4 Technology for Quality Learning and Teaching

Understanding the Issues

It would not be an exaggeration to argue that most teaching and learning aids are largely extensions and enhancements of the basic face-to-face method of education. In a conventional school setting, these aids promote greater effectiveness and efficiency within the finite real-time encounters of face-to-face learning situations. How can one teach the history of a foreign country in two 40-minute periods, or complex mathematical theorems in three lessons? The answer, if we are talking about effective teaching and learning, has to include the use of aids. This concept of 'aids' should remind us that they are in a sense supplementary to the fundamental process of teaching and learning, which involves a process of engaging minds and opening up avenues for exploration and discovery. This process generally involves such acts as providing information; explaining concepts; illustrating principles; giving examples; outlining procedures; demonstrating processes; advancing arguments; highlighting points; asking questions; giving feedback; exchanging ideas; and performing tasks. Fundamental and most central to this process is talking and communicating through language. It is this that is augmented in various ways by the teaching and learning aids used in education. Therefore, even the best aids cannot be a substitute for a good teacher. Human communication is central to the process of learning. To the extent that technology can facilitate and enhance such communication it has the potential to improve pedagogy and the quality of education.

This is not to argue for a teacher-centred view of education, nor to deny that people can, and do, learn on their own. The intention is simply to highlight the important role of the teacher at a time when we are too easily tempted to believe that advances in technology are eroding the importance of the teacher's role in education. The reality is that the teacher's role is changing significantly, but it remains fundamental to what we call education. The explosion of knowledge and information over the past few decades has meant that teachers can no longer be viewed as the source of all that the learner needs to know. However, mere availability of knowledge and information should not be confused with the process of education. It is essential that learners are initiated into the ways of understanding and making use of the available knowledge and information. This is what lies at the heart of good teaching. On this basis it can be argued that the greatest success of any teacher is to help create an autonomous learner – one who can go on learning alone long after the teacher has 'withdrawn' from the process.

The collection of books in any library does not constitute knowledge as such. It is only with the guidance of the teacher and the development of certain skills by the learner, that the collection can become a source of information and knowledge to be mined by the learner. Similarly, the vast amount of information on the internet, or the world-wide web, does not in itself constitute knowledge. It is only to the extent that learners know what to do with such information that we can begin to talk about it as knowledge, as distinct from mere information. This entails much more than simply knowing how to access information on the web. It is important to reiterate that learning is primarily the responsibility of the learner, and that the teacher's role is that of 'tour guide' on the magical exploration of the world of knowledge. It is equally important to remind ourselves that without this kind of guidance provided by the teacher, most learners would flounder on the vast and infinitely complex web of information and knowledge that is available in the modern world.

So what are the key professional attributes that enable teachers to perform the crucial role for learning and education to take place? In a word, much of it is about good pedagogy. Parents, peers and many other people facilitate learning by various means. What is special about the teaching profession is that it makes the most intensive and systematic use of pedagogy to promote effective and efficient learning as part of the process of education. Teachers are expected to be experts at promoting and facilitating learning. In order to do so they need a comprehensive bank of pedagogical skills and teaching aids. Many would argue that in addition they need certain personal qualities that enable them to engage learners in the process that results in education. For instance, it is vital for teachers to be able to attract the attention of learners, and to hold their interest on a sustained basis, as well as to win their trust and respect. The personal qualities that enable teachers to achieve this are very important, and it is not surprising that some people argue that 'good teachers are born not trained'. Be that as it may, the essence of professionalism is that good teachers do not simply provide learners with information or guide the learning process. They inspire learners and help to bring out hidden talents and latent abilities that would otherwise lie dormant. They help to shape perceptions, cultivate attitudes and values, and change behaviours and habits. In sometimes quite remarkable and fundamental ways, good teachers change the lives of many of the learners in their charge! As the saying goes, 'no one forgets a good teacher'.

It is a truism that, given enough time and resources, anyone can be a teacher. This has more to do with the fact that learning comes naturally to human beings (often against great odds), and less to do with any innate teaching abilities we may all possess. It can be argued that in many developing countries the teaching profession has suffered from this phenomenon through which learning is an integral part of human nature. It is one of the few major professions in which governments have easily made do with a high proportion of unqualified and untrained practitioners. It is also a profession that many people have all too readily treated as a 'holding area' in which they can be gainfully employed while trying to qualify for another profession. These unfortunate trends have often resulted in much bad teaching being endured within the education systems of some Commonwealth countries. Policies and strategies relating to the use of technology for improving pedagogy and quality in education should not only support the good teachers, but also help to change bad teaching. This implies an urgent need for continuous professional self-development on the part of all teachers.

So far this brief introduction has explored the nature of good pedagogy; outlined the place of teaching and learning aids in the educational process; highlighted the central role of the teacher, and affirmed the ultimate responsibility of the learner in the process that results in education. A final issue which needs to be touched on, is that of the organisational practice that results in education taking place in formal institutions called schools. It needs to be emphasised that education can and does take place outside such institutions. So what attributes of the school are critical for good pedagogy and quality education, and how can technology enable us to strengthen these attributes within the school as well as to reproduce them in other educational settings outside the school? Conversely, we need to take full cognisance of those attributes of schools which inhibit or impede good pedagogy and good quality in education.

Schools and other educational institutions are different from information centres or learning centres. They do not simply make information available, or provide a space within which learning can take place. As Malcolm Skilbeck expressed it in Botswana, 'schools are places to be'. That is why we talk of schools as having a culture and an ethos, as well as a mission and a curriculum. Over the years schools have been credited, among other things, with a socialising function as well as with the economic role of preparing learners for the world of work. It can be argued, of course, that other social institutions, such as religious bodies and training centres, also perform some of the functions attributed to schools. What is unique about schools is the scale and intensity of the manner in which they perform these functions.

Given an intake of learners, often from diverse backgrounds and of different abilities, schools create a community within which these learners can be properly prepared for a multiplicity of roles in society. It is in this community that perceptions are shaped; principles learnt; values acquired, and relationships formed. Here the emotions are mastered; characters built; behaviour practised, and identities created. Also, and most importantly, it is in this community that learners acquire the life skills that will make them creative and productive members of society. These skills range from basic literacy and numeracy, through mastery of the wide range of forms of human knowledge that are in the curriculum, to pre-vocational, practical and extra-curricula skills. As a community, schools also provide society with what is still the most practical means of transmitting its most cherished values and preferred way of life to the next generation. Because learners constitute a kind of captive clientele, schools can and do provide a very intense and sustained initiation into the norms and values of the society.

However, the organisational principles of the formal school are not always conducive to good pedagogy and quality education. Grouping learners into grades, based ostensibly on age, and expecting each cohort to progress through the system at the same pace can sometimes be counter-productive. Learners of different abilities and from different backgrounds may need to be taught in different ways, and will progress at a different pace from each other. Most teaching targets the average learner, and does not do justice to the slow learner or the fast learner. Similarly, the non-negotiable structure and rather inflexible sequencing of a prescribed curriculum means that most learners cannot learn what they want, when they want, and therefore cannot take full responsibility for their own learning. The constraint of time and place involved in school attendance also means that learners often have to make tough decisions about investment of their time in the learning process, in preference to other activities which may be more critical at that point in their lives. Full time schooling shuts out almost everything else! In a sense also, the school is often separated from the community and the wider society, so that there is a kind of isolation from reality that hinders experiential learning. These weaknesses are often tackled successfully in less formal educational settings. It is also the case that progressive schools and good teachers tend to have their own battery of organisational practices and pedagogical skills for overcoming these difficulties.

The issue is that while many functions, including teaching and learning, can be performed outside the formal school setting, we must not lose sight of the totality of what schools offer in terms of being a 'one-stop' socialising and life-skills development community. At the same time, schools tend to pay a high price for this function in terms of rigid structures, inflexible learning sequences and constraints of time and place for learning. There is much value in a holistic, 'one-stop' community for education, yet there is also much value in the diversity and flexibility that is possible outside the formal school setting. In what ways can technology help us to choose wisely and hold things together as we seek to improve the quality of education within our schools as well as in alternative settings outside schools?

The Fundamentals of Quality in Education

Quality in education is characterised by the three important dimensions of relevance, effectiveness and efficiency. The dimension of relevance highlights the fact that, in practice, quality is not a neutral or absolute concept. It involves valuing, and this is something that different people or communities do differently. Quality is therefore always perceived in relation to something that is valued and desirable in a given context. In this sense, relevance has to be seen not only as pertaining to what is familiar, or what fits in a given context, but also as what relates to the perceived and latent needs of a community of learners, as well as their own hopes and aspirations. All of this helps to shape the curriculum and determine how it is interpreted in various parts of the education system. In this regard quality starts with good curriculum design that takes into account the following components of relevance:

- appropriate forms of knowledge in terms of subjects or disciplines;
- national priorities, goals and objectives that relate to education;
- international issues and concerns that have implications for education;
- local priorities and concerns that relate to education;
- background realities and defining characteristics of the learners; and
- hopes and aspirations for the future (learners, communities and nation).

But even with the best curriculum, the quality of education depends ultimately on how teachers handle what is prescribed for learners. Teachers are responsible for making a curriculum come alive for learners; for helping them to relate to prescribed learning experiences in ways that will useful for them, and for inspiring them with a vision of what they can become on the basis of the curriculum. To carry out this important function teachers need to make maximum use of teaching and learning aids and various forms of technology. The key issue, therefore, is how technology can help us to improve the relevance of education in different settings and localities, when we are dealing with a prescribed curriculum that is often national rather than local.

Effectiveness is about achieving the goals and objectives prescribed in the curriculum, as well as those set for the school itself. This is where good pedagogy is most important, and where we need to be most clear about learning objectives. What is usually advocated is that these objectives should be stated in such a way that we can measure the extent to which they have been achieved at the end of a certain period of time. We rely heavily on tests and examinations to measure learners' performance, and this in turn tells us something about how far the objectives have been achieved at the end of the prescribed period. The important issue here is how to use technology to improve learners' performance, and hence the effectiveness of the educational process. Given what we currently know about how people learn, how best can we use the kind of technologies that we have in order to enhance the learning process? It is likely that we should include greater provision for self-learning; improved access to information and knowledge sources, and more teaching and learning aids in the classroom. All of this implies using technology more intensively to enhance the role of the teacher as the key facilitator of the educational process, while strengthening the role of the learner as the person with central responsibility for learning achievement.

Efficiency is about optimum use of resources to achieve the goals and objectives that are prescribed in a relevant curriculum. It is about cost-effectiveness and value for money, but it should not be seen in purely monetary terms. Often the key question is whether the available resources could be used differently to achieve the same goals and objectives. If less resources are used to achieve these goals, then there are savings in the use of resources. If the same level of resources is used to yield greater benefits, then there are gains in achievement. In both cases there is an increase in efficiency in the educational process. The resources in question include time and opportunity, as well as the usual human, physical and material resources in schools. When learners take seven years to complete a five-year course there is wastage which amounts to inefficiency. When teachers spend a good part of teaching time copying notes from a textbook on to the blackboard, for students to copy into their exercise books, this is a waste of time and opportunity which results in inefficiency.

Pedagogy in Practice

Learning is essentially about acquiring tools for living in the broadest possible sense. It is not simply about passing examinations, or taking in an undifferentiated deluge of information, or even acquiring a set of marketable skills. In the educational context, learning implies knowledge and this is much more than mere information. This is why we are normally critical of what is known as 'rote learning' or memorisation without understanding. The process of education entails promoting learning as the key with which individuals can have access to the extensive range of tools for living accumulated over the centuries and now enshrined in the various forms of human knowledge or disciplines available to us. The main challenge for good pedagogy is how to promote relevant, effective and efficient learning in the face of an ever-expanding range of human knowledge. Technology certainly has a major role to play in facilitating good pedagogy that can rise to this challenge.

Another important challenge for good pedagogy is how to ensure that learners can relate the achievements of schooling to the real world in which they live and function. One of the great mental tricks in playing the 'knowledge game' is to break up reality into various disciplines which then take on a life of their own as tools for exploring and creating knowledge as well as ways of understanding and mastering our world. This trick has enabled us over many centuries to become very effective and efficient in the business of learning as well as in making new knowledge and reshaping our world. On the one hand good pedagogy needs to exploit the rigour and depth of the various disciplines to promote effective and efficient learning. On the other hand, it is important that learners develop the ability to draw on and integrate aspects of these disciplines, in order to create a more holistic tool for understanding and acting on reality at different times and for different purposes. This is often facilitated by the creation of inter-disciplinary subject areas and integrated project work for learners.

Against the background of these and similar challenges, various categories of teaching styles have been used over the years to promote learning in the conventional education system. Technology can play a major role in improving pedagogy within all of these categories, but we need to make sound choices about what is best in different circumstances. In conventional schools, teaching styles are premised on assumptions of a cohort of more or less homogenous learners (similar age and ability) in the same grade, and progressing at the same pace through the system. Normally, this grouping of learners is dealt with on the basis of one teacher in charge for a given period of time, during which the business of teaching and learning takes place. There are usually several such encounters with different teachers in the course of a school day, and these periods of teaching and learning have come to represent what we regard as the rhythm of schooling. What teachers do individually and collectively during these periods is what defines the predominant teaching style in a school. In broad terms it is possible to categorise teaching styles as either teacher-centred or learner-centred. In practice, most teaching styles involve some combination of both approaches. The different styles of teaching are summarised in Table 4.1.

Table 4.1 Teaching Styles and the Use of Technology

Teaching style	*Main pedagogical characteristics and implications for the use of technology*
Teacher-centred approach	Focus is on the teacher as the source of knowledge. Teacher tends to be active while learners are expected to receive the knowledge being dispensed rather passively. The teacher talks; the learners listen. The teacher acts; the learners watch. Convenient for large class sizes. *Wide range of technologies can be used to aid the teacher's presentation and performance. Handouts, overhead projector (OHP) slides, models, etc. can all be used to capture and retain the learners' attention.*
Learner-centred approach	Emphasis is on learner as knowledge-seeker, with teacher as facilitator and guide. Learners tend to be active. They talk and do things in the process of learning. Teachers design and manage the setting as well as the process for learning. Difficult with large class sizes. *Technology can be used extensively to help learners make sense of the tasks assigned and learn what is required. However, there is usually a need for multiple units of the technology which all the learners need to use. Work sheets, models, equipment, etc., all need to be available to learners on an individual basis or in small groups.*
Combination of the two approaches	Attempts to strike a balance between the teacher as the main source of knowledge, and the learner as an active seeker of knowledge. In some matters the teacher dispenses knowledge and the learner has to take things on trust. At other times the teacher simply creates the conditions for the learner to explore and discover knowledge. At its best is highly interactive, with the focus shifting alternately from teacher to learners at different points in a lesson. *Technology can be used to aid the teacher's presentation as well as to assist learners in their exploration.*

Technology as an Aid to Teaching and Learning

The technology that can best serve as an aid to teaching and learning depends very much on the context. The latest or most sophisticated technology is not necessarily the most appropriate, even if it can be afforded. New technologies tend to have new requirements that determine their use – training, infrastructure and maintenance, for example. Using a new technology often implies much more than simply purchasing the technology.

Most old technologies, however, have a value and importance that is basic and fundamental to good pedagogy. We need to be careful about trivialising a technology simply because it has been around for a long time. It is instructive to consider the pedagogical uses of a random selection of technologies:

- *Chalk and board:* This technology has been unfairly caricatured in the literature. It is most closely associated with the so-called chalk-and-talk method of teaching, which has been heavily criticised due to its excessive use in poorer schools, and the tendency for untrained teachers to seek refuge in it as a safe pedagogy. In schools with very few resources it is not uncommon for untrained teachers to spend most of the teaching period copying notes from a textbook on to the board, for students to copy into their exercise books. This is the worst case scenario of wasted time and opportunity. However, the chalk and board technology can also be used in positive ways to improve the quality of teaching and learning. The mathematical problem set out on the board and solved step by step, with full participation of the whole class, can be a very rewarding learning experience. Similarly, the practice of getting learners to come up to the board and demonstrate something or write down an answer can be rewarding. Generally the chalk and board is used to note down key points as teacher and learners interact in the process of exploring a particular topic. Even when it is used to write down things for learners to copy, this can be a worthwhile exercise for young learners who need to develop the skills of 'copying from the board'. Some advantages of this technology are that it is long-lasting, requires little or no maintenance, and can be readily used with little training. It is cheap and uses chalk, which is an easily obtained resource. Small boards can be provided for young learners to use, especially when they are learning to write or need to practice a lot, but cannot afford to waste other resources like paper and pencil.
- *Overhead projector (OHP):* In one sense this technology is akin to a modern electronic chalk and board, but it is much more versatile. As with chalk and board, it enables the teacher to 'write and display' to the learners in real time. However, it also enables the teacher to display material prepared in advance. It is very versatile in terms of what can be displayed, ranging from notes and diagrams prepared by the teacher, to complex diagrams and photographs copied electronically on to the OHP transparency. Another advantage is that the same transparencies can be preserved and re-used as a teaching resource. The OHP allows the teacher to make use of an extensive range of illustrations and notes that are readily available. So the teacher can focus on the interactive business of teaching and learning, instead of spending time and effort writing and drawing on the board. On the downside, the OHP requires electricity supply and regular maintenance as well as a supply of special transparency sheets and special pens. These cost factors have to be weighed against the advantages of the OHP as a pedagogical tool.

- *Charts, maps, photographs, handouts, etc.:* These technologies have the main advantage of enabling the teacher to present 'ready-made' illustrations and aids, rather than do these in real time that should be devoted to the interactive process of learning and teaching. As pedagogical tools they promote more effective and efficient learning, in line with the notion that 'a picture speaks a thousand words'. These are technologies that lend themselves to all situations. Every teacher can prepare them in some form and make use of them in the classroom. They can also be mass produced in standard versions and supplied to schools.
- *Textbooks:* This is by far the most widely used technology in efforts to improve the quality of teaching and learning. Its importance and effectiveness have been emphasised by several studies showing that 'textbook availability' is the single most important variable that influences the quality of primary education in many developing countries. The best textbooks serve both as a guide to good teaching and an aid to self-learning. In terms of unit cost, textbooks must rank among the lowest-cost technologies, yet availability of textbooks continues to be a major issue and problem in most developing countries. This is a complex matter having to do with the publishing industry that deals with the development and production of textbooks. Many countries still lack a strong publishing industry and the business of developing and producing textbooks can be very expensive under in such conditions. Talk of one day getting computers and relevant software into every school should be treated with great caution in a world that has so far failed to get a simple textbook into the hands of every child in every classroom.
- *Programmed learning materials:* These technologies include workbooks that accompany some textbooks; self-learning texts as used in distance education, and the interactive electronic gadgets used for self-paced learning exercises. The main advantage of these technologies is that they help to promote learning with minimal involvement of a teacher. They also make it possible for learning to be centred on the level of ability and progress of the individual learner, rather than on some class average. Unfortunately, formal schools tend not to benefit fully from the advantages offered by these technologies, because they are used more in non-formal and distance-learning programmes than in regular schools.
- *Radio and audio recorders:* These technologies enable the teacher to bring other resource persons into the classroom through their voices. They can also be used for illustrative purposes, such as getting learners to hear musical scores or listen to forest noises. The use of recorders in particular enables the teacher to prepare good quality audio-learning aids that can then be used over and over again in the classroom whenever required. These technologies require electrical power, but even where the infrastructure is not available it is possible to use batteries and even human muscle power (wind-up radio). The issue of cost is still a problem for many countries, although unit costs of radios and audio recorders have decreased steadily over the years.
- *Television and video recorders:* These technologies represent the interactive and dynamic versions of charts, pictures, slides, etc. They also enable the teacher to bring other resource persons into the classroom through their images as well as their voices. Like the radio and audio recorder, they can be used for a wide variety of illustration, and they have the added advantage of engaging the eyes as well as the ears of learners.

- *Computers*: This currently ranks as the ultimate technology available for teaching and learning, especially when it is linked into the world-wide web. The potential versatility of this technology is enormous, and in time it could subsume most of the functions and advantages of other educational technologies. Computers offer teachers great possibilities in terms of the range of materials they can prepare for use in their classrooms, through word processing, spread sheets, graphics, etc. They can also be used to teach these very skills to learners as part of preparing them for the modern world where they are increasingly a part of life in the work-place. In the classroom, computers can be used in conjunction with special projectors to perform functions similar to the OHP and the slide projector. The best functions of programmed learning can be performed with the computer. Software packages exist for self-instruction in a wide range of areas. The computer is the tool *par excellence* for self-learning. Most importantly the computer can be used to access the world-wide web, where both teachers and learners can discover an infinite range of materials and pedagogical aids. The case study on Mathematics teaching (page 115) shows that there is much that teachers and learners can get directly from the web on various topics.

Overview of Current Practices

It is encouraging that most countries appreciate and value the key role of teachers, and focus on their training and professional development as a critical factor in policies and strategies for improving quality in education. However, we are still a long way from developing the combination of policies and strategies that will be best suited to preparing the most appropriate teachers for our schools in an era of globalisation. It is not clear that serious efforts are being made to build key technology elements into teacher training courses. In many countries there have been no major revisions to courses dealing with the use of technology for pedagogy and improvements in the quality of education. Indeed, in most countries, such changes as have been made in teacher training have been due to expediency in dealing with course restraints, rather than to sound pedagogical considerations.

The old model of preparing teachers through several years pre-service education and some practice teaching, or short period of pupillage, has proved to be very resilient in most countries. Where this has changed, invariably it has been due to constraints on time and cost, rather than for pedagogical reasons. For instance, when a country declares universal primary education over night, or decides to expand enrolment rapidly, there is a need to have trained teachers in place at a faster rate than can be delivered through the usual two- or three-year pre-service training programmes. Moreover, such a country may not be in a position to afford the short-term costs of rapidly expanding student enrolment at its teacher training colleges, necessary to produce the required numbers of trained teachers. In such situations, innovative 'crash training' programmes tend to come into being. Although these are often hailed as a significant breakthrough in teacher training strategies, they are seldom regarded as being on a par with conventional pre-service training. At best they enable countries to cope with the constraints involved in getting adequate numbers of trained teachers into the system. What is positive about these innovations is that they have helped to focus attention on issues of content and entry requirements for teacher training programmes, the duration of these programmes and how they should be structured over time to provide the most effective and efficient teacher training strategy for a country.

Unfortunately much of the current debate in most countries has tended to neglect the pedagogical considerations relating to content and duration. The focus has been on a search for 'quick fix' answers to questions of how to train more teachers, more cost effectively (code for cheaply), and in a much shorter time. This focus has seen a shift towards shorter pre-service education, less demanding intake requirements and more emphasis on training while teaching. The process has been facilitated by the use of distance education for teacher training, which helps to explain a current trend towards emphasising the advantages of using distance education in this way. While most of the advantages claimed in this regard cannot be disputed, it would be most unfortunate if the essential point of distance education came to be seen as training more teachers cheaply. The use of distance education in teacher training assumes that what should be the focus of such training is not the most problematic issue, and that there are no serious difficulties with how the training provided should be used. It is only when we begin to address these matters that current practice will begin to shift towards a more sensible basis for selecting and using appropriate technologies for improving pedagogy.

In this regard, it needs to be acknowledged that efforts are being made in many countries to shift from the old teacher-centred pedagogy to a more learner-centred approach. A wide range of in-service programmes are designed to train teachers in child-centred methodology and make them aware of the kinds of changes they need to introduce in the classroom. However, attendance at such training programmes is not a guarantee of change in the classroom. The persistence of large class sizes makes it difficult for teachers to put child-centred techniques into practice, and the shortage of teaching/learning technologies in most schools leaves teachers with very little choice other than to teach in a didactic manner. How does a teacher with a class of 80 or more pupils and no technology aid promote discovery learning, or help different children to learn at their own pace? These pedagogical considerations must also be addressed. The methods and techniques used in multi-grade teaching may well prove relevant in large classes in which there is a need for greater emphasis on self-paced learning, small-group work and the discovery approach. It will also be necessary to have a reasonable complement of technology that would make multi-grade techniques feasible. In general, it may be time to shift from the economics of course content, structure, duration and intake qualification for teacher training, towards the pedagogy of how to help real teachers bring about real change in real classrooms!

Addressing the Challenges

Learning how to learn is ultimately the greatest challenge facing education in the age of globalisation. There continues to be an exponential increase in the volume and complexity of what we need to learn in order to function in the modern world. However, human beings are naturally equipped to cope with this rapid expansion in knowledge and information through their innate mental ability to select, structure and organise information and knowledge in multifarious ways, to deal with every specific situation. Human beings have been very successful at augmenting, extending and improving this natural ability to cope with information and knowledge.

We have long used technology to reinforce and boost our capacity to make abstract and symbolic representations of our world, as well as our ability to process rapidly and manipulate the resulting concepts, principles and rules in infinite ways. We have therefore been able to use technology to create new realities and new tools, not only for understanding our world but also for acting on it and re-creating it in new ways. All these possibilities are potentially available to anyone who has mastered the business of learning how to learn. It is clear that technology can help to facilitate this process.

Given the continuing expansion in knowledge and information, and the proliferation of possible sources, the process of education can no longer be confined to mastering a finite selection of prescribed content. Increasingly it has to be about mastering the business of learning how to learn, which is the passport to the wealth of information and knowledge available in the modern world. It also has to be about what is most relevant to learners, rather than what is prescribed by others. How can we bring about the major shift in focus and the change in pedagogy and curriculum that are necessary to achieve this mastery of learning how to learn what we need to learn? In what ways can technology play a role in this area that is so important for quality education?

Training teachers and providing for their continued professional development is the second most important challenge facing education systems in most Commonwealth countries. For many of these countries the task is nothing short of rediscovering the professionalism that should characterise teaching. In this regard the most important point to be acknowledged is that pedagogical expertise, rather than knowledge of an academic discipline, is at the heart of teaching as a profession. A good teacher is not one who knows everything in a discipline, but one who knows *where* to find things about a discipline; *how* to find out things in a discipline, and *what* to do with what one finds. This is what good pedagogy is really about. It is what sets teachers apart from others who may also promote learning in various settings outside school systems.

The next important point to acknowledge is that developing an appropriate range of good pedagogical skills is more a matter of long-term experiential learning than short-term conceptual learning. This raises important questions about the length and emphasis of college-based teacher education courses. It also highlights the need for more attention to be given to in-service training and on-going support for the professional self-development of teachers. The challenge is for teachers to become more reflective about their own practice and to take greater responsibility for their professional self-development.

A third important challenge is to facilitate the role of people other than teachers in the business of using appropriate pedagogy for improving the quality of education. Good teachers have always recognised the importance of using other resource persons in the process of promoting learning. Taking learners for a museum visit; using local elders to teach about village history; making use of craftspeople to teach practical skills, are all examples of how teachers use others to improve the quality of education. This kind of pedagogy will become increasingly important, given the explosion in modern knowledge and information, and the wide diversity of sources and expertise that now exists outside the school and is potentially available to learners.

Improving the tools for good pedagogy and making them more widely available to teachers and learners is another important challenge that needs to be addressed. In the case of teachers, it highlights the need for greater interaction and peer support that will enhance professional skills-development. Teachers need to share good practice more among themselves, and encourage collaborative efforts to improve pedagogy. The future of teaching hinges on professional self-development by individuals and professional self-reinforcement by the profession as a whole.

Formulating Policies and Strategies

The remaking of the teaching profession should be at the heart of policies concerned with pedagogy and improved quality in education. The main goal of such policies should be to help create a teaching force that is:

- focused on mastering the business of planning and managing the settings and the processes through which learning takes place;
- concerned with promoting and strengthening active self-learning, rather than with passive acquisition of knowledge and information;
- geared to promoting and supporting professional self-development efforts on a systematic and sustained basis;
- committed to the appropriate use of technology as an aid to teaching and learning;
- dedicated to reflecting on their own practice and seeking constant improvements; and
- willing to try out a range of technologies that may be relevant to improving the learning process.

Strategies for introducing technology that relates to good pedagogy and improvements in the quality of education should focus on teachers. Ultimately they hold the key to what happens in classrooms and they must be at the centre of technological change. Against this background the following factors must be taken into account:

- teachers need access to centres where they can safely try out various types of technologies and seek help where necessary;
- schools need leadership that is committed to using technology for pedagogical purposes, and that is supportive of teachers in this regard;
- strategies should focus on introducing technologies that are affordable and can be maintained within reasonable budgets; and
- a comprehensive approach should be taken in selecting technologies, so that they can serve multiple purposes in the education system (pedagogy, management, access, etc.).

Decisions on policies and strategies for technology to improve pedagogy will not be based on pedagogical considerations alone. Issues of cost and affordability are likely to be major factors that will influence any conclusions and recommendations to decision-makers in each country. Indeed, much detailed work needs to be done to give a full cost-benefit analysis of proposed technologies before a decision is taken. In this regard consideration should be given not only to the fixed costs of setting up and making the technology functional (buying the equipment, constructing infrastructure, designing software, preparing print and audio-visual materials, etc.); but also to the variable costs that will increase according to the number of users (teachers' time, print runs, end-user supplies, etc.), and to other recurrent costs that must be regularly budgeted for over time, such as maintenance, electricity, telephone and other utilities and service charges associated with the technology.

As a rule, the less technology there is in conventional schools the lower the fixed costs will be, and the more technology there is the higher the fixed costs will be. It is important to appreciate that introducing new technologies into a school system bring in higher fixed costs which make education more expensive. Such additional costs need to be justified in terms of the pedagogical and quality gains likely to result from the introduction of these new technologies. However, most modern technologies also yield economies of scale that often more than make up for their high fixed costs. For instance, good programmed learning material involves high fixed costs in terms of initial development, but it can be reproduced for a whole education system at relatively little additional cost. The high fixed costs can therefore be spread over the large number of copies, thereby providing economies of scale. This makes each copy of the material relatively inexpensive and therefore justifiable in terms of the purchase cost.

Another general rule is that low technology in a school system usually implies high variable costs, particularly in terms of teachers' time. If teachers do everything with little or no technology, more teachers are required. They must spend more time on preparation and have more contact time in order to achieve a similar pedagogical impact to a system with reasonable technological aid. Indeed, a common justification for the introduction of technology in education systems is that it will produce savings in terms of teachers' costs, while improving the quality of the learning process in schools.

All these and similar cost considerations can make decision-making a very complex process. It is therefore useful to explore cost issues in a more aggregated manner, in terms of standard indicators such as unit learner cost, or the cost of producing each graduate from a training programme. These indicators can be used as part of a model to explore how costs change with the introduction of different kinds of technology into the system, or even into each kind of institution.

Case Study 4: The Training Implications of the ICT Revolution on Secondary Mathematics

Douglas Butler

Director, Centre for ICT Training and Research,
Oundle School, Oundle, UK

New Opportunities and Challenges for the Secondary Mathematics Teacher

Mathematics is possibly unique among school subjects: not only is it taught the world over, but school children in nearly every country learn much the same content. The language of delivery varies, of course, but the written notation (certainly in 'western' cultures) is mostly the same, and the opportunities presented by ICT are there to be shared by all.

Since the subject came into being, the dedicated enthusiasm of countless generations of teachers has educated the worlds' school children in the finer points of Mathematics using no more than a piece of chalk – and this is how it still is in the majority of Mathematics classrooms today.

A growing number of Mathematics teachers are now beginning to discover what the ICT revolution has to offer, not only in their own personal productivity, but as a teaching aid in the classroom (Figure 4.1). This study aims to summarise some of the variety and sparkle that can be added to a lesson if the teacher is trained and has access to appropriate software and hardware. The corresponding visualisation of the subject can dramatically improve pupils' motivation – in particular it can open the eyes of the more reluctant pupils who regard Mathematics as a dreaded necessity!

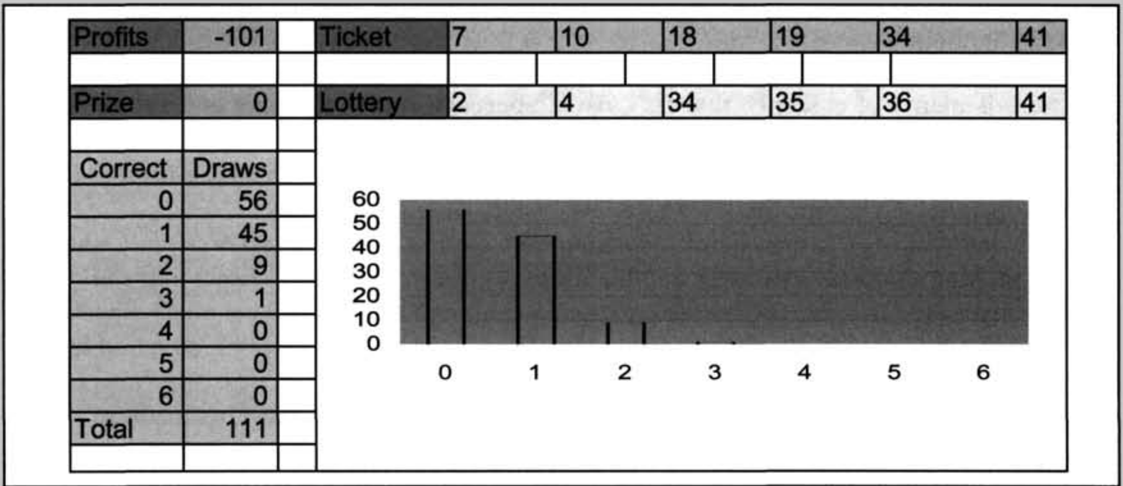

Figure 4.1 A Spreadsheet Simulation of a Series of National Lottery Draws, Indicating How Often Correct Matches were Obtained, and the Net Loss After a Number of Draws, Used to Illustrate the Underlying Principles of Probability and Chance (DISCUS Project, University of Coventry, UK)

The Challenge

It is a major concern that the world's schools are becoming more and more polarised between those that have plenty of access to ICT, and those that have none. It is also the intention of this study to explore what can be achieved in ICT using modest resources, and to try to prioritise spending when budgets are tight (Appendix 1, page 123).

Teachers fortunate enough to have new ICT resources to hand are now faced with an embarrassment of riches. The challenge is to train teachers to select them carefully, and above all to use new methods sparingly. Many observers of computer-enabled classes are surprised at how little, but how effectively, the new methods are employed – the majority of a lesson is still undertaken by traditional means. The ICT opportunity is easily wasted if misused or over-used.

The Impact and Scope of New Software in the Secondary Mathematics Curriculum

Perhaps more than any other school subject, Mathematics has a rich source of new methods to draw on using ICT. It is convenient to group these as follows, though inevitably there will be more and more overlap as the products evolve:

- *The graph plotter – e.g. Autograph, Omnigraph, Coypu:* This is probably the most important software group: the graph plotter has great scope for visualising many of the basic concepts in Mathematics. Also, this group is not expensive, and there are some very adequate plotters available for free down-load from the internet.
- *The spreadsheet – e.g. Excel:* This important tool, designed for the business community, is now firmly established as a mathematical tool for schools. The ability to perform repetitive calculations and create graphs from data can give great satisfaction to pupils.
- *Statistical analysis – e.g. DataDesk, Fathom, Minitab, Discus:* With the increasing occurrence of statistics in the world's school Mathematics curricula, teachers can bring in 'real life' data from the internet and enliven their classes with computer-assisted analysis.
- *Dynamic geometry – e.g. Geometer's Sketchpad, Cabri II, Geometry Inventor:* There is plenty of evidence that this visual approach to the teaching of a fundamentally visual subject is very popular, and pupils are motivated by this (Figure 4.2). However, the dynamic approach offered by the computer can very rarely substitute for a rigorous pencil-and-paper proof.
- *Mathematical DTP – e.g. Word (MS Equation Editor), MathCad:* The simple way to type Mathematics is to use a combination of superscript (for indices) and the standard symbols font (for various mathematical signs). For more complex expressions, the Equation Editor that comes with Word is effective, creating an editable graphic of the formula.
- *CDs – e.g. Escher, Art and Mathematics, MathWise, TransMath:* This medium may prove to be short-lived as the internet takes over, but in the meantime a number of important resources are available on CD, for example Escher pictures and a growing number of CDs for revision, or for structured learning (known as 'interactive learning systems').

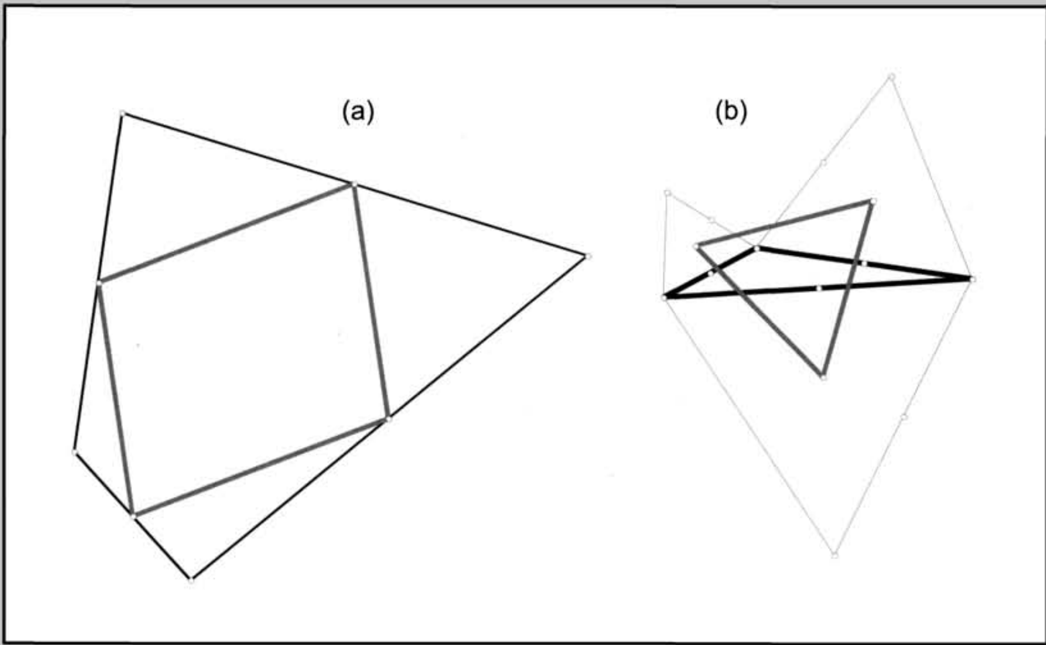

Figure 4.2 Two Examples of Dynamic Geometry: (a) Illustrates the Theorem that the Mid Points of the Sides of Any Quadrilateral Form a Parallelogram; (b) Illustrates Napoleon's Theorem (Geometer's Sketchpad)

- *Symbolic algebra systems – e.g. Derive, MathView:* What is becoming clear from this category is that algebraic software can now do much of the Mathematics that is taught in schools (Figure 4.3). The challenge therefore is increasingly not only how to teach the subject, but what to teach.

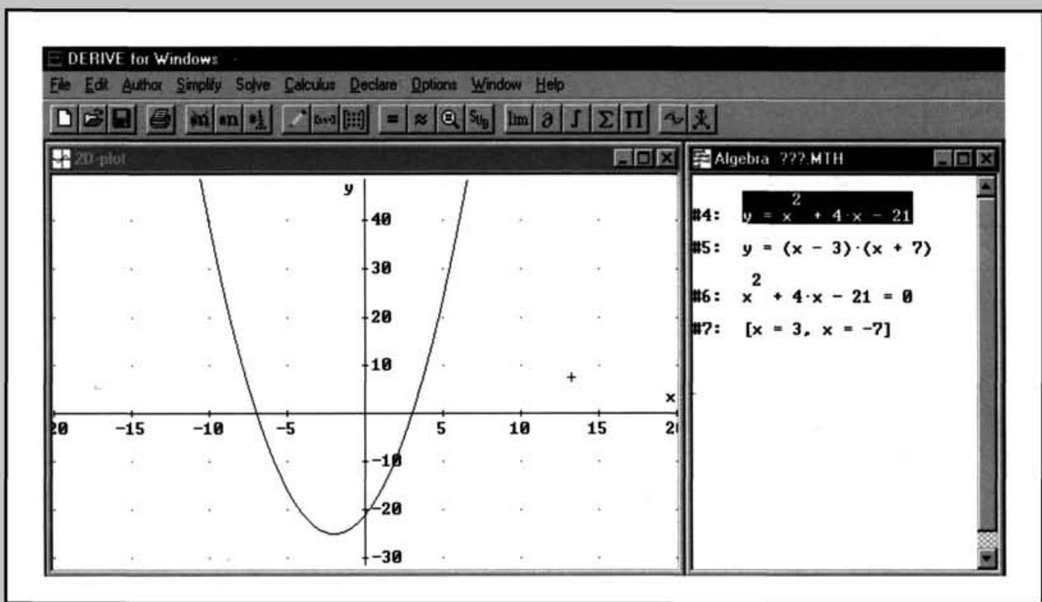

Figure 4.3 The Use of an Algebra Window Alongside a Plotting Window Allows a Symbolic Algebra Package to be Used to Illustrate a Number of Properties of the Standard Factorisable Quadratic (Screen Created Using Derive)

- *Hand-held calculators*: These are getting cheaper and more powerful almost daily. So far, solar-powered calculators are restricted to the small screen 'scientific' category. Graphic models can handle numerical, graphing, algebraic and statistical operations. Many calculators can connect to OHP pallets for class display. The disadvantages are the low resolution images and awkward keyboard entry.
- *The internet, e-mail and video conferencing*: This category is the most significant development so far and warrants a study in its own right. Mathematics is a global subject and there is already a huge bank of resources available to teachers from all over the world. Teachers need to learn how to find them, and how to incorporate data and graphics into their worksheets, and in their day-to-day teaching. (For an example of a worksheet based on internet resources, see Appendix 2, page 124). Oundle School has made a good starting resource available on: http://www.argonet.co.uk/oundlesch/.

  Email has a special potential, as teachers can use specialist discussion lists to contact other teachers and professional organisations.

  The ability to send and receive pictures and sound over the internet is now a reality. The PC camera is cheap (or you can use a regular video camera); the communications software is very versatile and is free (Net-Meeting from Microsoft). This allows both parties to share a white board, chat line and any applications that one or other is running (e.g. a spreadsheet). We can now look forward to the prospect of affordable distance teaching.

Appendix 3 (page 125) lists school-level Mathematics topics suitable for ICT treatment.

The Impact and Scope of New Hardware on the Learning Environment in Secondary Mathematics

Whole-Class Teaching

Whole-class instruction can now benefit from a dynamic new teaching environment using computer-generated images. To achieve an image that is large enough to be seen by the pupils, the options are:

Figure 4.4 Whole-Class Instruction Can Benefit From the Use of Computer-Generated Images

- *a large television (with a suitable adaptor)* – the image is a bit grainy, but this is the most affordable solution, and has the surprising benefit of being able to write on the television screen with an ordinary white-board marker.
- *a 'Cruiser' laptop* – this is a new concept: a high performance PC laptop with a detachable screen that then acts as an OHP pallet. The image is bright enough for most conditions, and a remote keyboard and mouse can be passed around the class for pupil input.
- *a computer projector* – ideal, but at the time of writing still prohibitively expensive for schools. Ideally it should be ceiling-mounted, shining on to a white writing surface. This avoids the glare that follows from projecting horizontally, and the teacher can also write on the image.

Using the ICT Laboratory

With a classroom display system, the teacher remains in control, driving the pace. Taking a class to a lab needs careful thought, and the essential ingredient is the well-planned worksheet to ensure that the pupils benefit from a worthwhile learning experience. Pupil-controlled images add interest and there is scope for working with peers (Figure 4.5).

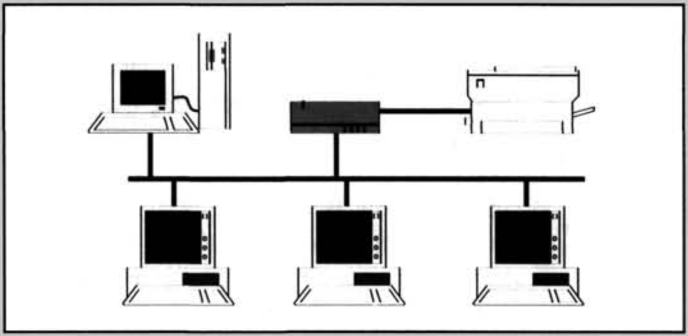

Figure 4.5 Using an ICT Laboratory Gives Scope for Pupils to Work with their Peers

Training Strategies for a Secondary Mathematics Department

The first objectives are:

- *To plan for equal provision of the three essential ingredients:* training, hardware and software (Figure 4.6). Lagging behind with any one will lead to opportunities in the other two being wasted: for example, trained teachers with no ICT support, or brand new equipment being ignored by teachers unaware of the possibilities. The most common error is to assume that funds are needed only for hardware and that somehow the other two will just happen!

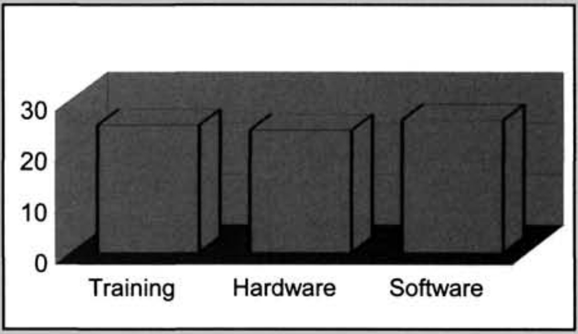

Figure 4.6 The Equal Provision of Training, Hardware and Software is Essential

- *To convince school and curriculum managers that Mathematics is a subject that can materially benefit from investment in ICT.* Despite the many opportunities that will be obvious to the committed user, this objective can be difficult to achieve in the light of many centuries of successful teaching without them. Also without the informed backing of school heads and their deputies, an ICT departmental programme is likely to founder.

Face-to-Face Training

Within each academic department a member of staff needs to be asked to act as an ICT 'anchor'. This person will provide the leadership necessary to see a training programme launched and followed through in the department.

The 'anchor' should attend a regional training day, which would aim to cover an introduction to the general and subject-specific skills. The format should be part presentation (when the trainer dictates the pace) and part hands-on workshop, with no more than 16 in the group. The departmental 'anchor' should have the confidence to start using ICT methods to improve personal productivity (word-processing and spreadsheets) and consider the following objectives:

- review existing hardware and software provision in the department;
- review existing ICT expertise within the department;

- recommend hardware and software purchases, probably a rolling programme over two to three years;
- advise on integration of a departmental network with the school's network plans;
- recommend which parts of the syllabus can benefit from ICT methods;
- compose a two to three-year training schedule for the rest of the department;
- indicate how ICT can increase personal productivity using word-processing and spreadsheets; and
- lay the foundations for a departmental intranet for electronic storage of resources.

This is a significant challenge even for an ICT-literate teacher.

On-Line Training

Those schools fortunate enough to be able to send an 'anchor' teacher to a regional training day will have made a good start, but training must be ongoing, and there is also the need to train the other members of the department. There can never be enough trainers for this 'face-to-face' approach, and the internet offers a very practicable solution, requiring:

- teachers who are motivated to learn this way;
- reasonably fast internet connectivity;
- training materials of sufficient quality, and in the local language; and
- on-line tutorial help.

Face-to-face and on-line training can be combined (Figure 4.7).

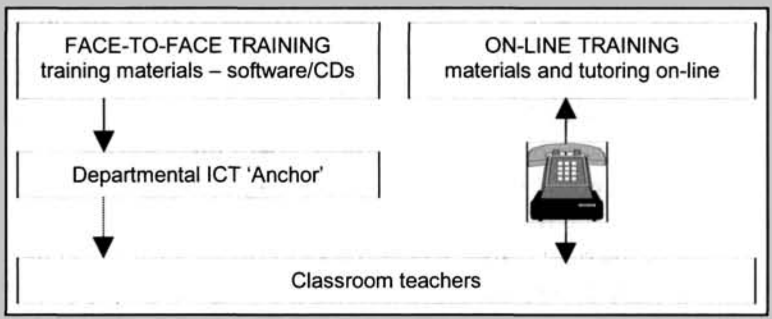

Figure 4.7 Face-to-Face and On-Line Training can be Combined to Train Classroom Teachers

Teacher Ownership of Hardware

It is important that any training programme devised for Mathematics teachers includes the use of ICT to help with their personal productivity. This should include word-processing for work-sheets, using e-mail as a professional communications tool, and using the internet as a classroom resource. Experience has shown that confidence with this technology cannot be really secure until a teacher owns a computer or has easy access to one at school and at home.

It should be a high priority in any ICT master plan, to assist with a teacher purchase scheme (if there is a likelihood of the teachers being able to afford one). It is also likely that portable computers will get cheaper and more powerful.

Already mentioned is the 'Cruiser' laptop with detachable lid for whole-class teaching. If a school authority is encouraging teachers to own their own machines, this solution is attractive because it provides the classroom computer and display system all at once. The solution is also particularly appropriate for schools that do not have classrooms dedicated to Mathematics.

The Cost Implications of Technology in the Curriculum

This is undoubtedly the most difficult area of this subject, with all three cost centres – training, software and hardware – greatly affected by local variations.

Face-to-Face Training

When any country starts to add up the number of hours of training required to bring even one teacher per school up to speed with the use of ICT in the classroom, the figures immediately suggest a major investment in time and resources. One full day per 'anchor' teacher and at least two half-day follow-ups are recommended. The cost of training and supporting the trainers is also significant, especially as they are likely to be seconded from the classroom.

On-Line Training

On-line training needs to be set up by local governments, tailored to local needs, including language. On-line tutors need to be trained and in place.

Purchase of Software

There is an increasing availability of high quality software free of charge from the internet. The list includes graph plotters, a dynamic geometry package and a large number of 'Java' internet applications that can be down-loaded legally. These are obviously not as polished as the commercial applications, but represent a good start for a cash-starved Mathematics department.

Of the commercial products, a graph plotter, a word-processor, a spreadsheet and possibly a dynamic geometry package should be the first items to go for. The unit cost can be reduced considerably by buying site licences.

Purchase of Hardware

With so many schools in the world struggling to find basic resources it will be useful to consider first what you can achieve with the bare minimum, and progress from there:

- *No electricity*
  - wind-up technology is here, and able to power simple computers;
  - solar-powered devices are not yet powerful enough to perform more than simple calculations;
  - mobile power units that generate electricity for small networks have been trialled.
- *No telephone connection*
  the only feasible way to connect to the internet without a land-line is through a satellite connection. With the internet having such enormous potential in remote areas, it is likely that this method of connectivity will be a priority for the local educational technology planners.
- *Just old computers and no funds to upgrade*
  there is a surprising amount that Mathematics teachers can achieve with old equipment (say 286- and 386-DOS computers). A number of important mathematical products were sufficiently well developed before the advent of Windows that their early DOS versions are still useful and still available. In particular Excel (spreadsheet), Derive (symbolic algebra) and Cabri Geometre (dynamic geometry).

- *With a school network in place*
  the network is the backbone of ICT success. With it resources and applications can be shared around the community. Another significant development is a networking tool that will allow older computers to sit on a modern network and act as 'dumb terminals' (or 'thin clients'). The picture is only just becoming clear, but the implications for under-resourced schools are obvious: the hardware that sits on the end of a network is likely to get cheaper and cheaper.

A useful site giving direct links to software and hardware suppliers can be found at: http://www.argonet.co.uk/oundlesch/suppl.html. It is divided into categories as follows:

- general suppliers (UK)
- symbolic algebra
- geometry packages
- graph plotters
- spreadsheets and statistics packages
- interactive learning systems (ILS)
- mathematical DTP
- graphic calculators
- advisory.

Conclusions

The main concern with ICT in schools is that there is a serious likelihood of scarce resources being wasted on software and hardware that is inappropriately used or not used at all. Everyone is clamouring for computers and far too many are being installed in schools throughout the world without due thought for their use.

The hardware that delivers the software is certain to change, and become more and more affordable, especially when connected to a network. It is also likely that the comparatively inexpensive calculators and palm-top categories will gradually close the performance gap to provide rich learning tools for pupils to use in the classroom.

Mathematics is fortunate – there are many obvious advantages to using ICT methods in the teaching and learning process, and this is not the case in many school subjects. Yet however obvious the advantages, training teachers to put them into practice is vital.

Clearly what is now needed is an international initiative to set up a programme for training the trainers, and at the same time a parallel initiative to put these training resources on the internet so they can be made available to all.

Some useful world-wide web sites for teaching Mathematics are listed in Appendix 4 (page 126).

Appendices

Appendix 1: ICT Basic Skills for Teaching and Learning Mathematics

The ICT revolution is advancing to affect nearly all aspects of human activity, and the evolution of the internet has accelerated this process. Education is not exempt, and teachers and students the world over are being offered exciting new challenges.

Both teachers and students need to discover and practise a range of ICT-related skills. Table 4.2 is a 'starter list'. Curriculum planners must consider carefully how to make available the time for teachers to be trained, and which subjects are to give the time for students to be trained.

Table 4.2 A Starter List of ICT Skills for Teachers and Students

General skills	**Algebra** using a symbolic manipulator (eg Derive); input notation; factor, expand, solve; calculus: differentiation, integration; plotting functions
Hardware basic connections: monitor, printer, keyboard, mouse; installing new software; running software; loading, saving, deleting files; copying images from any package; connecting to a projector; manipulating bit-map images	**Scientific calculator and graphic calculator** routine calculations; trigonometry calculations (radians/degrees); graphical work (axes scales); data input and statistical calculations
Spreadsheet cell co-ordinates; entering text; entering data; entering a formula; split screen working; relative and absolute cell references; fill-down; selecting one or more (non-adjacent) columns; drawing a scatter diagram; importing data from an internet page; incorporating an Excel sheet within Word; using spreadsheets for record keeping (marks, orders, grading, etc)	*Internet skills*
	World-wide web connecting to a modem or to the network; loading a browser; browsing off-line; entering a URL; copying a URL; using the favourites list; moving between visited pages; the use of page-up and page-down; selecting text and graphics to copy and paste; sensible use of search engines; downloading software, and 'plug-ins'; learning to authenticate a web site
Graph plotting entering an equation; setting the scales; zooming; drawing a tangent, normal; reading co-ordinates; plotting families; cartesian, parametric and polar co-ordinates	**Email** sending and receiving messages; subscribing to email discussion groups; managing attachments; copying text from an email; launching a URL from within an email
Sketchpad drawing points and lines; multiple selections; simple constructions; simple use of scripts; deleting and hiding objects	**Video conferencing** Microsoft NetMeeting: using the whiteboard, chat, sound and video
Word processing typing and simple formatting of text; copying and pasting images; using the symbols font for simple Mathematics; using the equation editor (in Word); importing text and graphics from the internet	**HTML worksheets** using Microsoft Word (Office 97) to incorporate live URLs and text/graphics from web pages.

Appendix 2: Using Internet Resources to Make a Work Sheet

Teachers can use the resources available on the internet and incorporate data and graphics into their worksheets. Figure 4.8 is an example.

You are to use the resources of the internet to investigate Pythagorean triples. The following headings are suggested:

1. The simplest Pythagorean triple is 3 - 4 - 5, since $3^2 + 4^2 = 5^2$.
Before looking at any web sites, write down any more that you know about Pythagorean triples.

2. On the Autograph 'Lists' site of Pythagorean triples, what do you think the numbers in square brackets mean? How has this list been ordered?

3. Do you notice that for a number of triples the difference between the two largest sides is one?
Show that in this case the sides can be represented by Ú(2n+1), n and (n+1).
See if you can copy this Autograph list into a spreadsheet.

4. With reference to the Autograph 'Lists' site of prime numbers, note that the year 1997 was both 'pythagorean' and 'prime'. What year does this next happen? How would you show that 1997 is prime?

5. Look at the 25 proofs of Pythagoras' theorem and find one that you would like to record.

6. Who was Pythagoras? See if you can download his portrait from the biography site quoted below, and incorporate it in a poster of your findings.

Some suggested web sites to visit:

1. Autograph lists
http://www.acorn.com/developers/autograph/calc/lists.html
2. 25 proofs of Pythagoras' theorem
http://www.cut-the-knot.com/pythagoras/
3. Pythagoras of Samos
http://euler.ciens.ucv.ve/English/mathematics/pitagora.html

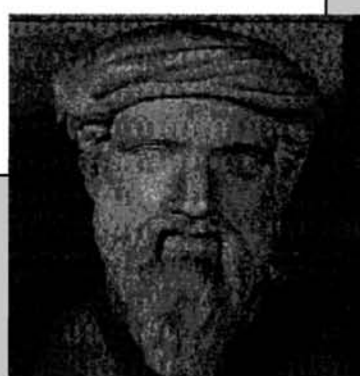

Figure 4.8 A Worksheet Based on Internet Resources

Appendix 3: Mathematical Topics Suitable for ICT Treatment

Table 4.3 shows some school-level Mathematics topics suitable for ICT treatment.

Table 4.3 School-Level Mathematics Topics Suitable for ICT Treatment

11–16 year-old Mathematics

Internet resources can be useful, e.g.:
Number: prime numbers, irrational numbers; measures; time; money; Greenwich time site
World camera sites, (to study longitude)
Currency converter site
Statistics and data handling: data sources
A growing list of topics can be found on Interactive Java sites (e.g. from Japan), including proofs of Pythagoras' theorem; transformations

Spreadsheet methods can be used to investigate various topics, e.g.:
Number: number sequences; nth term
Displaying data

A graph plotter can be used by the teacher and pupils to explore relationships and illustrate basic function concepts, e.g.:
f(x) and inverse, f'(x) • graphs in practical situations;
straight line graphs: gradient/intercept
y = kx^n (n=-2, -1, 0, 1, 2, 3); tangents to curves; investigating y = mx+c

Solutions of equations and inequalities
Solving linear and quadratic equations
Graphical representations of inequalities
Visualising transformations

Dynamic geometry packages offer new ways to explore geometrical relationships, e.g.:
Constructions; bearings; symmetry
Angle (parallel lines, triangles, quadrilaterals, polygons, circles); locus; mensuration; transformations

Statistics packages:
Histograms; cumulative frequency

Post-16 Mathematics

Here, the **graph plotter** can be particularly valuable as an aid to the visualisation of functional analysis:
The general quadrativ
Implicit lines, circle and ellipse
Curves and equations, transformations
Parametric and polar co-ordinates
Six trigonometric ratios and identities
Circular measure and Trig formulae
Solution of trig equations
Sin, cos, tan for small angles
Functions; inverse, composition
Exponential and logarithmic functions
Differentiation, inverse trig, ax, lnx
Composite functions, turning points
Definite integrals; areas and volumes
Rational functions

Hyperbolic functions and inverses
Further differentiation and integration
Mean values, centroids, arc lengths, volumes
First and second order differential equations
Simple Harmonic Motion
Curve sketching, $y^2 = f(x)$, $y = |f(x)|$
Numerical solution of equations
Maclaurin's series
Numerical integration (e.g. trapezium rule)
Matrices and transformations

***A* spreadsheet** can be used to study:
Sequences, APs, GPs
Solution of equations: bisection, x = g(x), Newton-Raphson
Numerical integration (e.g. Simpson's rule)
Step-by-step methods for solving differential equations
Curve fitting by least squares

Statistics packages:
Scatter diagrams; linear regression
Binomial , normal and poisson distributions
Sampling; confidence intervals

Appendix 4: Some Useful World-Wide Web Sites for Teaching Mathematics

A good reference site is http://www.argonet.co.uk/oundlesch/mlink.html, which divides the mathematical use of the internet as follows:

- Mathematical associations and magazines
- Mathematical resources
- Mathematical entertainment
- Statistical resources
- Other lists of useful links

For a fuller treatment, see *Using the Internet: Mathematics* by Douglas Butler, published by Pearson Publishing, Cambridge (March 1998).

A revolution is taking place in Mathematics teaching at secondary and college level, and TSM is pioneering an approach to teacher training that is both informative and practical. Teachers can discover ideas that add variety and a guaranteed sparkle to their lessons. Table 4.4 is an example of a TSM programme.

Table 4.4 A Typical TSM Programme

What's going on in other subjects eg Music (Sibelius – Music Processor)	**Mathematical DTP** Word (Microsoft, USA) MathType (Chartwell-Yorke)
Spreadsheets Excel-97 (Microsoft, USA)	**ILS (Integrated Learning Systems)** Transmath (Leeds University)
Graph plotters Autograph (Oundle School) Omnigraph (Sheringham High School) Coypu (Shell Centre, Nottingham)	**Statistics** Discus project (Coventry University) Autograph (Oundle School)
Geometry Cabri Géomètre-2 (Univ. Grenoble) Geometer's Sketchpad	**CDs** Escher Art and Mathematics
Symbolic algebra systems Derive (Soft Warehouse) MathCad (Waterloo Maple, USA)	**The internet, email and video conferencing** A rapidly growing resource

Notes

TSM is a teacher training activity based at Oundle School, Peterborough (UK), which tries to get to grips with the explosion of new products and ideas in this field. There have been six TSM day-conferences at Oundle, attended by teachers from all over the UK, and many associated TSM training days elsewhere in the UK and other countries.

Oundle School is the second largest co-educational boarding school in the UK, 30 miles west of Cambridge. The Mathematics department has been involved in using technology since the early days of the BBC micro, and has developed the use of a classroom computer connected to a TV display as a teaching tool.

Autograph is a suite of interactive programmes for teaching secondary Mathematics, created over the past 10 years by a team of teachers and pupils at Oundle School.

Autograph covers pure mathematics and statistics, and includes what is perhaps one of the most useful school-level graph plotters. It has been completely re-written for the PC platform as a dynamic co-ordinate geometry package. It is best known for being 'teacher- friendly', with intelligent default entries throughout.

MEI – *Mathematics in Education and Industry* – is a teacher-led group that provides examinations, support materials and INSET to over 600 schools and colleges in the UK. It is now the second largest provider of the modular Mathematics 'A' level examination.

Case Study 5: The State of Electronic Publishing and its Impact on the Availability of Source Materials for Higher Education and Research

Barbara Kirsop

Electronic Publishing Trust for Development,

Stanfield House, Lincolnshire, UK

Introduction

This case study reviews the present status of electronic publication and assesses its likely impact on the exchange of research information generated in both developed and developing regions of the world as well as its availability for higher education. Although the study focuses on scientific research, and uses a bioscience initiative as an example, the overall conclusions are generally applicable to other disciplines.

Professional ideas, research results and educational material are traditionally transmitted to peers throughout the world through the printed publication of journals. The rising costs of publishing on paper and the resultant cancellation of journals by libraries (Figure 4.9), which are themselves facing budget cuts, creates the need to reconsider the overall position. The situation is serious in all libraries, but is particularly acute in developing countries where librarians are trapped between the rise of commercial journal costs and the demands of their users.

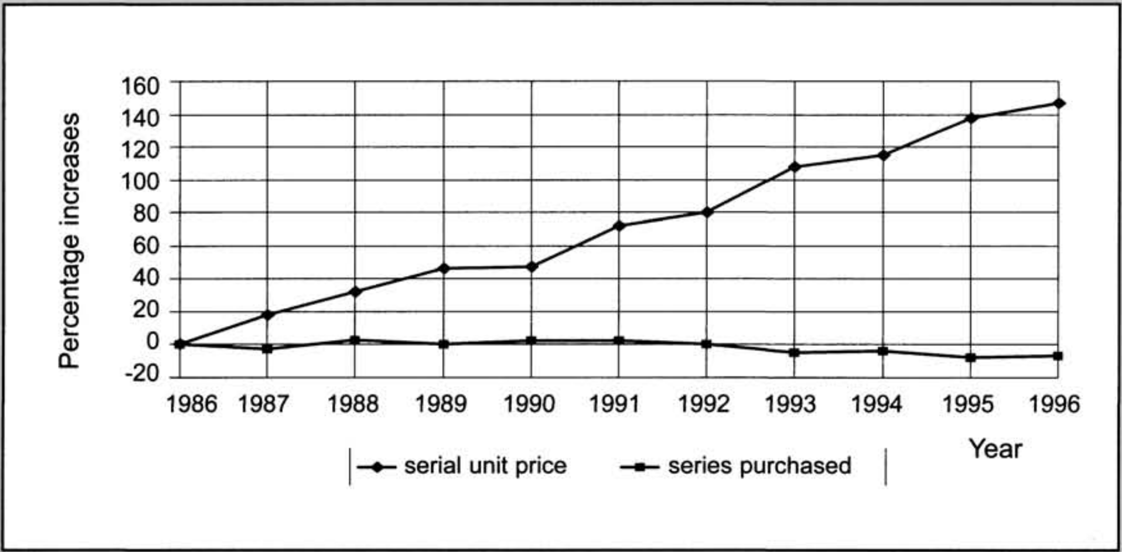

Figure 4.9 The Rise in Costs of Journals, and Its Impact on Subscriptions, 1986–96

According to the Association of Research Libraries, scholarly publishing and academic resource coalition (SPARC) libraries spent 124 per cent more in 1997 than in 1996 for 7 per cent fewer titles. The organisation is launching a programme1 to collaborate with partners in the development of 'prestigious, cost-effective alternatives' to existing journals; the programme also aims to restore publication rights back to the author.

In this climate, the advent of the internet, the world-wide web (the Web) and electronic communication is leading to a major reconsideration of the best way to exchange research material and an analysis of whether information distribution can be substantially enhanced and cost savings made by use of electronic media. Since the late 1980s a growing number of electronic publishing initiatives have been started; many information exchange mechanisms have become established and other models are under development. The technical opportunities have in turn led to a re-evaluation of what is important in scholarly publication and how the internet can contribute to the evolutionary process.

It seems clear now that electronic publishing is a positive development that is here to stay. At a recent International Council for Scientific Unions workshop,2 the general view was that in five years' time electronic publication would dominate printed publication, at least for academic journals. However, the best way to make use of the new technology is still under debate and research communities, librarians and publishers are actively considering how to change working practices to meet the new technological advances.

The opportunities are revolutionary and offer mechanisms for the academic communities in developing countries to increase hugely the visibility of scholarly research generated nationally. Many of the present difficulties met in transmitting research results by printed publications, and the feeling of academic isolation commonly experienced by researchers from national/regional institutions in developing countries, can be overcome by electronic means, leading to global distribution of research and teaching material and involvement in international academic activities.

The Internet and the World-Wide Web

The growth in use of the internet has been phenomenal, although estimates of the numbers of sites on the network vary wildly. Because of the unstructured architecture of the network, control is difficult and it is not surprising that standards are still under development. Locating material of interest becomes an increasingly important issue and concerns are raised about the identification of reliable material for academic purposes.

However disorganised general information may appear, the infrastructure and technology have been in use by the academic community for a considerable time and a good measure of organisation of academic information is already in place. Vast quantities of high-value scholarly information are already available on-line to the international community and it is now difficult to imagine a future where research and education will revert to a solely paper-based environment.

'The ability to build and mobilise knowledge capital will become as necessary to development as mobilisation of physical and financial capital in the years ahead … We must be determined that all countries of the world participate equally and benefit fully from the global information revolution.' (John Wolfensohn, President, World Bank)

There has been criticism that the internet will increase the gap between the 'haves' and 'have-nots' because much of the necessary infrastructure is not in place in countries where the need for information is greatest. This problem was addressed by the recent Global Knowledge '97 (GK97)3 Conference in Toronto, hosted by the World Bank and the Government of Canada and sponsored by UNESCO, UNDP and others.

The first regional follow-up of the GK97 Conference was the organisation of a conference in Addis Ababa4, in June 1998, on Global Connectivity for Africa, at which governments, development agencies, banks, companies and the International Telecommunications Union discussed the need for the development of goals and projects that would make a positive impact on public telecommunications in Africa. There is no doubt that the value of ICT (Information and Communications Technology) for development is well recognised and priority is being given to measures that support it. It can be expected therefore that the infrastructure for the support of electronic publishing will develop steadily, providing a growing number of opportunities for its use. With time and training, the knowledge gap can be closed.

The internet supports the world-wide web which provides a powerful mechanism for on-line linkages to different information resources. Not only can sites providing similar kinds of information be linked, but links can be made from terms used in documents to related data held elsewhere – either on the same computer or on different computers on sites in different parts of the world. The hypertext reference standards that have been developed provide a common command for insertion into text, allowing readers to click on the link and be transferred instantaneously to the other sites of interest. The potential this offers for academic research publications and distance learning initiatives is discussed further below.

The technology for the preparation of documents for the world-wide web is readily learned. Courses are increasingly organised (References, e.g. 5) for the conversion of text and graphics for the internet, and on-line tutorials are available for self-tuition (References, e.g. 6). 'Web authoring' tools are commonly available as part of word-processing software, and web-browsing software for both searching the internet and reading web documents is accessible from the internet itself from many software sites. Once the infrastructure for ICT is available, the cost of technology for electronic publishing is not prohibitive.

The Present Status of Electronic Publishing

The potential of electronic publishing has been recognised for over a decade, and during this time commercial publishers and academic organisations have been considering the impact of the technology, both on the enhancement of information exchange and on the economic changes that follow.

Commercial Publishers

Commercial publishers have been developing mechanisms that continue to allow control of documents and that are generally precise electronic versions of the printed publication. They are using the internet as a new and powerful distribution mechanism that has the potential to greatly expand markets. The fear has been that the traditional print-based market will be damaged by electronic mechanisms, and publishers have held many meetings to discuss the dangers of copyright infringement; of losing control of the material; the quality of publications (are peer-review procedures commonly practised in print-based journals applicable?); images and technical data problems; archiving and indexing problems, and – crucially to the industry – costs and pricing policies.

Many of the major commercial publishers have now made their publications available electronically, and the University of Toronto's Centre for Instructional Development technology web site (References, 7) has an exhaustive list of these, as have other sites. The development of a parallel means of publication has required new investment and, as a consequence, the prices of electronic versions of printed journals have either increased, remained the same or been only marginally reduced. Technical issues are being resolved, and controlled formats, such as that provided by ADOBE, have been largely adopted. Some services have been established that provide electronic distribution for other, usually smaller, publishers (References, e.g. 8), providing economies for the publishers and experience in the e-pub market.

It is widely found that up-take of the electronic material is slow and a number of reasons for this are propounded. Undoubtedly the paradigm shift from a print-based to an electronic environment will take time as publishers, distributors, libraries and end-users change their working habits and learn new skills. Additionally, mechanisms for different payment structures have to be put in place and library committees in universities, institutes and companies have to be persuaded that the change is beneficial. The whole revolution is taking place within a framework of falling library budgets and more stringent accounting procedures so that it is inevitable that change will take time.

Society Publishers and Their Academic Members

In general, scholarly societies that are also publishers are more concerned with the academic advantages of electronic publishing than are commercial publishers, and are driven by their members' demands. They too are affected by the increasing costs of traditional publishing and must recover development costs, and are taking a closer look at 'alternative' publishing opportunities offered by the web. Many of the major and most innovative developments are coming from societies, and in some regions initiatives have been launched that bring together government, societies, libraries and users into a consortium to develop a national or regional service, such as the Virtuoso partnership initiative in Canada. Many of these initiatives are listed on the Toronto Web Site (References, 7).

In science, the opportunities for adding value to the traditional published page are being widely welcomed. The ability to provide links to references, images, video clips and, most excitingly, to the major international public domain databases changes the static printed document completely, into an interactive on-line information resource. Users can click on the term 'tyrosine phosphatase', for example, and be transferred from the document to the entry for this enzyme in the Swiss database (EXPASY) for a volume of related data; click on the gene 'ade1' and reach the sequence databases in the USA or Europe; click on the name of a micro-organism and link to a database with further information on its properties and how to acquire a sample of it; click on a reference to the previous lecture in a course and immediately down-load it.

Secondary datasets, not suitable for print publication because of their volume, can readily be made available through the web linking mechanism. Discussion forums, newsgroups, supplier databases, e-mail, and other services can all be provided in association with a journal – or a collection of topic-related journals – forming a specialist location on the internet that is user-driven, international and interactive (References, e.g. 9). The potential for making maximum use of the web's linking capabilities is thus very great and is gradually becoming incorporated into publications as standards are being discussed and accepted.

Many society publishers are using formatting standards such as the hypertext mark-up language (HTML) (References, 6) and standardised general mark-up language (SGML) (References, 10). Information on these, and software for using the internet with Netscape and Internet Explorer Web browsers, is readily available from many internet sites, largely free of charge.

Authors from many disciplines are contributing to the debates on the merits of electronic publishing and its potential for improving information exchange. Traditionally, scientists and other academic authors publish the results of their research in printed journals, the copyright of which is held by the publishing company or the society. They are not generally paid for their contributions and the benefits arise primarily from the knowledge that their work forms part of the archived body of public-domain information and can be built upon by others for the public good. Additionally, authors anticipate accelerated career developments as a result of publications and this can be affected by the numbers of times their papers are cited by indexing, abstracting and other organisations – a policy that is currently being questioned since the number of times a paper is accessed is not necessarily the same as its scholarly worth.

However, the real wish of authors is for 'paternity' of their research and future association with it. They are less concerned with copyright issues than with international contacts, partnership prospects through increased visibility and a general wish to be part of the international academic society through their publications and ideas. Authors also want global distribution that is not limited by economic constraints. Additionally, the potential for facilitating access to secondary data, references and international databases is of fundamental importance and interest since this opens the gate to a wealth of subsidiary information often difficult to obtain. For teaching and training, the linking potential is very clear as teaching resources on the internet (books, manuals, check lists, lecture notes) are increasingly available and again lead to collaborative educational and research initiatives and course developments.

Authors are always concerned with quality and the need to conserve authenticity and accuracy and, thus, the need to preserve the peer-review system (or develop it into a more transparent system). There have been a number of meetings (References, e.g. 11) at which this issue has been discussed and it is now generally accepted that the traditional review process can only benefit from greatly speeded electronic communication between authors, publishers and referees. Moreover, new review mechanisms using a wider review community are being developed (References, 12), and these could lead to more open and improved means of assessing quality.

Libraries

While libraries welcome any developments that have the potential to reduce the costs of providing a comprehensive service to their users, it is recognised that traditional ways of providing this service must change and that there must be investment in development that can be off-set against future savings. In the developed countries there are already major programmes (usually nationally based) to establish the 'electronic library'. Such services provide multi-media facilities, on-line access and a platform of training and awareness activities to facilitate use. It is anticipated that, in time, the current investment will be rewarded by cheaper journals; better and more comprehensive collections; enhanced scholarly features (such as hyperlinks), and shelf-space savings. It is recognised that if electronic technology provides better information exchange, then this is the way to follow, at whatever pace resources currently allow.

Libraries in less developed countries face many problems at present, but can begin to visualise the benefits that electronic publishing could offer in the longer term. The technology offers the possibility to catch up and move towards more equitable access. Governments, national educational departments and teaching and research institutions need to work together to give priority to infrastructure development, perhaps working on a regional basis. Awareness and training are required to mobilise action. The author/reader communities should be involved in developments since their academic demands will be the driving force for progress. For libraries with slim resources, the eventual change from high-cost print-based journals to lower-cost electronic material is a development that must be welcomed wholeheartedly, while accepting that progress may be slow. Already steps can be taken to establish training and exchange programmes so that a body of receptive librarians is in place when the potential can be realised. Any suggestion that this new technology is not applicable for developing countries should be considered against the evidence of the great number of ICT programmes described in the GK97 Conference and already successfully under way, and the Electronic Publishing Trust for Development's activities described below.

On-Line-Only Electronic Publishing (O-L-O)

A further development that is emerging is the publication of journals that are only available electronically. This clearly has great economic impact in terms of cost-savings and a number of studies have now been carried out to assess the costs of electronic publication compared with print publication (References, 13, 14). Costs depend on the way the o-l-o publishing is carried out; the overheads that have to be met; whether archiving can be managed centrally; how much responsibility for formatting the documents is borne by the authors; the technical complexity of the documents (mathematical or scientific equations and terms), and whether a uniform style is desirable or necessary. It seems to be accepted that the major costs are in start-up and that these diminish as the software development is completed (though this is always liable to further bursts of development to keep up with new technical advancements). There are eventual cost savings to libraries by eliminating the problem of shelf space shortages, once computers and networking are in place, and further advantages in terms of single document purchase (not restricted to o-l-o journals, however), searching capabilities and monitoring usage for library policy decisions.

Several o-l-o journals have been set up and are becoming accepted by the academic community as the number of authors willing to support the new medium grows. It seems inevitable that this trend will accelerate as confidence in quality is confirmed.

A further issue under consideration is whether the existing annual subscription/document delivery charging system best serves scholarly publishing. It is being debated whether authors would be willing to pay a modest publication charge in return for which they would receive free global distribution; unlimited access to all other papers published in the same journal; retention of the copyright. Cost recovery models of this kind are already under discussion or operational.

Journal distribution on disk offers another means of reducing costs, leading in time to the elimination of printing costs altogether. The time is not right for this in many regions where (a) a printed publication is prestigious and an encouragement to scientific development (but see Developing Countries, below), and (b) an adequate computer-based infrastructure is lacking. Nevertheless, the advantages in moving away from print-based publication are attractive in terms of both economics and academic enhancement.

A Summary of Advantages and Remaining Uncertainties

The advantages and remaining uncertainties of electronic publishing are summarised in Table 4.5.

Table 4.5 The Advantages and Remaining Uncertainties of Electronic Publishing

Advantages	*Remaining uncertainties*
• Speed of review and speed of publication (therefore advantages in paternity, especially in highly competitive research areas)	• Economics of e-pub versus print-pub (especially for commercial publishers)
• Added-value through associated online subject-orientated services (discussion fora, secondary data, multi-media resources, suppliers' databases, e-mail, etc)	• Archiving technology (still need standards to be developed)
• Associated gateways to international public domain databases through hyperlinks	• Web organisation to ensure visibility
• Global distribution/international visibility	
• Flexibility in use for the reader (graphics/ no graphics, abstracts only, full text only, optional links, etc.)	
• International collaborative opportunities/ sharing information	
• Eventual cost savings	

The Opportunities for Developing Countries

Another aspect of electronic publishing of major importance to developing countries is the potential for greatly improving the current poor distribution of research results generated in universities and institutes. Because of the rising and increasingly prohibitive costs of printing and distributing scholarly journals, print runs are often small and international visibility is consequently poor. Authors become unwilling to commit effort to publishing in local journals since they feel that their research will remain largely invisible (References, 15).

The result of this is that essential information often remains unpublished since, except for the most prestigious institutes where research is fashionable (e.g. molecular biology and genomics), it is difficult for scientists in developing countries to have papers accepted in the mainstream journals published in the developed world. This is of particular concern in such disciplines as medicine (tropical medicine, epidemiology, emerging new infectious diseases), environmental sciences (including bioremediation, biocontrol, conservation), agriculture or taxonomy, where a global picture is required.

Electronic publishing offers an excellent opportunity to overcome the visibility problem. With only a relatively small investment in equipment (modems, scanners), software (image-handling, optical character recognition, web-browsing and formatting – some of which is available direct from the internet at no cost), and training (again much of which is available on-line), local publishers can make their material web-compatible and distribute it on-line, hugely increasing visibility and greatly encouraging the academic community. The benefits, particularly to society publishers, are clear.

'The invisibility to which mainstream science publishing condemns most Third World research, thwarts the efforts of poor countries to strengthen their indigenous science journals – and with them the quality of research in regions that most need them.' (Richard Horton, editor, The Lancet*)*

The British Council has adopted a major programme of support for the electronic publication of academic publications in developing countries (References, 5), and is focusing on raising awareness of benefits and initial hands-on training. It supported the participation of the Electronic Publishing Trust for Development at the GK97 and Toronto scholarly publishing conferences in 1997.The regional networks and support staff of the British Council form an invaluable resource for moving things forward and the programme is already under way.

The Electronic Publishing Trust for Development (EPT)

In recognition of the great potential of electronic publishing for the distribution of essential scientific information generated in developing countries, the EPT was established as a UK Charitable Trust at the end of 1996. Its formation was initiated by Bioline Publications (References, 9) – a not-for-profit, scientist-run system for the on-line distribution of bioscience and medical journals. Further information on the Trust, its activities and links to the journals can be found on its web site (References, 16). The distribution system used, as well as demonstration papers and additional services associated with the journals, can be viewed on the Bioline web site (References, 9).

At the time of writing (1998), the full text and graphics of 15 peer-reviewed bioscience journals from developing countries are available on-line. Some have been supported by such organisations as the Southern African Book Development Education Trust and the International Network for the Availability of Scientific Publications, others by Bioline itself. The journals currently on-line are:

- *African Crop Science*, Uganda
- *African Journal of Neurological Sciences*, Kenya
- *Biotecnologia Aplicada*, Cuba
- *Central African Journal of Medicine*, Zimbabwe
- *East African Medical Journal*, Kenya
- *Ichthyological Bulletin*, South Africa
- *Ichthyology Special Publications*, South Africa
- *Indian Journal of Experimental Biology*, India
- *Indian Journal of Biochemistry and Biophysics*, India

- *Indian Journal of Marine Sciences*, India
- *Insect Science and its Application*, Kenya
- *Memorias do Instituto Oswaldo Cruz*, Brazil
- *Transactions of the Zimbabwe Scientific Association*, Zimbabwe
- *Tropical Biodiversity*, Indonesia
- *Zimbabwe Science News*, Zimbabwe

Not only does distribution on the internet provide hugely increased visibility for these journals (the free abstracts and other material on the Bioline system are accessed by some 50,000 unique sites annually), but scientists are encouraged by greater recognition of their work and professional collaborative studies may be formed between researchers around the world. The listed journals have originally been formatted for the web by Bioline Publications, but gradually the technology is being transferred to the local publishers so that the system becomes sustainable.

The publishers of the journals benefit from the use of a well-established on-line distribution system. All material on the Bioline system is available through annual subscriptions or by single document purchase. Hypertext links are routinely incorporated, adding scientific value and providing gateways to international databases. A number of additional on-line facilities are available. The system aims at maximum flexibility in use and gradual cost reduction, and is currently also available by e-mail. It is managed by scientists and is driven by the needs of scientists.

Analysis of the usage of the journals on the Bioline system shows a steady increase in interest as users become familiar with the journal contents, and as a body of material is made available on-line. It is likely that in time additional annual subscriptions and single-document purchases will provide income to meet electronic publication costs.

The EPT is looking for other publishing partners and is working to set up resources to support new initiatives and sustain existing structures.

Future Prospects

Undoubtedly electronic publishing offers great opportunities for the more equitable, faster and academically enhanced distribution of knowledge. The benefits for publishers and the academic community in developing countries are very clear. Technology and its transfer are moving fast and, as the shift from a paper-based system to a more electronic mechanism takes place, cost savings can be foreseen. For research scientists, teachers, medical practitioners and all other academic workers, the web provides enormous opportunities to re-think the best way to distribute essential information. Many models are already operational or under way, and it is expected that within the next five years electronic publishing and distribution mechanisms will dominate.

It can be predicted that throughout the next decade academic researchers, librarians and publishers will be working together to raise awareness of the benefits of electronic publishing, developing standards, learning new technology, installing on-line systems and developing networks for the organisation of initiatives on a national, regional or international basis. The comparatively low cost of the technology and the emphasis now being placed on ICT infrastructure support are such that countries with economic difficulties will not be disenfranchised.

'Developing countries should recognise their role in the global community and give top priority to producing local information in strategic areas such as: policy and legal documents; reference and text books for primary and secondary schools; scientific documents and journals.' Canhos et al. (References, 17).

As new initiatives – often bottom-up, society-driven – emerge, organisation of academic publishing on the web will be required. The web visibility of these initiatives will best be raised by the establishment of umbrella sites for disciplinary or regional publications. In developing countries there may be benefits in the development of regional centres of expertise that can support e-pub training, act as an intermediary between publishers and host computers, and feed into umbrella sites.

It is likely that the structure will emerge gradually as initiatives evolve, the economic situation becomes clearer and the end-user community adjusts to the new environment. The EPT has considered the scheme shown in Figure 4.10 as a possible model.

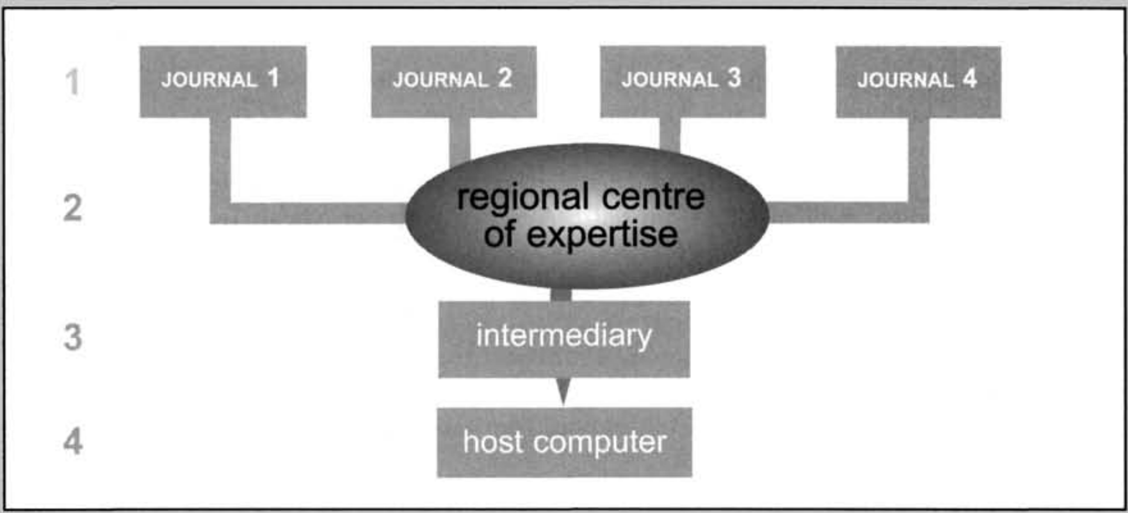

Figure 4.10 Electronic Publishing Organisation Model

References and World-Wide Web Addresses

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Notes

1 Journals from a country/region, or journals associated with a particular discipline.
2 Regional centre with experience in electronic publishing procedures; can act as training centre and also co-ordinate transfer of journals to host computer (probably through an intermediary organisation).
3 Intermediary organisation that standardises material into the specific requirements of the host computer (bibliographic referencing, file numbering, hypertext links, graphics formats etc); transfers all files to the host computer; manages user registration; handles subscriptions; returns income to publishers; manages usage statistics; provides general promotion.
4 Host computer and software development. Note: There may be various models of the above arrangement, depending on available expertise. The elements can be in different countries (cf. Bioline arrangements: publishers in several countries, the intermediary in the UK and the host computer in Brazil, each element providing specific expertise). More than one function could be combined at a single site. Such a distributed system makes best use of skills.