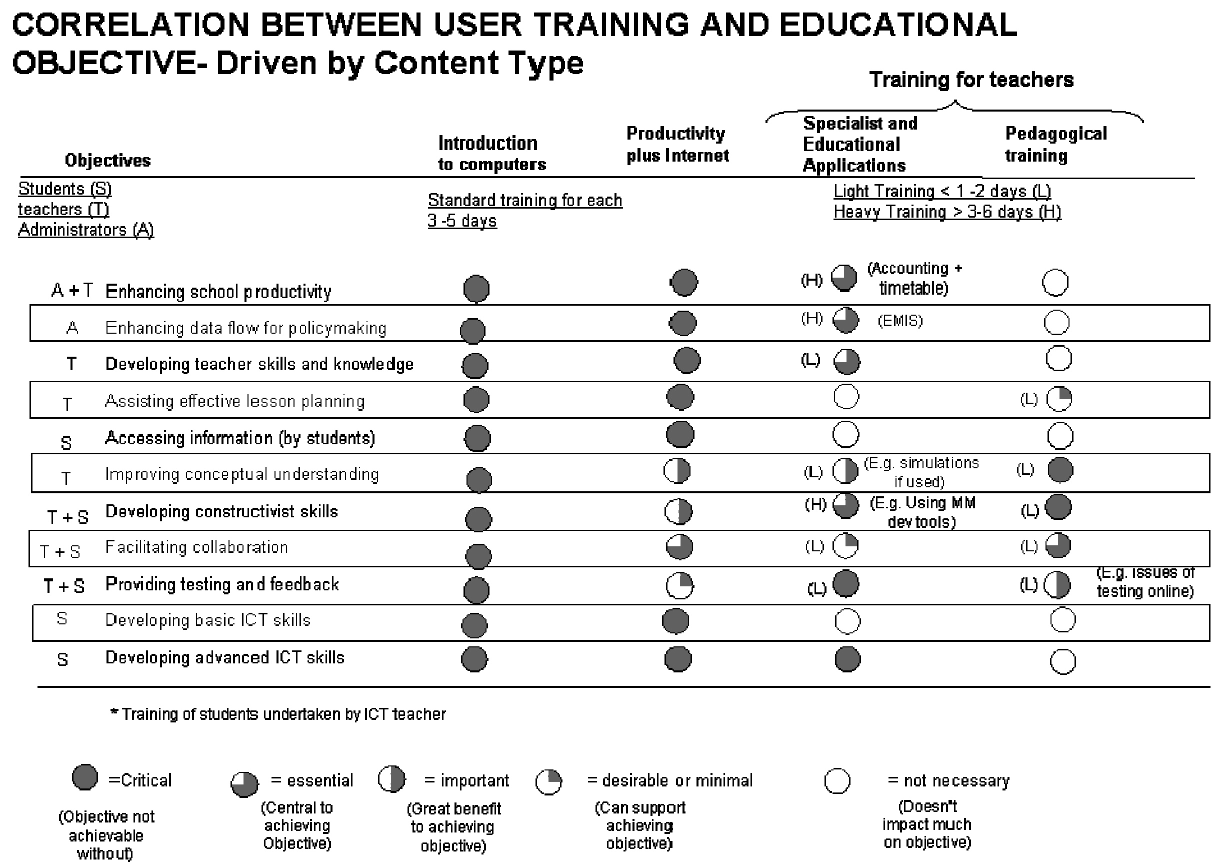

Figure 22- Training by content type

4.9 Maintenance and Technical Support

Once the solution is deployed and in use you will need to provide some type of maintenance and support services.

Maintenance- actions taken on equipment and systems to fix working problems e.g. repair, upgrades, diagnostic. Preventive maintenance is the processes done before a problem occurs in order to prevent it and extend life-span., <u>(Usually lumped under technical support)</u>

Technical Support- actions taken on behalf of users to keep them working or help them get more out of the IT systems e.g. help desk, initial training, FAQs

There are several options to deploy these services:

Front line (preventive maintenance, trouble shooting and training)

Model	Pros	Cons
User with help desk: school user has self-assisted resources and central help desk	Easier, simpler solution, can be used for many common problems	There is a limit to what the user can do on its own, and will certainly require another level of support Requires the development of documentation, guidelines, FAQ and some toolkits
Internal IT teacher trained to do maintenance	In house solution, always available	Teacher will need extra training and time (economic incentives?) There is a limit to what the teacher can do on his/her own Requires the development of documentation, guidelines, FAQ and some toolkits
Shared technician (shared among several schools in nearby area)	Fast answer to problems and good knowledge of each installation	Answer and solutions can take some hours or days Probably a fixed cost
Full time dedicated technician: only relevant if number of equipment is high	Immediate answer to problems	Higher fixed cost

Model	Pros	Cons

Repair

Model	Pros	Cons
External Annual Contract- 4 visits a year (quarterly), all repairs as needed, mainly preventive Could be with equipment supplier/ vendor Could be with third party	One fixed costs to solve almost everything	High Fixed cost
Case by case repairs	No fixed costs	Longer wait time Have to take machine to city where company is located
Contract for repairs only	No fixed costs	Individual repairs can cost some more

Conclusion

In this report we have presented several options that we hope can help schools in making better informed decisions regarding their investment in ICT tools and devices.

You can download the TCO tool (in Excel format) from **http://www.gesci.org/ict-infrastructure-connectivity-and-accessibility.html**, in order to simulate different investment schemes and their total cost over the years.

We suggest that you continue reading the TCO Manual, also available at GeSCIs website, in order to demonstrate the use of the framework and electronic tools.

Glossary

- **Bandwidth**: a measure of the capacity of a connection media to transport information. It is measured in bits per second.
- **Freeware**: software developed and distributed for free.
- **Internet**: The name given to the networked servers all over the world connected by the TCP/IP family of protocols.
- **Intranet**: a private network with restricted access, i.e. one created by the Ministry of Education for school access.
- **Open source**: In general the term refers to any program whose source code is made available for use or modification as users or other developers see fit. (Historically, the makers of proprietary software have generally not made source code available.) Open source software is usually developed as a public collaboration and made freely available.
- **Proprietary software**: or commercial software, is software where the buyer gets a license to USE a certain tool but never to modify it, as opposed to "Open surce"software.
- **Server**: a type of computer that instead of being used by persons is used to serve other computers with content, software or resources.
- **Shareware**: software developed and licensed for a small fee.
- **TCO** (Total Cost of Ownership): a financial analysis of all the costs involved in investing on a certain technology.
- **Thin client**: A low-cost, centrally-managed computer devoid of CD-ROM players, diskette drives, and expansion slots. Since the idea is to limit the capabilities of these computers to only essential applications, they tend to be purchased and remain "thin" in terms of the client applications they include.

- **VPN** (Virtual Private network): a secured connection among sites using an unsafe connection media like the Internet, creating a virtual private exchange of information.

Additional resources

- GeSCI TCO tools and Manuals: http://www.gesci.org/ict-infrastructure-connectivity-and-accessibility.html
- List of low cost devices for Education, developed by Infodev: http://infodev.org/en/Publication.107.html
- World Links for Development (https://www.world-links.org)

If you have any comments or suggestions please write to tco.tool@gesci.org