Communication and information technology in medical education

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The past few years have seen rapid advances in communication and information technology (C&IT), and the pervasion of the worldwide web into everyday life has important implications for education. Most medical schools provide extensive computer networks for their students, and these are increasingly becoming a central component of the learning and teaching environment. Such advances bring new opportunities and challenges to medical education, and are having an impact on the way that we teach and on the way that students learn, and on the very design and delivery of the curriculum. The plethora of information available on the web is overwhelming, and both students and staff need to be taught how to manage it effectively. Medical schools must develop clear strategies to address the issues raised by these technologies. We describe how medical schools are rising to this challenge, look at some of the ways in which communication and information technology can be used to enhance the learning and teaching environment, and discuss the potential impact of future developments on medical education.

Over the past few years, medical schools have substantially altered their attitudes with respect to computer facilities for students. Not so long ago, information technology was a term confined to word-processing, and medical informatics, if understood at all, was seen as a niche topic and an unwarranted drain on institutional finances. Within less than two student generations, communication and information technology (C&IT) has been repositioned as an integral component of the medical school environment. Two factors have contributed to this transition: the rapidly falling cost of networked computers and the advent of the worldwide web. Our most recent graduates started training before the internet became easily and universally accessible. Now, ubiquitous access to computers and the web at home and at school means that our new entrants have a degree of computer literacy exceeding that of some faculty members, and high expectations. Medical schools have invested heavily in computing facilities, not only to attract the best students but also because C&IT and informatics skills are seen as essential in a profession that is increasingly dependent on electronic information.

The maelstrom of activity engendered by the web and educational technology has affected every learning institution. Medical education, however, has some unique aspects, not least the learning that takes place during clinical care, and it offers opportunities to test methods of learning not used in other contexts. We outline how C&IT can be used to support learning and teaching in medicine, and discuss how the development of an all-pervasive, high-speed information and knowledge network could affect the traditional medical curriculum.

Campus networks and the internet

Campus-wide computer networks have transformed communications within medical schools. This infrastructure is increasingly being used for the provision of integrated learning and teaching environments, and e-mail is the medium of choice for communication between students and faculty. Most institutions allow unregulated access to the web. The internet provides a vast and rapidly growing source of information on anything imaginable, and some things best left unimagined. In terms of medical education, the web is an extremely important resource. However, the inherent nature of this new resource is largely unstructured and uncontrolled, which means that if students are to reap the most benefit they must learn how to use the web effectively, and manage the plethora of information that it can provide. The provision of a structured local environment from which to start will greatly assist in this task.

The “virtual campus”

Many institutions have developed virtual campuses on the web (panel), which are gradually taking over traditional paper-based administrative functions and the dissemination of teaching and learning materials. This development makes administration of large student cohorts increasingly efficient and has the opportunity for reducing costs, but only if carefully planned and not used simply to duplicate existing services. Close cooperation between academic and administrative staff and students is essential, and online feedback is an important component. As an example, the GKT (Guy’s, King’s, & St Thomas’ School of Medicine) Virtual Campus (www.kcl.ac.uk/gktvc) was developed as an all-inclusive joint venture (figure). Part of the impetus for the creation of the site was the greatly increased number of students after the merger of the GKT schools. Another consideration was that the new curriculum required most final year students to be off campus for extended periods, while training at district general hospitals and in the community. In the past, such students were disenfranchised from the support and learning resources available on campus. Initiatives such as the virtual campus can overcome this difficulty by providing an...
Examples of virtual campus sites and medical and biomedical gateways

**Virtual campus sites**
- www.kcl.ac.uk/gktvc
- omie.med.jhmi.edu/LectureLinks
- gmp.usyd.edu.au
- medical.faculty.ncl.ac.uk
- cvu.strath.ac.uk

**Guy’s, King’s and St Thomas’ virtual campus, King’s College, London**
LectureLinks, Johns Hopkins School of Medicine

**University of Sydney medical program**
University of Newcastle medical faculty
Clyde virtual university

**Medical and biomedical gateways**
- www.omni.com
- www.medic8.com
- www.medmatrix.org
- www.biomednet.com

OMNI Internet Resources for Medicine and Biocommunications
Medical web site directory and search engine
Medical Matrix: guide to Internet resources
BioMedNet: collection of resources and gateways for biomedicine

These sites are primarily provided for students and staff working within their respective institutions, and provide a wide range of course-specific resources and other useful information and links. Some areas are restricted to members of the institution.

The Clyde virtual university is a collaborative venture between several universities in the west of Scotland.

Easily accessible and consistent means of support for all students, whether they are on campus, at home, on placements, or on electives abroad.

Web environments are not limited to administration, however, and the most exciting and potentially important facet is the way in which they can be used to enhance the learning process itself. For instance, Johns Hopkins University School of Medicine, Baltimore MD, USA, began with a comprehensive website (LectureLinks, http://omie.med.jhmi.edu/LectureLinks) for the curriculum within the first year that the internet was widely deployed. Features included class schedules, full text lecture notes, and links for each lecture pointing to specific web resources suggested by fellow students or faculty. A recent project at GKT uses this type of functionality to improve students’ understanding of how each course element contributes to the core curriculum of essential medical knowledge. For example, selection on the timetable of a clinical module on treatment of asthma will create a thread linking resources directly coupled with this topic to relevant aspects of public health and primary care medicine, therapeutics, and basic science, and vice versa. This information will enhance the students’ ability to understand the topic as a whole, and brings true horizontal and vertical integration of the curriculum one step closer.

Structured use of the web is especially suited to problem-based learning and is exemplified by the comprehensive model implemented at the University of Sydney, Australia (www.gmp.usyd.edu.au). At this medical school, the problem-based learning programme is supported by mechanisms that guide students to patients’ data, including all clinical investigations (text and images), related lectures and practical classes, and laboratory resources (such as images from anatomy, histology, and pathology). Preliminary assessments of sites such as these show that they are very much appreciated by users and encourage students to adapt resources to their own needs, and tentatively suggest that knowledge is improved with repeated visits.

The development of such environments goes in two directions. In terms of depth, students want more material within each course. This requirement can be difficult to meet. Not all teachers are happy putting their material on the web (whereas others feel obligated to put as much work into web-based lecture notes as into published chapters) also, teaching content-management to staff is not a trivial matter (causing the process of turning word-processed and photocopied material into web-accessible files). Three levels of web-based material should be distinguished. Level one is similar to lecture notes: material that can be placed on the web as it is. Level two requires interactivity, linking multiple-choice tests with feedback or faculty assessments. Level three requires custom programming, such as animations or simulations—eg, the cardiovascular simulator developed at Johns Hopkins, http://omie.med.jhmi.edu/cvsim. In terms of breadth, these websites turn into “portals” that attempt to give students an appropriate perspective of the internet or local resources. LectureLinks, at Johns Hopkins, for instance, provides links to reviewed sites associated with each lecture in the curriculum. Searches on Medline or other databases can be “cached” (stored locally) to provide the user with up-to-the-minute search facilities and the opportunity to do keyword searches for sites that have been assessed and described by information and health-care professionals.
made much simpler by use of commercially available systems such as WebCT (www.webct.com) and Blackboard (www.blackboard.com). These sites are designed so that a course organiser with minimal C&IT skills can create a complete web-based module with little training. Such environments are in common use in the USA, and are making an impact in the UK.

**Learning environments and educational theory**

Changes of the kind outlined above have turned into action some important theories about students’ learning in professional settings. For example, situated learning emphasises the social nature of cognition and the importance of authentic situations and activities as ways of embedding learning.10 C&IT can tailoring the learning process to the individual student by providing teaching and support that respond to the learner’s immediate needs. It can also be used to bring experts to the learner, demonstrating skills that range from clinical reasoning to immediate or delayed repetition and by self testing, which helps the learner to make the new knowledge or skills explicit. These processes, essential to situated learning theory, put the student at the centre of the learning process, with a range of resources on hand to be used as needed, creating a huge number of different learning pathways and possibilities.

**Training in C&IT and information management**

Most medical curricula include C&IT training, although content can vary considerably. In the USA, the Association of American Medical Colleges has addressed the professional needs of future doctors as teachers, learners, clinicians, researchers, and managers, and has specified the informatics skills they should learn as students (www.aamc.org/meded/msop/informat.htm).11 An important aspect is that, increasingly, the clinical interaction itself is instrumented, with IT providing mediation between patient and physician. Whether it is a heart monitor, a digital stethoscope, digital endoscopy, or future “haptic (touch)-based interfaces, students must learn how to evaluate this data, much as a pilot must learn to fly on instruments. They also need the skills to use computerised patient-record systems and medical information resources.

Although online services such as Medline and sites set up by professional medical organisations provide powerful educational tools, the web has vastly increased the ease by which anyone can access published information. As such, the content of some so-called medical sites might be little more than pseudoscientific junk knowledge. This possibility has led to the development of criteria for quality assessment, based on credibility, content, links, design, and interactivity—eg http://hitweb.mitretek.org—and there are organisations that specifically act as portals to reviewed sites—eg, www.omni.com and www.medic8.com. However, the sheer volume of even reputable sources is a major difficulty. Every year more than two million new articles are published in biomedical journals.12 If students are to avoid feeling overwhelmed, they need the tools and training to find and evaluate the relevant data.13 The traditional role of the medical librarian is adapting to this challenge, and information specialists play a vital part in medical education by advising and training students in the use of resources and the construction of efficient search strategies.

Information management skills are a pivotal component of evidence-based medicine. Evidence-based medicine had become a key strand of the curriculum in Sydney, GKTI, and Johns Hopkins, as elsewhere, and is incorporated into many aspects of the course. Students are required to develop sufficiently sophisticated skills to meet the final objective: “to interpret results from clinical and population research, and decide how to apply these results to individuals or groups of people.” They are supported by information specialists and face-to-face tutorials, backed up by online access to locally produced guides, critical reviews of third party resources, the Cochrane database of systematic reviews, and evidence-based medicine reviews. The breadth-oriented resources mentioned earlier show the continuum between resources for problem-based learning, traditionally associated with early medical education, and sites for evidence-based medicine, associated with ongoing, clinical learning. In particular, the current “holy grail” of medical education development is an environment that uses the student’s or clinician’s interaction with the computer-based patient record system to afford a “teachable moment”.

**Computer-assisted learning**

The term computer-assisted learning is usually reserved for stand-alone teaching packages. Computer-assisted learning and so-called multimedia packages are often not found especially helpful by students. A large part of the problem stems from a failure to concentrate on good educational practice in the design of even technically sophisticated packages. Well designed computer-assisted learning can, however, be useful for conceptually difficult topics through use of interactive animations, video, and simulations. It is also suited to topics with a high visual (histopathology, anatomy) or aural (heart sounds)14 component, and has been used to supplement or replace traditional methods where the logistics for large student numbers are otherwise prohibitive. Key criteria for successful use of computer-assisted learning are that it closely approximates the course content, and that it is fully embedded and supported within the course. Proper assessment, not just on grounds of usability, is also essential to the design process.15

By contrast with classical computer-assisted learning packages, computer-based models for problem-oriented learning and clinical reasoning are simpler and cheaper to produce, and can be extremely effective. A good example has been developed at Sydney, with a simple “step-through” design, which uses a series of adjacent frames linked to a database. The program was chosen, in consultation with students, to represent the learning process as they experience it in clinical settings. Students can call up information to match the stages of the case described by clinical reasoning prompts. A complete case record, including students’ responses, can be generated at any stage. This type of development is both technologically straightforward and student-centred, and variations on this theme have been shown to be effective in several institutions.16,17

The advent of inexpensive high-power workstations is making possible the potentially extremely powerful method of interactive virtual-reality simulations.18 Virtual emulations of clinical procedures (catheterisation, laparoscopy, bronchoscopy, &c) are already used in some centres, and the development of haptics (tactile feedback) coupled with algorithms describing life-like tissue deformation make these all the more powerful, as for example, used in an angioplasty simulation.19 There are as yet relatively few controlled assessments of the benefits of training with virtual reality, though a recent study has...
shown that it can improve laparoscopic surgery skills.\textsuperscript{20} By contrast, there was no additional benefit recorded over traditional methods for training in venous catheter placement.\textsuperscript{21} Further research and development is needed before this relatively expensive technology becomes a mainstream teaching aid.

An example of computer-based teaching that is not web-based, and lies somewhere between virtual reality and the real thing, is the Harvey project,\textsuperscript{22} which links a computer with a mannequin for teaching cardiorespiratory medicine. Students can hear a heartbeat, measure blood pressure, and virtually inject medication, to see physiological responses in a close to real-life environment.

**Computer-based assessment**

Most computer-based assessment is still formative and based on little more than extended multiple-choice questionnaires. Although useful when coupled to instant feedback and learning resources, it is best suited to assessment of factual knowledge rather than understanding. Computer-based assessment is limited for summative assessment by difficulties concerning authentication of the candidate, and the number of workstations available at one place and time for formal exams. Nevertheless, there is keen interest in how computer-based assessment can be developed for medicine, as the technology could both reduce staff assessment load and, more importantly, increase consistency and objectivity of assessment. Hurley Myers from the University of Illinois has spent more than 10 years working towards a semi-automated method of evaluating students’ progress through a case. His most recent work is the clinical competency exam.\textsuperscript{23} A form of assessment that can really only be done properly with computers is computerised adaptive testing. In this powerful method, the selection of each question depends on the answer to its predecessors, so that the difficulty of the test adapts to each student. The student can thus be challenged without feeling frustrated by questions that are too easy or too difficult for their ability. An assessment of computerised adaptive testing for medical in-course purposes has shown that it not only maintains measurement precision of ability compared with traditional paper tests but is better received by students and takes half the time.\textsuperscript{24}

**Implications and dangers**

As C&IT becomes central to the activity of the medical school, and as student expectations increase, failure can have disastrous consequences. Such failure is not limited to hardware, but includes failure of content, poor security and protection against malicious attacks (hackers), and insufficient protection of patient confidentiality\textsuperscript{25} and of intellectual property rights. There is also the very real danger that such instant access could lead to a loss of demarcation between what is personally known or understood (personal knowledge) and what can be retrieved from the web (extrasomatic knowledge). As they discuss, this has profound implications for education. Once intelligent software retrieval agents and more sophisticated diagnostic support systems become a reality,\textsuperscript{26} the challenge for medical education will be to identify what kinds of information practitioners need to carry in their heads for everyday practice and what kinds of information are better accessed with evidence-based medicine tools. There is the inherent danger that in this challenge is not met then the latter will predominate, giving rise to a “just-in-time” knowledge culture.

Other challenges must also be met. As C&IT infiltrates and influences the medical curriculum, we should ensure that each new methodology is rigorously assessed for educational effectiveness, and, because money is important, for its cost-benefit ratio. Various centres are already examining the former, although wide variation in design and ethos often makes direct comparison difficult. Analysis of cost-benefit ratios should theoretically be easier, if only in terms of savings (or otherwise) in staff time. Currently, however, there are few published reports in this area. Moreover, apparent savings could be obfuscated by transfer of costs to other areas—eg, C&IT departments—and in the case of course materials placed on the web, the cost of photocopying could be transferred from the school to the student,\textsuperscript{27} the desirability of which is open to question.

C&IT can provide powerful tools for learning and teaching in medicine, and will alter the way in which the subject is taught. However, the pace of technological development and the drive to incorporate such technologies into the curriculum threatens to outstrip our understanding of how they can be used most effectively, and indeed the ability of our teachers to use them at all. If we are to avoid this, we must proceed on a firm basis of educationally sound design, rigorous evaluation of educational cost-effectiveness, and, above all, provision of adequate training for teaching staff.
References


