

Information technology in dental education

H. K. Yip,¹ and I. E. Barnes,²

The use of information technology in dental education is continually increasing. In this article, IT is defined, and its uses in teaching and learning explored. Examples of the appropriateness of multimedia teaching in dental education are given. Successful multimedia teaching, especially in clinical settings, relies on the proper use of IT and an implementation strategy. The applications of IT to curriculum development, computer-assisted learning (CAL), educational administration, dental practice, hospital administration, and clinical research are also considered.

Information technology (IT) comprises electronic systems that are used to create, acquire, process, store, retrieve, select, transform, disseminate and use vocal, pictorial, textural and numerical information. It is increasingly being used for educational development, including dentistry.

Following the case made by the Evidence-Based Medicine Working Group of the American Medical Association,¹ for the increased use of evidence-based medical practice there was a similar call by Richards and Lawrence for evidence-based dentistry.² There is an equal need for evidence-based dental education. This paper reviews the development of IT in dental education from the early attempts in the use of instructional technology to more recent developments in IT. Even now, there remains a lack of focus and global collaboration in research into the proper application of these ever-emerging instructional technologies. Despite the lack of a systematic approach to research in IT relating to dental education it is possible to identify a number of significant advances that have been made. These include curriculum development, educational management, dental practice

and hospital administration, and clinical research in relation to dental education.

The review aims to identify not only the advances and successes, but also to generate a view of the potential barriers and solutions to the implementation of IT in dental education.

Methodology

The use of advanced technology in instructional studies has been evolutionary and it is not possible to cover every aspect of its development. General education has a long history of research into IT and the literature is extensive. Only the most seminal references are included here. A CD-Rom MEDLINE search, and a hand searching followed by an additional CD-Rom Medline search

were carried out using various keywords such as information technology, information and communication technology, computer, education, dentistry and dental education. Advice was sought from the Centre of Advancement of University Teaching (CAUT), the University of Hong Kong.

IT in dental education

The ultimate aim of learning and teaching is to produce a creative thinker. The elements of text, sound and image can be used for group teaching, as in lecture theatre presentations, as part of a laboratory course, or for individualised learning where the presentation and manipulation of information is controlled by the participant.³ Despite advances in IT technology it remains true that the teacher is the prime. Teaching influences learning,⁴ and the exclusive use of computers and videos in higher education has been found not to come up to expectations.⁵ So, emphasis is shifting from asking 'which medium is the better teacher' — to the quest for what 'attributes' of various media might combine with learner traits under task conditions and performing demands, to produce different kinds of learning.⁶

Until recently there has, in general, been less emphasis placed upon the development and analysis of teaching method, such as the mastery of critical information and problem solving skills.⁷ In times of diminishing resource, added impetus is given to the development of IT.⁸ However, this approach has its own problems in that the information-base is currently doubling every 5 years, and will soon double every 4 years. Unless steps are taken to marshal and sensibly use this huge pool of knowledge we are at risk of being 'inundated with facts but starved of understanding'.⁹

Many of the earlier dental applications of IT were medical protocols modified to accommodate aspects of dental care, such as the provision of restorative and surgical treatments in outpatient settings.¹⁰ Medicine has greatly broadened its base, and computer systems developed for medical practice increasingly find an application

In brief

- There is an increasing use of information technology in dental education, for education and administrative purposes. Developments require to be further subjected to trial and evaluation.
- An understanding of the learner and the process whereby instruction is organised is critical for the successful implementation of information-technology based training and learning.
- The development of information technology can be constrained by cost, and lack of political will and support.

¹Assistant Professor, Faculty of Dentistry, The University of Hong Kong, Room 3B62, The Prince Philip Dental Hospital, 34 Hospital Road, Hong Kong SAR, China; ²formerly Professor, Faculty of Dentistry, Universiti Kebangsaan Malaysia, Fakulti Perigian, Jalan Raja Muda Abdul Aziz, KL 50300, Kuala Lumpur, Malaysia

REFEREED PAPER

Received 20.07.98; accepted 12.11.98

© British Dental Journal 1999; 187: 327–332

in dentistry. While the applications in dentistry may differ, the concepts, problems, technologies and training needs are common to both medicine and dentistry.¹¹⁻¹³ The application of IT to dental education, research, administration, and patient care has been labelled as dental informatics.¹⁴ This paper focuses primarily on the application of IT in dental education.

IT has moved on rapidly from a time when the desktop PC was used solely for word-processing, toward networked systems with access to shared information databases and with the capacity to transmit data electronically anywhere in the world.¹² Earlier reports of such sophisticated systems, often linked to the university network, came from the UK, US and Canada.^{15,16} The American Association of Dental Schools started to collate nation-wide information in dental education in 1988 and initiated several projects.¹⁴ Considerable advances have also been made in respect of national and international cooperation¹⁷ despite the lack of scientific published papers on the subject.

Undergraduate curricula

Protocols for problem-based learning curricula in dentistry, involving integrated instructional technology have already been developed, trialed and evaluated.¹⁸ The development of such programmes demands multi-disciplinary effort, and are expensive.¹⁹ In a review article, Tobin drew attention to the evidence supporting the effectiveness of technology-based teaching and learning, though he stated that there is no 'best' medium.²⁰ Rather, understanding the learner and the process of organising instruction would seem to be critical.²¹

Recently, the World Health Organisation²² concluded that dental education should be student-centred, and socially and culturally relevant. If a global perspective of dental education is to be achieved there must be a sharing of resources such as a standardised curriculum database which comprises curriculum scheduling information,

course outline information, and content keywords. Such a development would cross territories and traverse cultures. A standardised database would facilitate the preparation of schedules and accreditation reports. It would allow on-line access to all course outlines, so enabling collaborative planning between faculties which teach related subjects.

Another strategy is to place course material, images and text in a networked system within a dental institution (intranet), protected from outside access but acting as a channel to the external internet. Instead of conventional classroom teaching, course materials and class notes would be supplemented through the intranet, allowing quick and easy updating.²³

Information retrieval

The most comprehensive access to innovation and new knowledge comes from an examination of the published literature.²⁴ Following the development of new software and systems, many undergraduate scholars now undertake their own electronic searches. Even with limited training, the novice can retrieve around 60% of that which can be retrieved by an expert.¹⁰

Electronic mail and conferencing, extensions of previous technologies, offer significant benefits.⁵ The use of such telecommunication technology has been reported to be useful in undergraduate medical teaching²⁵ and dental education.²⁶ All types engage tutor and student (or student and student) in a two-way conversation and allow an audience of other students to listen to, or observe the discussion, by way of a telephone bridge, or a network.⁵ In conjunction with the formal introduction of a totally integrated problem-based curriculum (PBL) in the Faculty of Dentistry, the University of Hong Kong, in 1998, a centralised network, WebCT, is now being used to promote the use of electronic curriculum in dental education.

Electronic mail, conferences and list-servers are being used by academic insti-

tutions and dental speciality groups.²⁷⁻²⁹ Electronic resource systems such as DEIR were constructed and allowed access through the internet.³⁰ Electronic transmission of information is fast expanding and will soon supplement more traditional forms of communication in accessing information.³¹ Various packages are available on the internet as distance-learning materials (Table 1).^{32,33}

The use of distance education and telecommunications to support classroom-based instruction changes the dynamic between students and teachers, and the nature and location of the classroom. The use of these technologies is simple, once the basic skills have been learned.^{7,22} The proliferation of electronic venues for the exchange of scholarly ideas and research in dental education is challenging the traditional protocols of publication and review.

Postgraduate training

In recent years, GDPs and academics have resorted to electronic transmission of continuing dental education courses.¹⁴ Users will be able to download computer-assisted instruction programs, some of which contain simulated cases for clinical assessment and management. A practitioner's clinical acumen will, in turn, be assessed and a score generated together with a critique of his management approach. Databases in the UK have been developed for continuing education and postgraduate training for GDPs.^{34,35} Further to critical assessment of the program's structure and content, there is a need for IT support for GDPs to allow them best to use the programs for continuing education.³⁶ Such support might be used for re-accreditation and re-certification purposes for GDPs who require evidence of continuing postgraduate education.³⁷

Librarians' role

Dental librarians have traditionally been among the earliest adaptors and users of new information technology in academic centres. They have used computers for database searching since early 1970s.³⁸

Table 1 Various learning packages and useful websites in dentistry^{32,33}

Website address	Descriptions
<i>Organisations</i>	
http://www.derweb.ac.uk/bscd/index.html	British Society for CAL in Dentistry
http://www.derweb.ac.uk/	DERWeb (Dental Education Resource on the Web)
http://www.dentanet.org.uk/	Dentanet: details of CAL programs
http://www.pitt.edu/~cbw/dental.html	The Dentistry Homepage
http://www.sci.lib.uci.edu/~martindale/Dental.html	Martindales Virtual Dental Centre, USA
http://galaxy.einet.net:80/galaxy/Medicine/Dentistry/janicequinn/dentistry.html	Internet Dentistry Resources
<i>Dental schools</i>	
http://bharm.ac./dentistry/hot	School of Dentistry, The University of Birmingham
http://www.bris.ac.uk/Depts/Dental	Bristol University Dental School Home Page
http://www.elec.gla.ac.uk/TILT/D-Dentistry.html	Glasgow University TILT Group in Dentistry
http://www.umds.ac.uk/elsewhere/dental/denthome.html	United Medical and Dental Schools home Page
http://ch.nus.sg	Cyberspace Hospital
http://www.siumed.edu/dept/indes.html	Southern Illinois University, Problem Based Learning
<i>Other sources</i>	
http://www.butterworth.heinemann.co.uk/ortho/ortho.html	Butterworth Heinemann, packages in Orthodontics
http://www.signet.com.sg/~jonfantan	OMFR Dental Resources, Singapore
http://alumni.nus.sg/dental/main.html	Singapore based
<i>Discussion groups and journals</i>	
news.sci.med.dentistry	news
http://www.priory.co.uk/journals/dent.htm	Dentistry On-line
http://www.tambcd.edu/DentalCE/dsc	Dental Study Club On-line (Baylor College)
http://www.vol.it/dentistry/	Dentistry Tomorrow
http://www.odont.lu.se/projects/ADEE/	ADEE
http://www.derweb.ac.uk/bscd/bsjour.html	Journal of Computer Aided Learning of Dentistry

From using fax machines, to the use of networked computers for the creation of large databases (eg online catalogues) and the development of sophisticated teaching learning centres, librarians have been among the leaders of academic dental centres in the adoption of IT. Given their knowledge and expertise in IT, librarians can make important contributions to the design and development of an integrated system for dental education.

The administration and management of dental education

The academic setting, with its variety of teaching, research and outreach experts is an ideal context in which to test and further develop continuous improvement processes in management.³⁹ IT holds considerable promise of dealing with these problems in a comprehensive, reliable and efficient manner.⁴⁰⁻⁴³ Such information-based management plans have been shown by a number of workers

to be effective in tertiary institutions.⁴¹⁻⁴³ Clinical management systems can be used to record and analyse students' clinical performance with a greater degree of sophistication than has previously been possible. Performance criteria can be incorporated, as can the rater's calibration and the student's self evaluation.⁴⁴

IT and patient-care in dental institutions

IT offers the opportunity to evaluate and improve dental care in relation to dental education.^{18,43} An ideal patient administration system should be capable of producing returns quickly and accurately, at the very least, offering clinical audit, quality assurance and resource management. An example of the successful implementation of IT in patient administration is the DELPHI (Dental Education Logistics and Patient Health Information) system adopted by the Prince Philip Dental Hospital, of the University of Hong Kong. IT

was implemented at the planning stage of the Faculty between 1978 and 1982. The system was the same as that used since 1978 by the School of Dentistry in West Virginia, being transferred to the Hong Kong Dental Teaching Hospital in 1981.⁴⁵ This real-time system is called Odontics (Omnibus Dental On-line Treatment and Information Control System) and is primarily concerned with patient-management and the supervision of dental students. It is linked to a network of terminals in the clinics and reception desks. All stages of a patient's progress through the hospital are recorded, from registration, through screening and placement on a suitable waiting list, to assignment to a student. Thereafter, every appointment is recorded, as are all treatments given on each visit. Regular reports allow teachers to monitor the progress of students; and student achievement can be compared with predetermined goals. This is one of the most advanced dental hospital systems

available at present. The system is similar to many of those in use in UK hospitals.⁴⁵ Another commonly-used management system is DIANE (Dental Institute Area Network). The benefits of this system are that each operator has his or her subfiles, and valuable resources are controlled by the appointment system. The interested reader is referred to the paper on the subject by Smales.⁴⁵ A third system namely UCPA, has recently been favourably evaluated by staff and students of the Department of Child Dental Health at the Dental School in Cardiff.⁴⁶ Although computer systems for dental hospitals have steadily developed during the past few decades, there still remain problems to be solved if performance indicators and clinical budgeting are to be ideally achieved.

Barriers and solutions to the implementation of IT teaching and learning in dental education

The implementation of IT teaching and learning can be problematical for a number of reasons.

Computer software

Currently, there is a deficit of good educational software in dentistry and that which does exist is not indexed on the networks in the same way as journal articles or books. There is no effective distribution mechanism for much of the software, and there is no efficient means of finding reliable descriptive or evaluative accounts of the software. These problems have been identified in the report of the Computers in Teaching Initiative (CTI) of the UK.⁴⁷ There is also a vast amount of information available on the internet, but to be efficiently used good management systems require to be developed.

Knowledge

In reviewing the literature, Goddy⁴⁷ found evidence that knowledge of, and a proficiency in, the use of computers favourably influenced teachers' attitudes toward their use in teaching practice. Students' attitudes to computer-aided learning are also influenced by their computing confidence.⁴⁸ The trend is, encouragingly,

for students entering university increasingly to have more computing knowledge and skill than their predecessors.⁴⁸ Nevertheless, the need to teach basic computer literacy is increasing.⁴⁹⁻⁵¹ It has been suggested that specific information on IT should be incorporated into undergraduate curricula,⁵² and a course on IT is now recommended for new undergraduates by many universities, including the University of Hong Kong.

Limitation of space and time

Many dental institutions were not planned to accommodate the use of IT, and shortage of space restricts the range of IT that can be used.⁵³ The problem can be overcome to some extent by using centralised university facilities in the early years of undergraduate study. A recent initiative of the University of Hong Kong has been to encourage every student to own a laptop computer, the cost of which is partly offset centrally. Considerably less space is required than for desktop computers. In the study area, network ports are available for the students to access the networks and download information. The information that is available includes course calendars, course contents, course tools, reading notes, glossaries, bulletin boards, frequently asked questions, student assessments and course evaluations. The system has popularised the use of the network among students, and faculties are adapting to the challenge of harnessing the huge potential of IT with web-based teaching and learning.

Lack of resources and funding

The cost in time and money that has to be committed in order to produce material for new technologies can be significant and a barrier to progress, especially if new technologies are to be widely used and properly integrated.⁵⁴ However, this must be balanced against the advantages of the reduced instruction time required and the ability to distribute information easily to several locations.⁵⁵ In order to overcome the problem of cost, it may be necessary to 'start small'. Also, savings can be made

by sharing ideas and programmes between interest groups at institutional, national and international levels.

Perception and attitude

In his review, Goddy reported that in the 1970s, teachers had a more negative attitude toward computers than did the general public.⁴⁷ More recently, most, though not all of the same types of educator have expressed enthusiasm for, and have been positive about, the introduction of computer technologies into teaching and learning processes.

The production of good IT teaching material takes a great deal of time, and also often requires computing skills not possessed by the average clinician. Consequently, there remains a dearth of virtual reality instruction material for clinical techniques. It has been suggested that a positive step to encourage the development of IT might be to offer software developers and educational technologists the academic credits necessary for tenure and promotion on a par with basic science researchers.⁵⁶

Staff training

The integration of IT into dental curricula requires a body of teachers who can expose students to the full breadth of computer applications.⁵⁷ In an analysis of technology in Australian universities, it was suggested that many educators in the tertiary system think that they only have to purchase the equipment, put it in the schools and it will work.⁵⁸

In the absence of personal technical expertise, heavy reliance is placed upon technical back-up for the development and delivery of courseware.⁵⁹ Such resource is often scarce. A useful approach is for computer science and media resources departments within the university to undertake the responsibility for staff training in computer competence.⁵³ In Hong Kong University, the Centre for Advancement of University Teaching (CAUT) coordinates seminars and workshops throughout the year. It also sets up interest groups and publicises new IT techniques and technologies.

Planning and policy making

Within an institution, the application of IT may vary between disciplines and departments. Notwithstanding, it is helpful to define a general faculty policy.

In line with the goals that have been recommended by Cameron⁶⁰ to encourage the creation of departments or divisions of dental informatics in all dental schools, the University of Hong Kong has recently made a similar set of recommendations in relation to IT. The dental school has formed a Committee on Information Technology and Educational Resources to draw up and implement IT within the faculty.

Strategy for using IT

Technical prowess does not ensure successful IT teaching. Two further elements are essential: First, a central policy; seeking funds, providing academic vision, and coordinating departmental connections; and second, sufficient hardware.

In respect of IT, Oblinger^{61,62} has proposed the following strategies:

- Place pedagogy before the wizardry of IT
- Decide what types of media need to be incorporated into the programme
- Talk to those who are experienced in IT development
- Seek advice on the hardware and software that best meets needs and resource
- Understand the technical authoring skills and time requirements necessary for the achievement of goals, and
- Plan for staff and faculty training.

A cost benefit analysis will also help to design, implement and evaluate the use of IT (Table 2).

The future of IT in dentistry

IT will increasingly be used in dental education to:

- Build career technology skills
- Improve information gathering skills and opportunities
- Expand learning opportunities
- Increase communications between teachers and students
- Encourage more active and collaborative learning.⁶⁴

Table 2 Cost benefit analysis of the use of IT

Benefits
1 CAL can be carried out at the user's own pace, rather than dictated by someone else (eg a lecturer) ³³
2 Potential saving of time when using CAL based teaching materials ⁶³
3 Assist the faculty members in improving their instruction and at the same time, to keep the unit cost of instruction reasonable and constant ⁵³
Cost
1 Can be time consuming as well as costly ³³
2 Start-up cost can be high ³³
3 Users and producers of teaching materials in this form need to develop a different approach in order to use CAL effectively
4 It can take time to see efforts rewarded by appearing in the curriculum ⁶³

The sharing of resource through the internet and world-wide web will enable the wide and rapid spread of teaching and research technologies, and global collaboration.⁶⁵ The dental education environment should serve as a laboratory for testing and evaluating hypotheses about learning transfer, understanding, acquisition of conceptual linkages, and the computer-based technologies for teaching cognitive, perceptual and psychomotor skills. Strategic plans and guidelines for consortia require to be developed, IT conferences organised, research grants for future development earmarked, and awareness increased.⁵³ Similarly, new guidelines will need to be formulated in respect of IT for peer review and evaluation of teaching, scholarship, and service.

Conclusions

The use of IT in classroom-based instruction changes the dynamics between students and teachers, so improving effective learning. Successful multimedia teaching, especially in clinical settings, relies on the proper use of IT and an implementation strategy, including the consideration of such factors as computer literacy, staff training, awareness, incentives, planning, and policy making. Despite the several

constraints to its adoption there can be little doubt that IT in tertiary education will continue to increase as a result of increased exposure to the international network and incentives for overcoming the barriers. International collaboration encourages the sharing of ideas and the development of consensus. In the University of Hong Kong, the laptop initiative has popularised the use of network among students, while faculties are adapting to the challenge of harnessing the huge potential of IT with web-based teaching and learning. Consortia are also being set up to audit, review, and report on IT, so as to ensure progress in evidence-based learning in the new implemented problem-based learning curriculum. The future of IT in dental education will be of increasing importance.

The authors would like to thank Mr Jonathon Marsh, Centre for the Advancement of University Teaching, the University of Hong Kong and Dr Ian Hart, Director of Centre for Media Resources, the University of Hong Kong for helpful comments.

- 1 Evidence-Based Medicine Working Group. Evidence-based medicine: a new approach to teaching and practice of medicine. *J Am Med Assoc* 1992; 268: 12-17.
- 2 Richards D, Lawrence A. Evidence-based dentistry. *Br Dent J* 1995; 179: 270-273.
- 3 Andrew W F. Applied information technology: a clinical perspective. *Comput Nur* 1995; 13: 38-40.
- 4 Clark R E. Reconsidering research on learning from media. *Rev Educ Res* 1983; 53: 445-459.
- 5 Laurillard D. Rethinking university teaching: a framework for the effective use of educational technology. pp 159-161; 164-180; 210-256. London and New York: Routledge, 1993.
- 6 Clark R E, Salmon G. Media in teaching. In Wittrock M (ed) *Handbook of research on teaching*. 3rd ed. pp 464-478. New York: MacMillan, 1996.
- 7 Cohen P A, Forde E. A survey of instructional technology in dental education. *J Dent Educ* 1992; 56: 123-127.
- 8 Gibbon S Y. Learning and instruction in the information age. In White M A (ed) *What curriculum for the information age?* Hillsdale, N.J.: Lawrence Erlbaum Associates, USA, 1987.
- 9 Tedeco L A. Responding to educational challenges with problem-based learning and information technology. *J Dent Educ* 1990; 54: 544-547.
- 10 Crall J J. Informatics futures in dental education and research: quality assurance. *J Dent Educ* 1991; 55: 257-261.

- 11 Heathfield H A, Wyatt J. The road to professionalism in medical informatics: a proposal for debate. *Meth Inform Med* 1995; 34: 426-423.
- 12 Greenwood S R, Grigg P A, Vowles R V, Stephens C D. Clinical informatics and the dental curriculum: a review of the impact of informatics in dental care, its implications for dental education. *Eur J Dent Educ* 1997; 1: 153-161.
- 13 Hasman A, Sosa M. Education and training of health informatics in Europe. *Technology and Health Care* 1994; 2: 61-70.
- 14 Eisner J. Computer talk. Prospects for a new form of communication in the profession. *Can Dent Assoc J* 1987; 53: 108-111.
- 15 Eisner J. Instructional and information technology initiatives: the potential for delivery. *J Dent Educ* 1991; 56: 112-116.
- 16 Smales F. Personal communication, 1996.
- 17 Sally J J. The national and international dimensions of dental informatics. *J Dent Educ* 1990; 54: 599-600.
- 18 Johnson L A. Tools for technology assisted learning: teaching problem-solving skills with patient simulations. In Abbey L M, Zimmerman J L (ed) *Dental informatics: integrating technology into the dental environment*. pp 215-248. New York: Springer-Verlag, 1992.
- 19 Institute of Medicine. Dental education at the crossroads: challenges and change. pp 25-71, 99-100. Washington: National Academy Press, 1995.
- 20 Tobin J M. Evaluation and research frontier: what do we need to know? In Roberts J M, Keough E M (ed) *Why the information highway? Lessons from open and distance learning*. pp 201-225. Toronto, Trifolium Books, 1995.
- 21 Yip H K, Barnes I E. Learning and dental education. *Eur J Dent Educ* 1997; 1: 54-60.
- 22 Aldred M J, Aldred S E, Elliott R G, Seymour G J. Towards a resolution of the dilemma of assessment in problem-based learning. Proceeding of the 6th Annual Meeting of the South East Asia Association for Dental Education. 1995; 26-27.
- 23 Preston J D. The practice of dentistry, year 2005: a vision. *J Dent Educ* 1996; 60: 68-75.
- 24 Rudin J L. Computers in dentistry. *Compendium* 1993; 16: 866-872.
- 25 Norman J N *et al*. Telematics in undergraduate teaching. *Med Educ* 1995; 29: 403-406.
- 26 Eisner J. The developing electronic curriculum consortium. *J Dent Educ* 1990; 54: 598-599.
- 27 Eklund S A. Is it time for CONFER, a computer-based conference for dental public health? *J Public Health* 1988; 52: 525-529.
- 28 Weintraub J A, Eklund S A. Development of a computer-based communication network for a dental speciality group. *J Dent Educ* 1988; 52: 525-529.
- 29 Lang W P. An application of computer conferencing in dental education. *Int J Biomed Comput* 1992; 31: 221-231.
- 30 Lang W P. Considering a dental electronic information resource (DEIR). *Int J Biomed Comput* 1994; 35: 219-230.
- 31 Soh G, Keng S B. Applications of computer technology in dentistry. *Ann Acad Med* 1990; 19: 720-723.
- 32 Tan J, Leung D, Tay P. The use of the internet in dentistry. *Br Dent J* 1997; 182: 191-194.
- 33 Grigg P, Stephens C D. Computer-assisted learning in dentistry: a review from the UK. *J Dent* 1998; 26: 387-395.
- 34 Eaton K A. CAL for general dental practitioners: an evaluation of the current scene. *Healthcare computing* 1994; May; 97-102.
- 35 Long A F, Mercer P E, Stephens C D, Grigg P. The evaluation of three computer-assisted learning packages for general dental practitioners. *Br Dent J* 1994; 177: 410-415.
- 36 Mercer P E, Ralph J P. Computer-assisted learning and the general dental practitioner. *Br Dent J* 1998; 184: 43-46.
- 37 Juniper R P. Re-accreditation, re-certification and the postgraduate database. *Br Dent J* 1998; 185: 94-97.
- 38 Fuller S, Braude R M, Florance V, Frisse M E. Managing information in the academic medical center: building an integrated information environment. *Acad Med* 1995; 70: 887-891.
- 39 Hill F M, Taylor W A. Total quality management in higher education. *Int J Educ Manag* 1991; 5: 4-9.
- 40 Aronow D B, Coltin K L. Information technology applications in quality assurance and quality improvement, part 1. *Joint Commission J on Qual* 1995; 19: 403-415.
- 41 Aronow D B, Coltin K L. Information technology applications in quality assurance and quality improvement, part II. *J Qual Manag* 1995; 19: 465-478.
- 42 Saunders I W, Preston A P. A model and a research agenda for total quality management. *J Qual Manag* 1994; 5: 169-184.
- 43 Severs M. Clinicians and information technology. *J R Coll Phy Lond* 1990; 24: 258-259.
- 44 Edwards W S, Morse P K, Mitchell L W. AVLINE: a search source for audiovisual instructional materials. *J Dent Educ* 1979; 43: 693-696.
- 45 Smales F C. Computers in dentistry. In Abott W, Barber B, Peel V J (ed) *Information technology in health care*. pp B2.7.11: 1-24. Essex: Longman, 1993.
- 46 Oliver R G. Student and staff opinion of electronic capture of data related to clinical activity. *Eur J Dent Educ* 1997; 1: 25-29.
- 47 Goddy G. Tertiary educators' perceptions of and attitudes toward emerging educational technologies. *Higher Educ R&D* 1998; 16: 343-356.
- 48 Osman L M, Muir A L. Computer skills and attitudes to computer-aided learning medical students. *Med Educ* 1994; 28: 381-385.
- 49 Chadwick R G. Basic IT skills of dental undergraduates: a case for supplementary tuition at university? *Med Educ* 1997; 19: 148-149.
- 50 Jones R B, Navin L M, Barrie J, Hillan E, Kinane D. Computer literacy among medical, nursing, dental and veterinary undergraduates. *Med Educ* 1991; 25: 191-195.
- 51 Pao M L, Grefsheim S F, Barclay M L, Wooliscroft J O, McQuillan M, Shipman B L. Factors affecting students' use of MEDLINE. *Computers Biomed Res* 1993; 26: 541-555.
- 52 Bright G R, Hall III P W. Information technology in medical education: the case western reserve university experience. *J Am Med Assoc* 1995; 273: 1064-1065.
- 53 Craig J F, Moreland E F. The technology assisted learning environment. In Abbey L M, Zimmerman J L (ed) *Dental informatics: integrating technology into the dental environment*. pp 179-200. New York: Springer-Verlag, 1992.
- 54 Boddy G. Tertiary educators' perceptions of and attitudes toward emerging educational technologies. *Higher Educ Res Dev* 1997; 16: 343-356.
- 55 Knirk F G, Christinaz D. Instructional technology adoption in the best adult training organisations. Paper presented at the Annual Meeting of the American Educational Research Association, Boston, USA, 1990.
- 56 Abbey L M. Some comments on the state of dental informatics. *J Dent Educ* 1981; 55: 647-648.
- 57 Schleyer T K L. How should dental informatics evolve? *J Dent Educ* 1996; 60: 291-295.
- 58 King P M, Russell Y M, Davis-Harrison D. Integrating technology into continuing professional education. *Aust J Adult Comm Educ* 1995; 35: 157-163.
- 59 Dodson A. Studying by simulation strikes chord. *The Times Higher* 1994, September: 16.
- 60 Cameron D A. The AADS strategic plan for dental informatics. *J Dent Educ* 1990; 54: 593-594.
- 61 Oblinger D G. *Instruction to multimedia equipment*. IAT Publications, 1993.
- 62 Oblinger D G. *Multimedia across networks*. IAT Publications, 1993.
- 63 Carotte P, Davis L, Duffin R, Griffiths A, Walsh T. The development of two computer assisted learning (CAL) packages within restorative dentistry. *Computers in Teaching Initiative Centre for Medicine Update* 1996; 7: 8-11.
- 64 IT and T Task Force. Where are we in this university? The University of Hong Kong, 1998 (also sited on <http://www.hku.hk/caut>).
- 65 Aiton J F. The world-wide web: an interface between research and teaching in bioinformatics. *Disease Markers* 1994; 12: 3-10.