Transforming Medical and Health Science Education at Tufts University

The Tufts University Health Sciences Database combines course delivery, digital library, knowledge management, and curriculum management systems

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For more than a decade, traditional approaches to health science education have been called into question by complex political, social, and technical forces. Major factors underlying these forces include

- significant changes in our nation's health care system,
- the exploding volume of health sciences information (for example, more than 20,000 health-related Web sites at last count),
- the extensive number of scientific discoveries, and
- increased societal expectations for health care delivery.

In addition, the advent of managed care has led to a greater focus on health maintenance, prevention, and cost containment. Consequently, less emphasis is placed on broad medical training for physicians. The multi-faceted nature of today's major public health issues, such as those related to the environment, also affects health science education. Solving these issues requires educating veterinarians, dentists, physicians, and public health practitioners in new ways, transcending profession-specific boundaries.

Creating the Solution

During the mid 1990s, Tufts University recognized the need for major shifts in how health science course
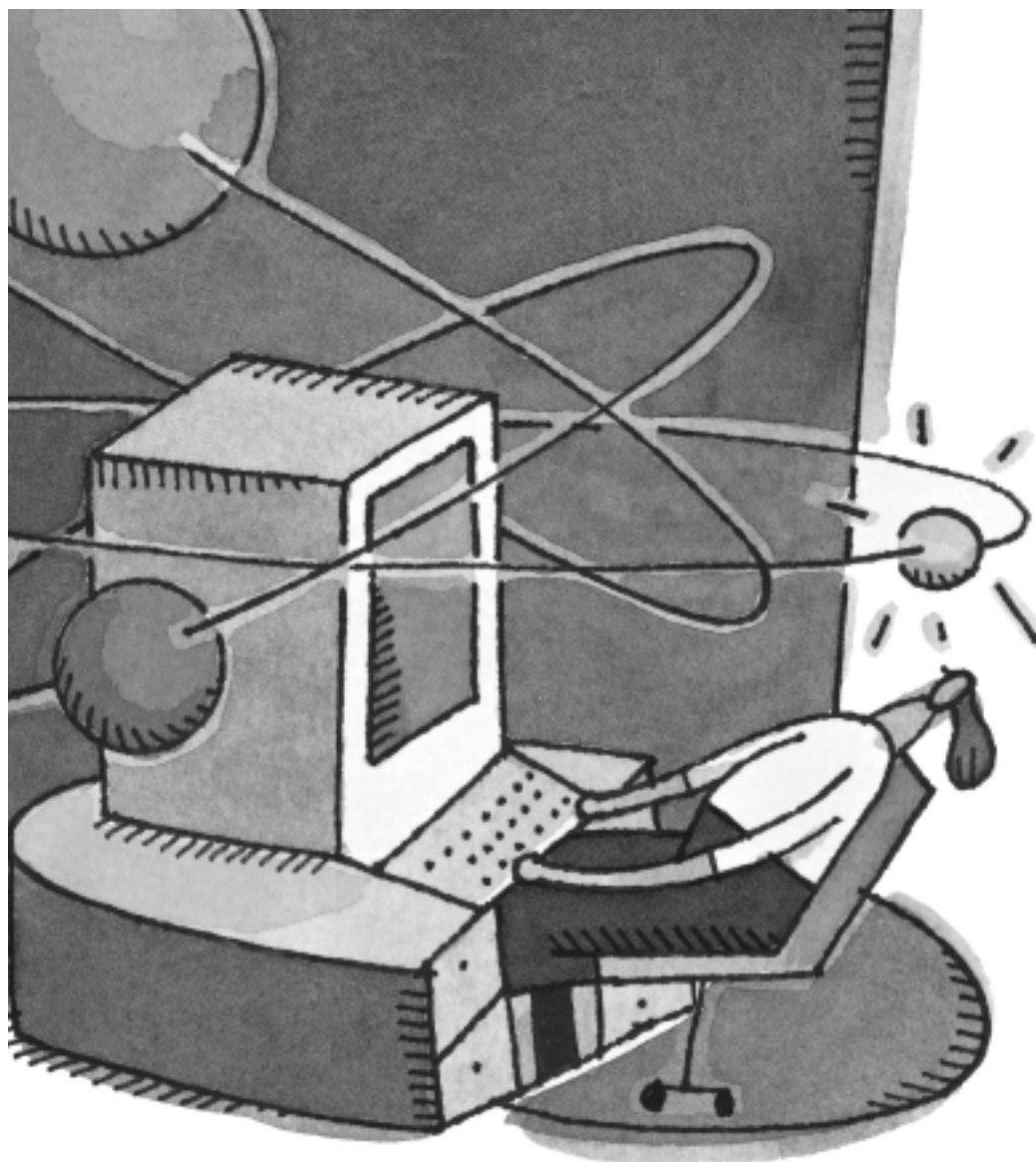
material is managed, kept current, and integrated into the curriculum. The medical school dean's office and the health sciences library led the university's efforts to develop a dynamic new educational model based on the latest advances in information technology. Startup funding from the National Library of Medicine and the medical school enabled a dedicated project team to create the Tufts Health Sciences Database (HSDB) — the first Web-accessible, multimedia database of health science curricular information.

Prior to bringing the initial version of the system online in September 1997, the HSDB team held a number of focus group sessions with faculty and students to determine how technology could best help them teach and learn. Based on these meetings, the team developed a plan of action. The HSDB would first contain a library of digitized images of high-demand laboratory slides that faculty used in key courses attended by hundreds of students. Next, the team included more extensive course content in the system by forming partnerships with select faculty who had already taken the initiative to start their own digital curriculum projects.

Now in its fourth version, the HSDB has grown considerably since its introduction. The present system contains a vast array of health science curricular materials, innovatively combining the capabilities of a digital library, course delivery system, knowledge management system, and administrative curriculum management system. Over the past few years the HSDB's content has expanded beyond the medical school to include course material from other health science schools at Tufts, including dental and veterinary, and the graduate school of biomedical sciences.

Table 1 shows the growth of the HSDB over a four-year period.

As the table illustrates, the number of courses in the HSDB increased from 23 in the first year to 125 this past year. Currently, more than 1,000 students in Tufts' medical, dental, and veterinary schools use the system extensively. The HSDB now contains approxi-

Table 1		
Growth in HSDB Usage		
Academic Year	Number of Courses	Number of Hits
1997–1998	23	84,000
1998–1999	45	560,000
1999–2000	106	823,000
2000–2001	125	1,700,000

mately 70 percent of the medical school curriculum. The system includes 20 veterinary school courses (compared to 2 the first year) and 42 dental school courses (compared to 3 the first year). The HSDB contains more than 15,000 documents and images in addition to the courses. Current plans call for including 100 percent of the courses in Tufts health science schools in the HSDB over the next two to three years.

By the HSDB's third year of operation, usage statistics began to show the desired effect of integration across years of study, courses, and schools. For example, when asked, medical students indicate they are reviewing last year's material, and dental students say they are studying basic science courses, posted by both the medical and dental schools.

Faculty look in the system to see where else in the curriculum particular material is being taught, helping them determine what links they can create or what material they can refer to. Custom-developed XML authoring tools provide a drag-and-drop utility, enabling faculty to search the HSDB for images and text across courses and schools. Using these tools, faculty simply drag selections from the search into their current document.

Examples of content sharing abound. Medical, dental, and veterinary histology courses now share image collections. Veterinary and medical physiology courses share a set of 700 review questions. And the dental gross anatomy course is referenced in the medical gross anatomy course and vice versa.

The speed of the HSDB's adoption is largely attributable to a shared vision by faculty, administrators, and the project team. The vision upheld the HSDB as a powerful, integrated tool that delivers health science curricula in new, more effective ways. As their familiarity with computers increased, faculty became more interested in using the new system for course presentations, particularly slides, videos, other images, and audio. Faculty wanted to learn and become experts; the HSDB staff provided needed support and training. School curriculum committee members, department chairs, and key senior administrators all became enthusiastic supporters of the HSDB, forming a core advisory group and encouraging faculty across all health science disciplines to make maximum use of the tool.

Today, the HSDB's initial core advisory group has evolved into a university-wide steering committee, providing effective oversight. Membership consists of key people from all health science schools at Tufts, including faculty, department chairs, academic administrators, financial personnel, and representatives from the information technology council, the university's primary IT governing body. Responsibilities of the committee include determining the HSDB budget, allocating resources, dealing with copyright issues, and deciding on courseware development timetables.

Confirmation of the HSDB's excellence comes from a number of sources external to Tufts. For example, the Association of American Medical Colleges (AAMC) recently selected Tufts School of Medicine as one of the ten top schools recognized for innovation in medical education, due in large part to the HSDB and the curricular reforms that the system enabled.

Dr. Jordan J. Cohen, president of the AAMC, lauded Tufts' innovation:

The Tufts education database system permits faculty and students to teach and learn in exciting new ways. As the scope and complexity of medicine and health care have exploded, medical schools

across the country have respondeed, using the newest technology — computers, software, and digital images — in serving their oldest and most important goal: educating future physicians. Tufts is a leader in this area.

This year, Tufts received the prestigious *CIO Magazine* enterprise value award for the HSDB, becoming the first university to win in the award's nine-year history. One of the judges, John Glaser, vice president and CIO at Partners HealthCare in Boston, commented,

Educational institutions need role models, and Tufts is one. In training physicians and health care professionals in a complex, volatile industry that is less amenable to time restraints, managing and keeping course material current and integrated is crucial. Tufts has taken a very messy educational challenge, done an extraordinary job of sizing up that challenge, and is doing some pioneering work.

Technical Profile of the System

The HSDB's architecture evolved from the basic premise that the system should primarily serve the learning needs of Tufts students. Accomplishing this goal required that the system be capable of performing four major functions, all key to increasing instructional quality:

1. provide any time, anywhere access to comprehensive, up-to-date educational material;
2. integrate course content across distinct health science disciplines and across multiple years of professional study;
3. emphasize the teaching of a carefully determined set of core competencies and key concepts that health science practitioners must know; and
4. provide the means for acquiring the knowledge, skills, and attitudes required for a lifetime of learning.

The overall requirements guided the HSDB project team's development efforts and led to the creation of the following six primary system components:

1. a flexible, integrated data model that enables the storing, cross-referencing, and indexing of information;
2. an object-oriented programming interface to quickly develop high-level applications for added functionality;
3. user interfaces that build simple applications in response to user requests;
4. authoring interfaces for faculty to create and maintain digitized content;
5. external data incorporation and maintenance tools and utilities; and
6. XML data type definition to facilitate authoring, articulate didactic content such as keywords and topic sentences, generate connections, and enhance searching capabilities.

The HSDB data model contains curricular content items (that is, the educational material); information related to administrative entities, such as course descriptors and student evaluations; information created by users, such as student and faculty identifiers; and the myriad of relationships among all these entities. The data model and document infrastructure facilitate a high level of educational material integration, enabling students, faculty, and practitioners to transcend course-, discipline-, and profession-specific boundaries.

Curricular content items in the data model include a variety of objects, such as textual documents, images with descriptions, self-study questions, practice exams, external Web pages, library collections, and other interactive materials. Content items are stored in extensible mark-up language (XML) along with their associated metadata (data about the data) to provide a powerful way of describing and indexing elements in the database.

The National Library of Medicine's unified medical language system (UMLS) metathesaurus assists in the automatic assignment of keywords for content items in the HSDB. To accomplish this assignment, the project team created a software tool that maps the title and text of all stored documents to UMLS concept names to identify keywords. This approach provides a method to make connections between common terms used in clinical, research, and educational arenas. Through this common language, a faculty member can search the database for images, documents, and multimedia materials, and find data entered by educators or clinicians tailored to his or her teaching needs. These collections are dynamic and regularly updated. This novel approach creates a foundation for sharing course content among health science schools at different institutions.

The HSDB resides in MySQL (version 3.23), an SQL relational database. Apache Webserver provides the Web interface. The HSDB servers include two dual-processor, 300-MHz Sun ultra 60 machines. One of the servers functions as a RealNetworks' streaming audio and video server as well as an MGIsoft zoomserver. The zoomserver provides streaming images that mimic the action of a microscope. A Sun Enterprise model 250 computer serves as the data repository, while a Sun Sparc 20 functions as a log server. All Sun machines run Solaris 8.0.

The Perl programming language is used to develop HSDB architectural components and applications. Indexing and searching software provides simple and advanced searching. Softquad's Xmetal XML editor, customized for Tufts' needs, serves as an authoring interface for syllabi, evaluations, and quizzes. Additional multimedia software employed includes Adobe Illustrator and Photoshop; Macromedia Premiere, Director, Flash, Shockwave, and Dreamweaver; and a variety of RealNetworks' applications.

The university's high-speed, gigabit ethernet data network provides access to the HSDB from any one of Tufts' three main campuses. Off-campus access is available 24 hours per day, seven days a week over the standard Internet.

Primary Benefits of the System

The HSDB is the cornerstone of new educational models in health science schools at Tufts. It plays a major role in enhancing the quality of instruction while improving organizational effectiveness and efficiency.

Students regularly report that they highly value the easy access to all course materials, including course syllabi, bibliographic full-text journals, teaching images, lecture slides, quizzes, and audio and video learning aids. (At Tufts health science schools, course syllabi are like full textbooks in content and length.) Student learning is enhanced by the opportunity for continual review and reflection at any time from any Internet-accessible computer.

Dr. John Harrington, dean of Tufts' medical school, has been a strong advocate for the innovative system from the beginning. According to Harrington,

> The faculty tell me that with the Health Sciences Database, furious note taking during class is a thing of the past. Students are better prepared for class, and they're listening for understanding rather than note taking. I'm told the students are even asking more and better questions, which means our classrooms have become more dynamic and interactive.

He added,

> Our first- and second-year medical students in histology and pathology lab classes used to view slides with lab microscopes. With the slides now digitized and available for viewing online, we've been able to cut back on staff time, instrument repair, and slide replacement, which sometimes costs $200,000 per set.

Said Anthony Schwartz, associate dean for academic and outreach programs at the veterinary school, "The interdisciplinary implications of the HSDB are very powerful." For example, medical students studying salmonella in humans can link to veterinary school material to learn about the source of the bacteria, its effect on chickens and cattle, ways it is transmitted to humans, prevention, and treatment. "These kinds of concepts can be taught not by new courses but by cross-disciplinary linkages, so that students have a direct understanding," according to Schwartz.

The HSDB has increased faculty collaboration substantially. Options to compare materials from different classes, such as by juxtaposing images of normal and abnormal pathology on the same screen, have greatly increased course integration by faculty and students. Faculty members in Tufts health science schools regularly link to each other's materials both for concurrent and subsequent courses, minimizing redundancy and encouraging planned reinforcement. Students compare materials across multiple courses and even across years as they learn and review. For some courses, the structure of the HSDB encourages students to learn in small groups, making learning more efficient, collaborative, and engaging.

Since health science education requires the application of knowledge from so many discrete disciplines to solve a particular problem, the ability of the HSDB to integrate related material from separate courses has an especially profound impact on learning. As students work to answer questions or solve problems in their courses, they use the HSDB to quickly find related disciplinary and interdisciplinary materials that are organized based on particular learning objectives and curricular goals.

When faculty were asked to put their syllabi and course material online, they took time to update and add materials before going "live." When asked to check keywords, the overlap of content between courses became obvious with other material already online. Dialogue among faculty ensued. Faculty then worked to eliminate redundancy in topics presented in different classes and to highlight intentional reinforcement of material across courses. In some cases, these efforts led to a complete revamping of the course schedules and even the curricular materials. Given all the demands on faculty in the health science schools, faculty time to create new materials is becoming increasingly difficult to find. Removing unnecessary course overlap and optimizing the coordination and scheduling of courses helps ensure that available faculty time is used as effectively as possible.

By accessing curricula material online, students also find that they can use their time more effectively. Before the HSDB, students frequently went to the Health Sciences Library for course-related material. In a typical situation students found two slide carousels on reserve and hundreds of students waiting for them to be returned. Now, with the HSDB, students have 24-hour access to all curricular materials including much of the material that could be viewed only when the library was open.

Significant organizational improvements have resulted from the course evaluation component of the HSDB. This part of the system enables ongoing assessment of the curriculum and quality improvements in courses and teaching. Currently, every student in the medical school is required to fill out an evaluation of every course and clerkship (for example, clinical rotation in a hospital or clinic) over the Web through the HSDB. Compliance is almost 100 percent, but more impressive are the thoughtful, respectful comments. The evaluations, reviewed for immediate action, are used in the more formal, in-depth peer review performed every three years on all required courses and clerkships by the medical school. Annual progress reports are then presented to the medical school curriculum committee noting what corrective actions have been taken and what remains to be done.

Lessons Learned

The HSDB has captured the attention of more than 30 universities as far away as South Africa, whose representatives have come to see demonstrations of the system. Many have gone

away with an interest in acquiring the system for their own use. Based on this interest, Tufts is currently exploring different approaches to expanding use of the system by other medical and health science institutions. The potential benefit to the larger academic community far exceeds the original benefit the HSDB project team had in mind when they digitized the first laboratory slides for class use. The value of the HSDB experience for Tufts provides a vital lesson for IT and other campus leaders: Support and encourage people in your organization who are committed to an idea that they believe will advance your institution in innovative ways. You never know which idea will succeed to become the next Health Sciences Database.

This type of success, though, doesn't happen without overcoming major problems along the way. Early detractors considered the HSDB too big a task and believed that it would be simpler to let each department figure out its own solution. Early faculty adopters helped overcome the resistance,

spurred on by students who lauded the effort. However, working with faculty to get their content online proved to be a lengthy and at times difficult process. Faculty development became a key issue, necessitating the use of support staff beyond the HSDB core project team.

Copyright became another important issue. Some faculty were reluctant to share their material because part of it came from books or other copyrighted sources. They wondered whether fair use guidelines prevented uploading this content to the database. A permissions researcher was hired in response to all the copyright questions. The researcher supports faculty by answering their copyright inquiries and, working with reference librarians, helping them find alternate materials when necessary.

Interestingly, the HSDB helped overcome one aspect of copyright. With the advent of online journals, faculty are providing links in the HSDB directly to specific online articles to which the library subscribes. The linkage puts an end to the practice of making multiple copies of journal articles in printed syllabi, saving printing costs in the process.

The need for additional financial and staff resources has been perhaps the most pressing ongoing issue. Once students experienced value from the HSDB, they wanted everything available at once. Given the project's success, expectations today are even higher — people typically want their material available in the system as soon as possible. The HSDB team manages expectations on a regular basis, balancing them against the team's early philosophy of never saying no to a request.

Now that the HSDB is a production-level system, continued development focuses on improving services. A prime concern is enabling faculty to perform more content authoring and editing on their own. Additional easy-to-use, customized XML and case-shell authoring tools are presently under development. Future plans call for the development of enhanced

interactivity and community building tools such as user forums, on-demand printing capabilities, and wireless applications. Web-based administration tools for authors and course directors will also be created. The conversion of all textual material in the HSDB to XML will be completed next year, as will conversion of the underlying database to Oracle and the application logic to Java.

Recently, the university's information technology council created the Tufts Digital Library Initiative, a project that builds on the HSDB and other digital library projects at the university. The overall goal of the initiative is to develop one central meta-repository accessible by multiple curricular applications. The repository would contain all topic-related content, metadata, and digitized material, regardless which course, discipline, school, campus, or database the material resides in. With its content stored in a common infrastructure, the HSDB will continue as one of the university's main curricular applications. In its new form, the HSDB will consist primarily of application programming logic and user interface tools. The separation between digital content storage and digital material delivery should enable the HSDB to support health science curricula at Tufts in even more power, flexible, and customizable ways. *e*

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