Published in final edited form as:
J Dent Educ. 2012 January ; 76(1): 142–153.

From Information Technology to Informatics: The Information Revolution in Dental Education

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Abstract

The capabilities of information technology (IT) have advanced precipitously in the last fifty years. Many of these advances have enabled new and beneficial applications of IT in dental education. However, conceptually, IT use in dental schools is only in its infancy. Challenges and opportunities abound for improving how we support clinical care, education, and research with IT. In clinical care, we need to move electronic dental records beyond replicating paper, connect information on oral health to that on systemic health, facilitate collaborative care through teledentistry, and help clinicians apply evidence-based dentistry and preventive management strategies. With respect to education, we should adopt an evidence-based approach to IT use for teaching and learning, share effective educational content and methods, leverage technology-mediated changes in the balance of power between faculty and students, improve technology support for clinical teaching, and build an information infrastructure centered on learners and organizations. In research, opportunities include reusing clinical care data for research studies, helping advance computational methods for research, applying generalizable research tools in dentistry, and reusing research data and scientific workflows. In the process, we transition from a focus on IT—the mere technical aspects of applying computer technology—to one on informatics: the what, how, and why of managing information.

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Keywords

information technology; informatics; dental informatics; dentistry; dental education; clinical care; research; review

This article examines one of the most significant changes ever to affect dental education: the development of information technology (IT) and informatics. In both large and small ways, the information revolution has fundamentally reshaped dental education. The seventy-fifth anniversary of the *Journal of Dental Education* is therefore an opportune time to take stock of these changes, but also to ask how IT and informatics will influence our future. Or, more to the point, to ask: How can we use IT and informatics to create the best possible future for dental education?

It is easy to be awed by the precipitous developments in information technology since the 1940s. While the concepts of computing predate the arrival of modern electronic computers by thousands of years, it was only in 1947 that the transistor enabled the miniaturization of computing devices we have grown accustomed to. In the 1960s, the invention of the integrated circuit, the basis of modern computer chips, set the stage for the microcomputer revolution.[1] Suddenly, we could produce computers in mass, at ever-shrinking sizes and ever-increasing capabilities. Today's mobile computing devices, each one of them many thousands of times more powerful than early computers, are tangible proof of this development.

At the same time, we went from transmitting digital data using 300 baud modems between mainframe computers to watching YouTube videos on smartphones. Hardware is cheaper and more ubiquitous, network bandwidth is more plentiful, and software applications are more powerful and varied than they have ever been. Today's worldwide computing and communication infrastructure, consisting of billions of microcomputers, Web servers, cell phones, and mobile computing devices, has realized Vannevar Bush's 1945 vision of a worldwide, networked store of knowledge.[2]

While the technical developments of IT were certainly impressive, more fundamental changes have happened at the generational, social, and cultural levels. As Don Tapscott chronicled in his book *Growing Up Digital*,[3] the "Net Generation," having grown up with digital media, is changing how we produce and consume information and how we think and interact. Our students arrive on campus immersed in and equipped with contemporary digital technologies in all their forms. They expect IT to be the fabric of life in dental school. Yet, they meet a faculty that is aging,[4] learned about IT late in life, and has struggled to integrate IT into the professional context for many reasons.

In response, dental schools and faculty members have launched many promising and useful initiatives and research projects involving computers. However, we need to ask ourselves what lies beyond the simple application of and fascination with IT. "Our school is completely paperless in the clinic" or "our faculty put all their PowerPoint lectures on Blackboard" are catchy but meaningless phrases. The real questions are these: How are we leveraging information technology to improve clinical care, education, and research? What

new ways of using data and information do we have to invent to achieve this goal? How can we measure these improvements? As we ponder these questions, we focus less on IT—the mere technical aspects of applying computer technology—and more on informatics: the what, how, and why of managing information. In the following sections, we examine developments and opportunities for clinical care, education, and research in light of this evolution.

Clinical Care

In the early 1980s, computing in dental schools took its cues from the processes and approaches used in hospitals and other large health care organizations. With a few notable exceptions, many schools first focused on computerizing billing. Often, these projects used mainframe or mini computers maintained by the hospital or the university computing services organization.

However, it soon became clear that concentrating on billing and insurance-processing left aside many other potentially beneficial uses of computers, such as tracking clinical student progress, documenting patient care, and supporting research operations with computers.[5,6] Realizing these goals was difficult for many reasons. Computing equipment and networking infrastructure required large capital investments; most dental schools did not have significant in-house information technology expertise; suitable commercial products were essentially nonexistent; and custom software development was expensive and fraught with high risk.

As institutional systems began to evolve from a purely financial to a more multifaceted and inclusive focus, in 1990 several dental schools founded the Consortium for Clinical Information Systems (CCIS) within the American Association of Dental Schools (AADS; predecessor of the American Dental Education Association, ADEA). The mission of the CCIS was to provide a forum for the design and implementation of clinic information systems using concepts of the computer-based oral health record; to exchange experiences in acquiring, designing, developing, or implementing components of clinic information systems; to promote the development of standards for the integration of clinical information systems components from vendors and schools; and to advance the state of the art of clinic information systems used in dental schools on a national basis. Early on, the consortium produced a monograph entitled *The Computer-Based Oral Health Record: A New Foundation for Oral Health Information Systems*.[7] The monograph articulated a comprehensive vision for electronic systems in dental education that, even to this date, has not been fully achieved. Its full text is available on the Dental Informatics Online Community (http://bit.ly/dentalinformatics-COHR).

With the founding of the ADEA Section on Dental Informatics in 1998, the early informatics work of the CCIS transitioned into the mainstream of dental education. Some schools pioneered innovative patient management systems developed in-house,[8,9] as others began to adopt commercial systems, such as those from General Systems Design, Inc. (www.gsdgi.com/), Quality Systems, Inc. (www.qsii.com/), Dentrix Dental Systems (www.dentrix.com/), and Exan. Today, Exan’s flagship product, axiUm, is installed in 75

percent of dental schools in North America (www.exangroup.com/axium/). axiUm provides comprehensive functionality for a school environment, including billing and insurance processing, patient registration, scheduling, an electronic health record, chart tracking, document management functions, student tracking, and administrative reporting. The rise of axiUm has, in turn, spawned another consortium, this time the Consortium for Oral Health-Related Informatics (COHRI; http://cohri.org/), which currently counts over twenty dental schools in the United States as members.[10]

As of 2011, electronic dental records (EDRs) are quickly becoming the "Swiss Army knife" of dental education: they are the central nexus for connecting data among educational, clinical care, research, and administrative activities. Yet, in light of their potential, EDRs are still primitive tools, despite a period of lengthy development. Current opportunities for EDRs in the dental school context include the following.

Moving electronic dental records beyond replicating paper

EDRs must evolve to support quality improvement, the application of best evidence to patient care, decision support, and the generation of new knowledge. To do so, we must move beyond the EDR's current primary function as a recordkeeping method that only marginally improves on the capabilities of paper (see Figure 1). The limitations and design flaws of EDRs, both in private practice[11,12] and the dental school environment,[13,14] are fairly well understood. Landmark publications in medicine have articulated how electronic records could improve clinical care.[15–17] A recent report of the National Research Council[17] recommended, among other things, that electronic patient records should be designed for human and organization factors and should support the cognitive functions of all caregivers, including health professionals, patients, and their families. Following the recommendations made in these and other reports will do much to make electronic records more useful to clinicians and patients than they are today.

Connecting information on oral and systemic health

An increasing volume of literature is highlighting the importance of the connection between oral and systemic health. However, one would not know this by looking at the way we manage health information. A large number of dental schools are physically located in the vicinity of hospitals and other health care entities, yet their respective electronic record systems are separate. Patients who have just seen their primary care physician for a medical checkup are subjected to a similar procedure when their student dentist takes the medical history. To support inter-professional collaboration in health care,[18] we need to determine what information different health care providers commonly need from each other, evolve our systems to meet those information needs, and ensure that the resulting EHR helps care providers in understanding information received from others.[19]

Facilitating collaborative care through teledentistry

Beyond simply sharing information about the same patients among different care providers, electronic records must begin to truly support collaborative care. To date, telemedicine and teledentistry[20] have failed to yield broad benefits, several high-profile, successful demonstration projects notwithstanding.[21–23] Many interventions—for instance, for chronic

diseases such as diabetes and heart disease, tobacco cessation, and obesity management—work best when supported by coordinated and collaborative care among several types of providers. EHRs should not only support the associated information exchange, but individual and shared decision making, workflow, and assessment.

Helping clinicians apply evidence-based dentistry and preventive management strategies

The 2000 U.S. surgeon general's report *Oral Health in America*[24] is credited for raising the nation's awareness of oral health and identifying poor oral health as a "silent epidemic" in our nation. Dental caries is the single most common chronic childhood disease, affecting the whole lifespan of individuals. In spite of the report's emphasis on oral health, it largely failed in influencing oral health policy. In 2009, the Institute of Medicine report *Advancing Oral Health in America*[25] recommended strategies for improving the oral health of the U.S. population. One major focus was preventing disease, rather than allowing it to manifest itself and then treating it. The report emphasized that prevention "may help to reduce the overall need for treatment, reduce costs, and improve the capacity of the system to care for those in need." It also suggested expanding preventive services by all health care professionals, including non-dental health care professionals. IT has the potential to play a crucial role in facilitating the development and application of preventive management guidelines for various oral diseases. The significant improvement in the delivery of care for diabetes and cancer screening are strong testimonies to the impact of computerized guidelines and reminders.[26,27] Similar results are possible in dentistry by integrating guidelines into EDRs in meaningful and productive ways.

In a recent article, we highlighted additional opportunities for improving clinical care through EDRs.[28] In that article, biometrics and signal and image processing figure prominently in acquiring data from and about patients, as does automated, semicontinuous data capture for data reported by clinicians. Automated record and text summarization could help clinicians interpret and sift through complex and voluminous patient records, as well as information received from elsewhere. 3D imaging and model construction would be of particular interest for dental diagnosis, treatment planning, and actual treatment, as already evidenced by the rapid growth of cone-beam computed tomography.

Education

Just as in the clinical care domain, education often took advantage of emerging technologies for its own purposes.[29] For instance, many educational applications addressed the visual nature of dentistry through images, cases, and instruction delivered through videodiscs and CDs[30] in areas as diverse as geriatric oral health,[31] orthodontics,[32] and tobacco cessation.[33] Simulations emerged to provide more realistic instruction for actual patient treatment, both in the form of preclinical simulation labs and case simulations.[34]

Simulations also began to support another important aspect of dental education: the development of psychomotor skills. Probably the most well-known system of this type is DentSim (Image Navigation Ltd., New York, NY; www.denx.com/DentSim/overview.html), a virtual reality system for instruction in restorative dentistry.[35,36] DentSim provides a "virtual" environment, in which students and instructors can assess their progress

towards competence in restorative dentistry on the computer. One study evaluating DentSim[35] found that students learn faster, arrive at the same level of performance, accomplish more practice procedures per hour, and request more evaluations per procedure or per hour than in traditional laboratories. However, students' attitudes were mixed. In a more recent study,[37] students' attitudes were more positive. Another example of simulation technology uses a Phantom Desktop (Sensable Technologies, Inc., Woburn, MA; www.sensable.com/) to help students acquire psychomotor skill for endodontics.[38]

The Tooth Atlas 3D (eHuman, Milpitas, CA; www.ehuman.com) is a different form of simulation. It is a software application designed primarily for education in dental anatomy for predoctoral dental and dental hygiene and assisting students.[39] It uses an innovative approach, including stereoscopic 3D models of teeth to help students understand 3D structures and their relationships (see Figure 2).

E-textbooks were another pioneering application in dental education. Early on, the VitalSource system (VitalSource Technologies, Inc., Raleigh, NC; www.vitalsource.com) offered a library of textbooks that students could read on the computer, annotate, and cross-reference. However, one study[40] found that student satisfaction with the system was limited, mainly due to the effort required for reading extensive amounts of text on the computer and perceived high costs. The results were mirrored in a recent report,[41] which showed that 75 percent of college students prefer hardcopy as opposed to etextbooks. However, the march towards e-books in general, and e-textbooks in particular, seems inexorable as an increasing amount of content is moved to digital format. Many other technologies, such as intelligent tutoring applications,[42] student response systems,[43] and lecture recording and broadcasting[44] have reshaped the dental education landscape already and will continue to do so.

A consistent challenge is how to adapt instructional goals and methods in response to the opportunities and challenges that new technologies present and how to integrate these technologies most effectively into the curriculum.[45] This challenge is magnified by the steadily increasing perfusion of the fabric of education with technology. Early on, faculty members' access to and use of technology were constrained due to cost, limited capabilities, and need for technical staff. Today, sophisticated technology is widely available, and new presentation, authoring, and recording tools provide significant flexibility to educators in how to present instructional content.

As a result, faculty members are faced with questions such as these: Which technologies have the potential to help improve and augment education? Which applications are just technological fads? And, more importantly, how should we use technology in novel ways for the benefit of education? Current opportunities and challenges include the following.

Adopting an evidence-based approach to IT use for teaching and learning

The evidence-based approach is being adopted broadly in clinical care, but is receiving a lot less attention in education.[45] Part of the problem is that a well-developed infrastructure for generating evidence from the primary literature, such as the Cochrane Collaboration for clinical care, does not exist in education. While some resources compile best practices,[46]

finding evidence on what works and what does not is difficult.[47] In addition, evaluation research in education faces numerous challenges that require rigorous and sophisticated research methods.[48] To inform our choices for educational interventions, we need to augment the base of currently available evidence. Contributing to this evidence base may be an opportunity for teaching faculty members who otherwise have little or no opportunity to conduct research.

Sharing effective educational content and methods

How can we most effectively develop and share content, tools, applications, curriculum integration approaches, and strategies in dental education? Multiple factors, such as cost-cutting, the faculty shortage, and emerging methods (such as evidence-based dentistry) or content domains (such as dental informatics), essentially are forcing schools to share. Three current sharing mechanisms are MedEdPORTAL (endorsed by ADEA; www.adea.org/mededportal/), ADEA's Curriculum Resource Center (www.adea.org/crc/), and Universal Dental E-learning (www.udente.org). These platforms increase efficiency and facilitate access to teaching materials, increase resource quality through peer review, and allow faculty members to receive recognition for their work.[49]

Leveraging technology-mediated changes in the balance of power between faculty and students

The Web 2.0 and new media have fundamentally changed how we produce and consume information. Anyone, whether student or faculty member, can be a content producer, consumer, or commentator. Social channels are beginning to overshadow traditional search and retrieval in how we search for and receive information. The balance of power between the faculty as the sole provider of authoritative information and the students as pure consumers has shifted. This change requires faculty members to rethink how we can best use technology to educate students to think and read critically, express themselves clearly and persuasively, and solve complex problems.

Improving technology support for clinical teaching

Clinical teaching, which arguably comprises the majority of the time students spend in a teaching situation, is ripe for a complete rethinking in the context of technology. The key question is how we can exploit the capabilities of the software and hardware that are widely deployed throughout dental clinics to leverage methods that have been proven successful in educational research. These include scaffolding techniques for students and teachers; providing students with self-assessment tools; delivering educational content in the context of student level, patient characteristics, and instructional goals; and helping calibrate guidance by faculty. Yet, reality lags far behind. In most schools, access to the Internet (and, therefore, many useful educational resources) is severely restricted or impossible in the clinic due to security reasons. axiUm provides assessment forms, but no capabilities to integrate educational content. Existing clinical policies, which could be integrated into the workflow, are enforced in highly variable fashion by the mix of full-time and part-time faculty members.

Building a learner-centered information infrastructure

Instead of continuing to build information silos, we should begin to center the information infrastructure for learning around the student. At present, the materials that learners either receive or produce during their education vary in content, format, and platform. For instance, course syllabi, slide presentations, electronic books and papers, course discussion lists and blogs, and lists of references typically exist in different places, with different constraints on availability and accessibility. The fact that most materials can be "tied together" through the Web interface of a learning management system is scant consolation. The simple fact is that it is difficult, if not impossible, for most learners to create and maintain a comprehensive and organized portfolio of their learning materials as was possible in the paper world. We need to help learners create, maintain, and enhance their personalized store of learning experiences in a systematic, easy-to-use, and predictable way.[50]

Integrate systems for learning and teaching from an organizational perspective

A similar lack of integration also hampers teaching from the organizational perspective. At many schools, the systems that support teaching are poorly or not at all integrated. Such systems include registrars' student information systems, learning management systems—e.g., Blackboard (www.blackboard.com/) and Sakai (http://sakaiproject.org/)—intranets, student grading and tracking functions in axiUm, and standalone applications. The absence of a 360 degree view of students' progress and accomplishments hampers faculty and administrators in identifying individuals who have attained the desired level of competence, as well as those who need intervention and remediation.

Research

The use of information technology in dental research may be the least developed when compared to clinical care and education. Research in any biomedical domain has, historically, been viewed as idiosyncratic and specialized. Thus, researchers not only have developed their own research objectives and methods, but also their own ways of supporting them with IT. It is telling that Microsoft Excel is the most common tool for managing research data in biomedicine. Excel takes a lowest common denominator approach to entering, managing, and analyzing research data. It is fairly simple, widely available, and easy to learn and manage for the individual researcher, and it facilitates data exchange. It is also woefully inadequate for managing most research data.

During the last few decades, research has become significantly more complex and so have the requirements for IT to support it. Few dental schools have the resources necessary to maintain dedicated IT staffing for research. Yet, attempting to support research in dental schools with generic IT staff is, more often than not, a recipe for failure.

The requirements for collecting, managing, and analyzing research data have become more complicated for several reasons. First, we are acquiring research data at ever-increasing rates, primarily using automated equipment, such as gene sequencers, microarrays, and imaging devices, such as ultrasound and cone beam computed tomography. These devices generate huge volumes of data, and managing this output requires a sophisticated computing

infrastructure, including high-volume, reliable digital storage and high-speed communications. Second, federal regulations, such as those governing human subjects research as well as clinical patient data, have become more stringent and complicated. As a result, managing access, de-identification, and security for research data has become more difficult, and the stakes for failure have become higher. Last, the expectations for management, access, sharing, and reuse of research data have grown significantly. For instance, most grant applications to the National Institutes of Health must now include a data management and sharing plan.

These developments have, in the aggregate, made it more difficult for dental schools to manage research using IT. Yet, as potent contributors to generating new knowledge, dental schools should consider the following opportunities with regard to research.

Reusing clinical care data for research

To date, dental research, especially as conducted at dental schools, has made very little use of existing clinical data. Reusing clinical data is not only beneficial and advantageous for some types of research studies; it is essential for others, such as comparative effectiveness research. Several recently implemented systems in medicine have demonstrated that reusing patient care data for research is feasible and useful.[51–53] For instance, the Shared Health Research Information Network (SHRINE; http://catalyst.harvard.edu/services/shrine/) project at Harvard helps researchers overcome one of the greatest problems in population-based research: compiling large groups of well-characterized patients. SHRINE is useful for generating new research hypotheses, assessing the feasibility of studies, and identifying patient cohorts for clinical trials.

In dentistry, the reuse of clinical data for research is only in its infancy. Projects are typically conducted ad hoc, without a comprehensive and systematic infrastructure, and/or methodology for data representation and retrieval. For example, a recent study on oral bisphosphonate use and the prevalence of osteonecrosis of the jaw used data from an electronic dental record system (axiUm) to identify patients with a history of alendronate use.[54] In 2004, investigators in New Zealand used computerized data collection systems of school dental services to examine the relationship of water fluoridation to dental caries experience.[55] A current project at the University of Texas Health Science Center at Houston, the Oral Health Data Repository, seeks to aggregate clinical data from four dental schools into a user-friendly and secure repository that allows end users to explore and extract information to support their specific research and/or decision making needs.

Helping advance computational methods for research

Computer science, information science, statistics, biomedical informatics, and other fields are driving significant advances in computational methods for analyzing and processing data. For instance, machine learning, once an obscure branch of artificial intelligence, is now used for text mining, data analysis, medical diagnosis, and hypothesis discovery.[56] We must find ways for researchers in dental school to efficiently discover, apply, and help refine the computational methods that will drive future discoveries. This means that dental faculty members and researchers need to connect to informaticians and computer and information

scientists who may be able to help solve interesting dental problems. One of the ways of doing so is to search for collaborators with the right expertise broadly, for instance using recently developed research networking systems.[57,58]

Applying generalizable research tools in dentistry

A trend related to generalizable research methods is the emergence of generalizable research tools. For instance, several dental schools have developed proprietary data management applications for clinical, epidemiological, or survey data. This approach is inefficient and a suboptimal use of the scarce resources available for research. As a consequence, the National Institutes of Health and other funding agencies are promoting the development of tools that are flexible, widely available, and can be adapted to many research tasks. One such tool is REDCap (Research Electronic Data Capture; http://project-redcap.org/),[59] a Web-based tool for capturing data for research studies. REDCap has been used for more than 22,040 studies with over 31,230 end-users within the REDCap consortium, which comprises 273 active institutional partners in the United States and other countries.

Reusing research data and scientific workflows

Just as reusing clinical data for research makes sense, so does reusing existing research data and scientific workflows. One example is the National Institute of Dental and Craniofacial Research-funded FaceBase Consortium, which offers an integrated, one-stop source for data sets related to craniofacial development (currently focused on cleft lip and palate).[60] The FaceBase Website (https://www.facebase.org/) offers many different data sets, such as gene and protein sequences, as well as image data, for human, mouse, and other organisms. A key objective of FaceBase is not only to make different data sets available in a central place, but also to stimulate research that leverages the availability of these data sets. An example of the reuse of scientific workflows is MyExperiment[61] (www.myexperiment.org/), a virtual research environment that allows participants to share their workflows and annotate and comment on them within a social network context.

As the discussion of IT in clinical care, education, and research has shown, focusing merely on the technical aspects of how computers can support specific activities in dental education is too narrow. Informatics is crucial to inventing new ways of using data and designing information technology systems to solve domain-specific problems. New informatics disciplines, such as education informatics[62] and research informatics,[63] are joining the more established field of clinical informatics.[64]

Moving to a Higher Level in IT Use Through Informatics

While the concept of dental informatics has a fairly long history,[65] its practical implementation has lagged behind its theoretical development. Most, if not all, dental schools in the United States have information technology support departments, or at least some IT support staff, but very few employ formally trained informaticians. That is a problem for a number of reasons. Information technology staff are experts in IT, while dental faculty and staff are experts in dentistry. However, putting the two groups together in the context of a dental school does not guarantee success in using IT. Dental clinicians,

educators, and researchers do not speak the same language as IT professionals, and many schools fail to bridge that gap. Another key problem is that existing computing technologies do not automatically fit the requirements of dental schools. If computerizing dental school operations were a simple matter of selecting a few off-the-shelf software applications and hardware components and integrating them well, IT would by far not be the challenge it is.

While very little literature on the requirements for and success of computerization in dental schools exists,[13,14,65] anecdotal evidence suggests that there is significant room for improvement in how they use information technology. Dental informaticians can provide the integrative vision and strategic guidance for these improvements. They, like their counterparts in medicine, are individuals trained in both the clinical/academic discipline and information science/computer science. Optimal IT systems design and use require a clear view of the requirements of educators, clinicians, and researchers, tempered by an appreciation of the capabilities of and resources available for IT. Dental informaticians can function as mediators/arbitrators when it is difficult to bring requirements into alignment with constraints.

Dental informaticians can fulfill several roles in a dental school. First and foremost, they can serve as leaders of IT support departments. In the capacity of chief dental information officer (CDIO), they are comparable to the chief medical information officer (CMIO), a type of position increasingly common in medical schools and hospitals.[66] The increasing importance of the CMIO was recently formally acknowledged by the fact that the American Board of Medical Specialties recognized clinical informatics as a new specialty in medicine.[67] The CDIO can also handle educational, research, and administrative computing.

Aside from operational responsibilities, dental informaticians typically have a research program or agenda of their own. As the discussion in this article has shown, computing in most aspects of the operation of dental schools is immature at best, with significant opportunities for growth and innovation.[68] Dental informaticians can establish and/or guide research programs that enhance the quality of computer applications available to their and other dental schools, as well as dentistry in general. Finally, dental informaticians can help in educating predoctoral students and residents about IT and informatics. Dental practitioners face many of the same challenges in implementing computer technologies as dental schools do, only on a smaller scale. Without the requisite skills and knowledge, dental graduates are un- or underprepared for managing information technology in their offices successfully.

Conclusions

Many voices, ranging from the Gies[69] and IOM[70] reports on dental education to the Macy Foundation study[71] and the meetings of the Santa Fe Group, and even most articles in this issue, have advocated for positive and constructive changes in the dental education environment. Information technology and informatics are key to facilitating many of these changes. A major challenge for dental schools is that they must maintain and balance a complex mix of activities, including clinical care, education, research, and administration. This operational complexity, in turn, begets computational complexity.

Existing models for computerizing educational institutions in health care only partially serve to inform our efforts in dentistry. Our close cousins, medical schools, tend to be organized quite differently since they typically do not own and/or operate their clinical facilities.[72] A large segment of dental school IT activities—e.g., supporting clinical care with computers—is essentially outsourced in medical schools. Despite this complexity, it is important that each school pursue its own unified vision for information technology and informatics. The center of that vision should be its users: students, faculty, and staff. Few computerization efforts in dental schools have had, historically, a user-centered focus. In most instances, the center of attention for computerization has been the business function. This approach has created the information silos that partially impede and/or stymie efficient and effective operation. We need to craft and pursue a new vision that focuses on the needs of the individual and arranges information technology resources and functions around those needs.

In doing so, schools must make judicious decisions about when and how to invest in IT and/or informatics.[73] In times of significant fiscal constraint, such investments must have measurable and demonstrable benefits. As computer hardware increasingly becomes a commodity and many services transition to the “cloud,” the key questions for IT investments center not on what hardware and software to buy, but rather on how the purchase will support the mission and goals of the organization. The paucity or absence of hard proof for the benefits of such investments requires that these decisions be made with some degree of uncertainty. However, they should be as informed as possible by existing evidence at hand, tempered by the knowledge that potential payoffs do not come without risk.

Dental informaticians can bridge the gap between dental school faculty, staff, and students and information technology experts and guide IT investments meaningfully. To do so effectively, dental informaticians must participate in school administration in senior leadership positions. As the past has shown, pigeonholing dental informatics into random dental school departments is not conducive to realizing its benefits. As the cadre of well-educated and qualified dental informaticians is slowly growing, it is to be hoped that dental schools will avail themselves of their services. In the future, the competitive advantage of dental schools will be intimately connected to how successful they use information technology. Informatics is key to ensuring that success.

Acknowledgments

We would like to acknowledge the input and suggestions of several colleagues on the manuscript of this article.

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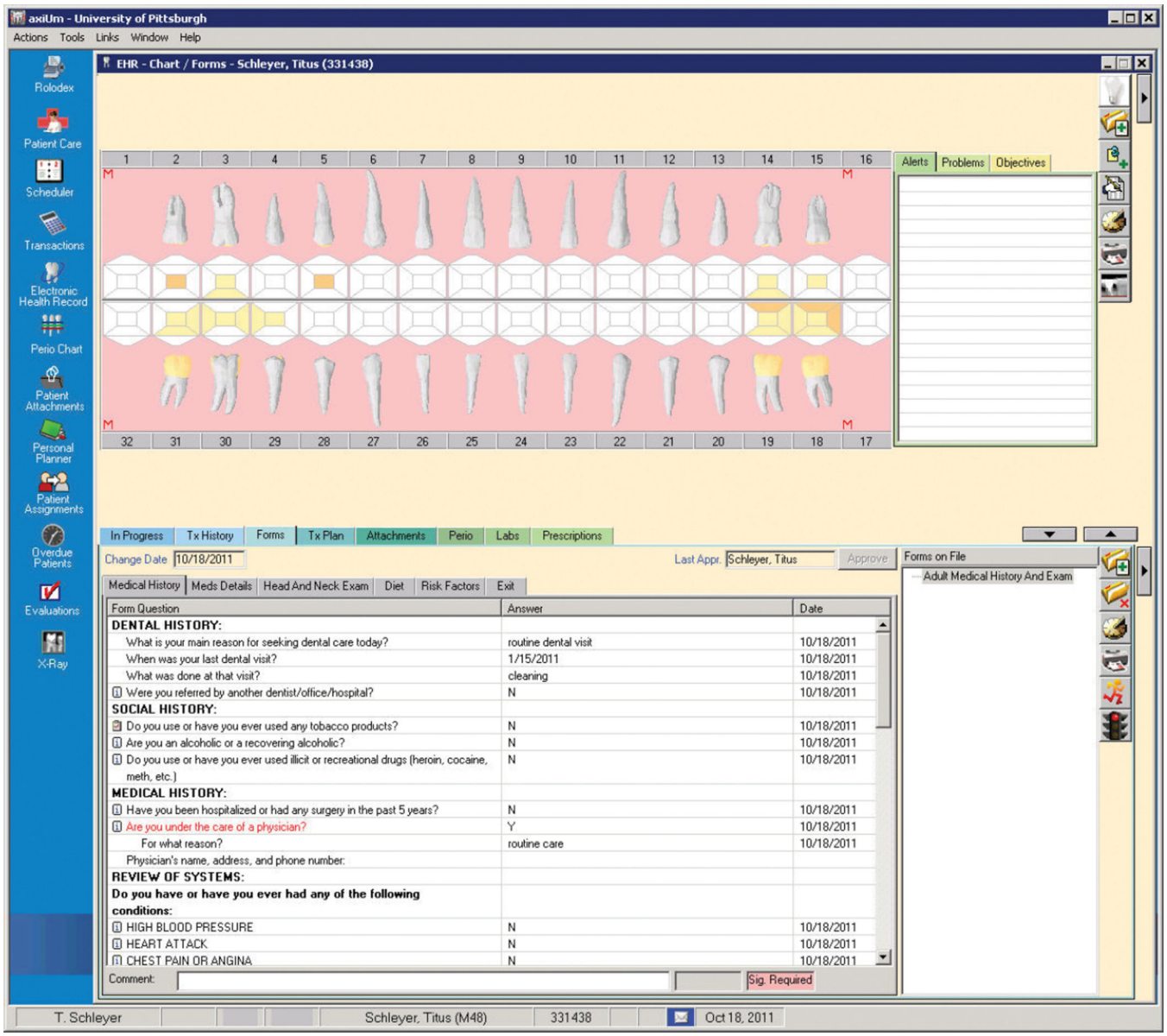

Figure 1.

Primary electronic health record screen of axiUm, which replicates the corresponding paper forms without enhanced functions, such as retrieval of EBD information and decision support

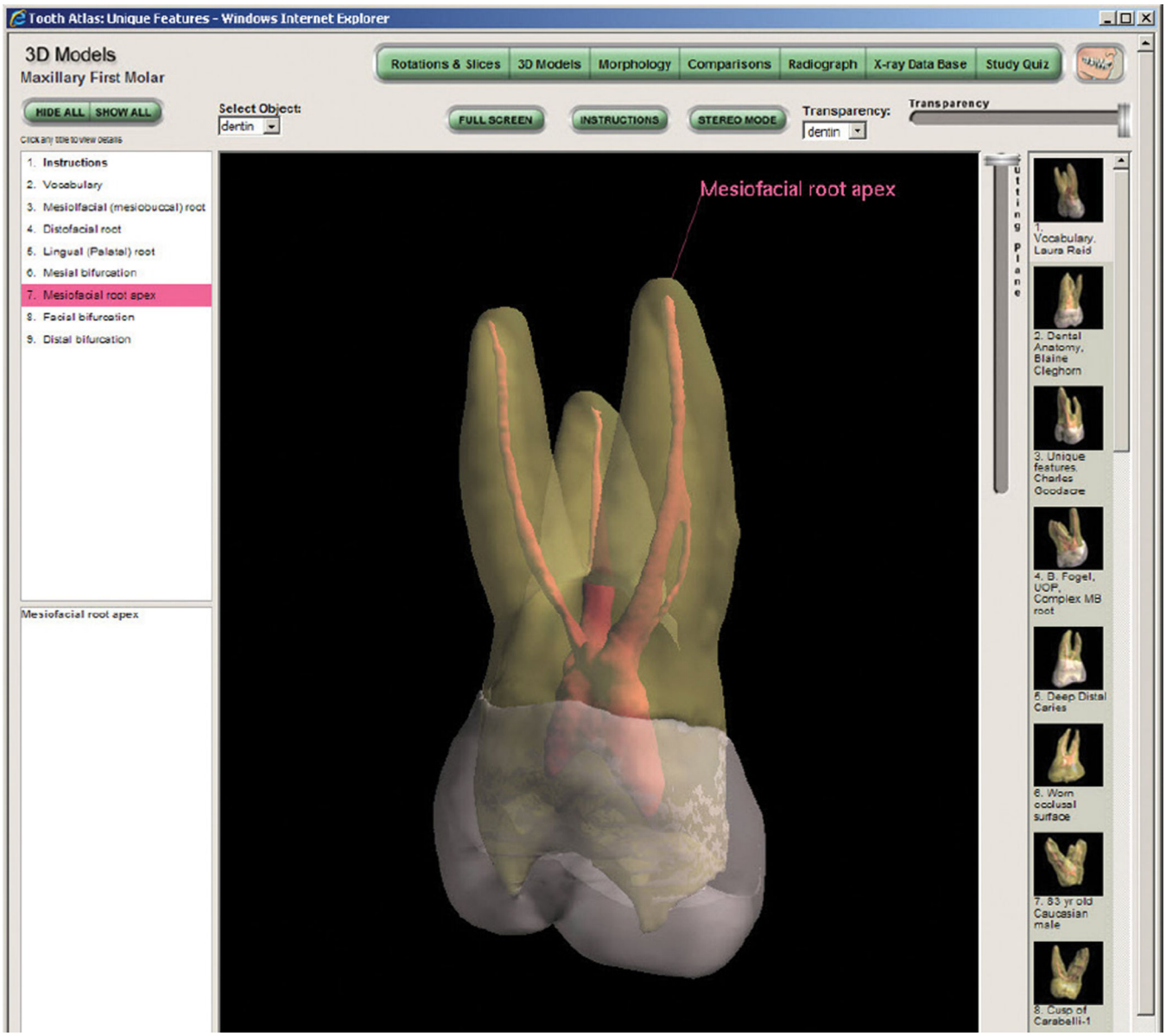

Figure 2.
The Tooth Atlas 3D allows students to explore dental anatomy in three dimensions