Application of Technology

Information Management of a Medical School Educational Program: A State-of-the-art Application

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Abstract  Quality in the design and management of a medical school education program depends on the ability to access and analyze relevant information in a timely fashion. The components of a medical-education information system should support learning and instruction as well as the administrative and research responsibilities of the program. A system capable of meeting these needs requires core, operational, and strategic components. This article discusses a conceptual schema of the medical school environment and reports the results of 3 1/2 years' experience developing core, operational, and strategic components at the University of Pittsburgh School of Medicine. The value of a simple conceptual schema as a design and development instrument was confirmed. Limitations of the system are discussed along with potential solutions.


Improving the quality of medical education is an investment in the future. To improve quality, a school of medicine must combine traditional responsibilities with a responsiveness to new mandates. Thus, a medical school must endeavor not only to guarantee the relevance of education to priority health needs and to apply effective learning processes, but also to participate actively in improving the quality and coverage of care, and to maintain a quality-assurance process.1

In 1992, the Association of American Medical Colleges published a report entitled “Assessing Change in Medical Education—The Road to Implementation” (ACME-TRI),2 which outlines the need to centralize decision making and resource allocation for the medical students' educational program. Although the ACME-TRI report provides goals, principles, and strategies to achieve these ends, substantive information on procedures, methods, and specific techniques is lacking in the ACME-TRI report as well as in the medical education literature.

The design and management of the educational program are essential parts of these endeavors, and they depend on the abilities to access and analyze relevant information in a timely fashion. The term “computer applications in medical education” is often limited to a narrow scope of resources such as computer-assisted instructional packages and parts of decision support and other clinical applications thought to possess pedagogic value. However, a broader scope of information resources is required to pursue excellence for
KNOWLEDGE THAT GUIDES DECISION MAKING TO BENEFIT THE ENTERPRISE

OPERATIONAL
INFORMATION USED FOR DAY-TO-DAY OPERATIONS OF THE ENTERPRISE

CORE
DATA ESSENTIAL TO THE ENTERPRISE
- e.g., demographics, digitized image collections, etc.

- e.g., databases and applications

- e.g., analytic and summary reports, etc.

STRATEGIC

**Figure 1** Selected components of a medical-school-education information system.

an educational program. Accurate and reliable information must be readily available to enable the program’s managers to learn from the program’s mistakes and successes as well as to support administrative decisions and to guide program strategy. A medical education information system (MEdIS) capable of meeting these needs requires core, operational, and strategic components.

Implementation of a centralized decision-making and resource-allocation process requires timely access to both raw data and processed information, ranging from analysis of curricular content, through contact hours and costs, to measurements of achievement and effectiveness. The data and information can support decision making by providing details regarding the activities of the enterprise as well as elements describing the internal and external environments within which the program functions. For example, ready access to data about faculty-teaching contact hours can aid a department in preparing and defending education-related portions of a budget. Access to residency match results and to longitudinal tracking data about graduates’ career choices (compared with regional, state, or national norms) can inform a medical school’s curricular revision process. The collection, analysis, and synthesis of large volumes of data are thus necessary. An automated information system can support direct learning and instruction while recording information about use and experience as a by-product. Such a system can offer cost savings and efficiency in dealing with such volumes of data as well as constructively supporting intelligent, timely decisions and allocation of resources.

In addition to the administrative capabilities just described, a medical-education information system must provide students with access to electronic resources stored locally and at remote sites. Electronic access to digitized images and data is rapidly becoming part of everyday medical practice and must become part of the medical school learning environment. Because material that supports learning is often tied to an instructional unit, an electronic representation of the structure of the curriculum is needed to organize the information. The field of medical informatics affords methodologies and tools that may be effectively applied to develop information management systems that serve both pedagogic and administrative purposes in the field of medical education.

The purposes of this paper are 1) to describe desiderata of an information management system to support the medical school educational program, 2) to propose a conceptual schema of the medical school educational environment; 3) to present the results of 3½ years’ experience developing core, operational, and strategic components of MEdIS at the University of Pittsburgh School of Medicine, and 4) to discuss limitations of the system as well as promising areas for future investigation.

**Desiderata of an Information Management System to Support the Medical School Educational Program**

Haphazard construction and use of computer-based tools to support individual components of the curriculum and of administration can solve only a few problems and cannot be scaled upward over the long term. The components of a medical-education information system should support learning and instruction, along with the administrative and research responsibilities of the educational program, in an integrated, conceptually based framework. These components are conveniently classified as core, operational, and strategic components (Fig. 1). An accurate conceptual representation of the curricular environment is essential to the development of components that are useful, efficient, extensible, and cost-effectively maintained. The components should be capable of communicating easily with one another, sharing data when necessary, and integrating information.

**Figure 1** Selected components of a medical-school-education information system.
that includes instructional activities, expenditures, faculty, students, and curricular content.

The information system should provide needed management information at the time and place it is required. It should provide access to administrative information such as individual schedules for students, individual schedules for faculty, and schedules for specific courses, among others. In addition, administrative functions should be available, including but not limited to analysis of instructional hours, analysis of faculty contact hours (by activity type, course, department, gender, professorial rank, or other attribute), assignment of students to small groups, analysis of expenditures (by course, activity type, or other attribute), and analysis of learning resources.

The system should provide access to resources that support learning, such as sets of digitized images, databases designed to support instruction, a World-Wide-Web browser, and e-mail contact with faculty and fellow students. Students should have access to these resources not only during self-directed study time, but also during scheduled instructional time, such as when they are in rooms for small-group learning. These resources should blend seamlessly into the small-group learning environment, as do other methods of communication that augment learning, such as the ubiquitous chalkboard and overhead projector.

Ready access to curricular content would be not only useful, but essential to the implementation of current initiatives in medical education that call for curricula to be integrated across all 4 years. Achieving access to the content of a curriculum raises several interesting informatics issues. Once it is determined which documents will be accepted as delineating curricular content, the challenges, as considered by several authors, include representation, indexing, browsing, and retrieving content. Ideally, the information system should be capable of analyzing the curricular-content database to identify unintended redundancies, to alert faculty to omissions, and to serve as an intelligent "assistant" to faculty members who are charged with organizing, teaching, and managing the curriculum.

New knowledge should be readily incorporated into the existing representation. An ideal scenario includes the easy sharing of multimedia data among information systems at different medical schools worldwide. Procedures for data capture and data entry should be automated to the fullest possible extent to minimize the financial and other costs associated with input errors. Appropriate attention should be given to interface design so that the user functions in a friendly, ergonomically effective milieu.

A Conceptual Schema of the Medical School Educational Environment

The objectives of modeling the curricular environment were to develop a simple, flexible, extensible representation driven by the needs of users and the school, rather than by current limitations of computer hardware or software. Obviously, at the implementation stage, certain current limitations need to be considered. However, ignoring these limitations initially is beneficial because 1) it can lead to innovative solutions to problems that otherwise might have been only avoided, and 2) the ongoing development of new hardware and software will likely allow many current limitations to be transcended.

An accurate conceptual representation, or schema, of the curricular environment is essential to the development of databases that form the supporting structure of an information system. The conceptual schema represents a coherent architectural model that is functional and scalable. A conceptual schema provides a concise documentation of the subsequently developed databases and enhances communication among designers, users, and administrators by clearly defining constituent elements and relationships of the system. Lack of a structured approach to database design can lead to a failed information system, due to underestimates of time resources, databases that inadequately support needed applications, limited documentation, and inefficient, costly maintenance.

The entity-relationship (ER) data model was chosen for the conceptual representation of MEdIS databases at the University of Pittsburgh School of Medicine for several reasons. First, the ER model is conceptually simple and can serve as a common language to facilitate communication of the medical school administrators and faculty who are responsible for the organization and development of the curriculum with those who are responsible for the logical and physical design of the databases. Second, entities can be readily incorporated into the schema at any point in the life cycle of the information system. Finally, the schema designed using the ER model is easily mapped to a relational, network, or hierarchic logical model, which is subsequently readily mapped to the physical structure of the database.

The essential occurrence in a medical curricular environment involves the interaction of one or more students with one or more faculty members for a finite period to achieve specified instructional goals. This situation was named an "activity" and has start and stop times that are not the same and that occur during the same calendar day. An "event" was defined as an
occurrence with a start date and a stop date that are not the same. An activity is part of one or more events. An event can be a part of a longer event. For example, a lecture is an activity that is part of an event (a course); a course is an event that is part of a longer event (a block); a 10-week instructional "block" is also an event. Figure 2 illustrates several of the entities and relationships proposed for a conceptual schema of the medical school educational environment. Note that this relatively simple model has been able to sustain many MEdIS components at the University of Pittsburgh School of Medicine. The activity, event, and other entities and relationships are generic enough to be easily portable to other institutions and readily adapted for use, despite potential differences in the structure of the educational program or intended uses of the information.

The ER model of the curriculum was mapped to a relational model and implemented as a relational database. A relational database was the first choice of the design team for several reasons, one of which is that readily available commercial relational databases feature user-friendly interfaces and good technical support. Within an academic institution, it is not difficult to find several individuals with expertise in relational database development and management. Also, at my institution, an off-the-shelf relational database management system was already in use and supported on the local area network serving the dean's area (which includes the Office of Medical Education). Existing relational databases of the medical school could be reverse-engineered to the ER model format and then easily integrated into the new information system as needed.

MEdIS: Results of 3½ Years' Experience

At the University of Pittsburgh School of Medicine, MEdIS has been a useful paradigm for the development of information resources to support the medical educational program, particularly during the implementation of a new, centrally governed and centrally managed curriculum. During the past 3½ years,
Table 1

Selected Core Components of a Medical School Education Information System

<table>
<thead>
<tr>
<th>Currently in Use</th>
<th>Processed and Maintained by the Office of Medical Education</th>
<th>Processed and Maintained by Other Divisions of Dean's Office</th>
<th>Processed and Maintained Outside of Dean's Office</th>
<th>Scheduled for Development and Purposes Only</th>
<th>Suggested for Inclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructional-activities data</td>
<td>Data from course evaluation by students</td>
<td>Medical student demographics</td>
<td>Data from evaluation of faculty teaching by students</td>
<td>AAMC* matriculation survey data</td>
<td>Curriculum content</td>
</tr>
<tr>
<td>Community sites used for medical educational experiences</td>
<td>Student peer evaluation of small-group performance data</td>
<td>Applicant demographics</td>
<td></td>
<td>AAMC* graduation survey data</td>
<td>Biomedical graduate student demographics</td>
</tr>
<tr>
<td>Digitized instructional images</td>
<td>Survey data of students’ perceptions at end of year 1</td>
<td>MD-PhD student demographics</td>
<td></td>
<td>Residency match results (career-choice) data</td>
<td></td>
</tr>
<tr>
<td>Digitized portraits of medical students</td>
<td>Survey data of students’ perceptions at end of year 2</td>
<td>Faculty demographics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Curricular-expenditures data</td>
<td></td>
<td>Alumni demographics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Staff demographics</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*AAMC = Association of American Medical Colleges.

Table 2

Selected Operational Components of a Medical School Education Information System

<table>
<thead>
<tr>
<th>Currently in Use</th>
<th>Maintained by the Office of Medical Education</th>
<th>Maintained by Other Divisions of Dean's Office</th>
<th>Maintained Outside of Dean's Office</th>
<th>Scheduled for Development and Purposes Only</th>
<th>Suggested for Inclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructional-activities database</td>
<td>Program for automated assignment of students to small groups</td>
<td>MD-PhD database</td>
<td>Application for processing and generating reports of evaluation of faculty-teaching data</td>
<td>POSTDOC application†</td>
<td>Curriculum-content database</td>
</tr>
<tr>
<td>Ambulatory Care course database*</td>
<td>Access to instructional resources (e.g., MEDLINE, World Wide Web browser, online health science library services, online general library services)</td>
<td>Admissions database</td>
<td>Application for viewing digitized video sequences</td>
<td></td>
<td>Biomedical graduate students database</td>
</tr>
<tr>
<td>Curricular-expenditures database</td>
<td></td>
<td>Staff database</td>
<td>Copyrighted resource use database</td>
<td></td>
<td>Program for automated assignment of students to community-based medical education sites</td>
</tr>
<tr>
<td>Application for rapid viewing of digitized instructional images</td>
<td></td>
<td>Grants and gifts database</td>
<td>Application for processing and generating reports of course-evaluation data</td>
<td></td>
<td>Program for automated assignment of faculty to small groups of students</td>
</tr>
<tr>
<td>Application for selection, display, and printing of digitized medical student portraits</td>
<td></td>
<td>Alumni database</td>
<td>Application for processing and generating reports of peer-evaluation data</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Clinical skills course database</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>Applications for processing and generating reports of survey data of students' perceptions at end of year</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*See references 23 and 24.
†See reference 16.
the information system as a whole has been conceptualized and iteratively refined to its present form, and it continues to evolve.

At this time, MEdIS is not a fully integrated system, and components have been developed using several different applications on Macintosh, DOS, Windows, and UNIX platforms. While many components are maintained within the Office of Medical Education, some are maintained by other organizational units of the institution.

Table 1 lists core components of MEdIS that are currently in use, as well as those that are scheduled for design and implementation, used for experimental purposes only, or suggested for inclusion. Tables 2 and 3 list operational and strategic components, respectively, in the same categories.

As illustrated in Table 1, the Office of Medical Education currently captures and enters data for nine core components. Other divisions of the dean’s office capture and enter data for at least six additional core components, several of which support curricular initiatives. A separate university office processes data concerning student opinion of faculty teaching. Automated data entry by optical scanning is used whenever possible, and files, such as digitized medical student portraits, are electronically transferred from the site at which they are initially captured.

Initially, data about instructional activities were entered manually. Course syllabi were chosen as the primary sources of data, because they included schedules, lists of teaching faculty, and other important information about instructional activities. To facilitate automation of this process, a standard format for the first few pages of each syllabus will be implemented. The standard format will allow data capture close to the source at which data are generated and will eliminate errors associated with manual data capture and its subsequent entry.

As depicted in Table 2, several databases and applications have been developed. The instructional-activities database is pivotal to the generation of many of the strategic components of MEdIS. Instituted in the fall of 1992 with the implementation of the new Physicians In Two Thousand curriculum, this database serves as an electronic record of instructional activities and related information (e.g., participating faculty, instructional modalities, facilities used, and hours of activities). The record provides the basis for reports

| Selected Strategic Components of a Medical School Education Information System |
|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|
| Currently in Use                                | Scheduled for Development and Implementation     | Currently Employed for Experimental Purposes Only | Suggested for Inclusion                         |
| Maintained by the Office of Medical Education   | Maintained by Other Divisions of Dean’s Office   | Maintained Outside of Dean’s Office              |                                                  |
| Analysis of cost of the curriculum              | Longitudinal tracking of attributes of medical school | Analysis of omissions of curricular content | Analysis and correlation of AAMC* matriculation findings |
| Analysis of faculty contact hours (by type of instructional activity, gender, professorial rank) | Analysis of survey data of students perceptions at end of year 1 | Analysis of unintended redundancies of curricular content | Analysis and correlation of AAMC* graduation findings |
| Analysis of scheduled instructional hours        | Analysis of survey data of students perceptions at end of year 2 | Intelligent assistant to course developer (using a curriculum-content database) | Analysis and correlation of summary findings of students’ perceptions at end of years 1 and 2 Patterns of use of information sources by students and faculty |
|                                                  | Analysis of medical student career choices (match results) | Analysis and correlation of student peer-evaluation findings | Longitudinal tracking of attributes of biomedical science graduates |

*AAMC = Association of American Medical Colleges.
generated in response to the information and manage-
ment inquiries from curriculum-related constitu-
encies. For example, departments may request reports
that list the individual teaching contributions of fac-
ulty by type of instructional activity and professorial
rank; the curriculum committee may receive summary
information on faculty contact hours or on the num-
ber of hours of examinations given during a specified
block of time. The database provides an efficient, cost-
effective means of providing various reports for
review and analysis. Due to difficulties previously re-
ported, including expense, maintainability, identifi-
cation of a data source, automated recognition of
medical concepts, and others, the current system does
not include curriculum content.

The current version of the instructional-activities da-
tabase includes the entities and relationships dia-
grammed in Figure 2 and the attributes listed in Table
4, and it contains approximately 3,000 activities per
medical school class per academic year. During the
first 3 years of operation, more than 650 analytic and
summary reports were produced for individual fac-
ulty members, medical school departments, the cur-
riculum committee and its standing subcommittees,
and individuals giving presentations to groups such
as the Board of Visitors and the school-wide annual
Curriculum Colloquium. The relational model has
been flexible enough to permit several extant data-
bases maintained outside the Office of Medical Edu-
cation to be reverse-engineered and incorporated into
MEdIS as needed.

Approximately 500 images have been digitized to
support small-group instruction to first- and second-
year students. The cost of digitizing an image is sim-
ilar to the cost of making a 35-mm slide. To support
16 small groups of students, an image needs to be
digitized only once, whereas 16 slides would be
needed. Image digitization has resulted in significant
cost savings.

The design philosophy of MEdIS at the University of
Pittsburgh views the computer as a tool to provide
access to resources to support the learning process.9
Branching logic tutorials are generally avoided. How-
ever, one application developed to support an inte-
grated case studies course (an experience designed to
help students bridge the gap between the basic sci-
ence material of the first 2 years and the experimental
clinical clerkships of the final 2 years) gives students
"gated" access to patient-specific data. The "gates" are
structured into computer-supported problem-
based learning cases and limit access to portions of
the patient database until certain information is "re-
quested." The gates, for example, determine how

| Table 4 |
| Entities and Attributes Included in the Current Version of the Instructional-activities Database |
| Activity identification | Expenditure (continued) |
| Activity date | Expenditure description |
| Activity type | Expenditure identification |
| Activity title | Level date |
| Activity miscellaneous | Fiscal year |
| Course identification | Faculty |
| Group identification | Faculty identification |
| Location identification | Status |
| Start time | Faculty type |
| Stop time | Practice specialty |
| Block | Contact phone number |
| Block identification | Rank |
| Start date | Title |
| Stop date | Degree |
| Block name | Title suffix |
| Budget subcode | Last name |
| Subcode identification | First name |
| Budget amount | Middle name |
| Subcode description | Location |
| Course | Location identification |
| Course identification | Room number |
| Start date | Room type |
| Stop date | Building |
| Block identification | Small group of students |
| Course design group | Group identification |
| Design group identification | Start date |
| Faculty identification | Stop date |
| Student identification | Group name |
| Course identification | Student identification |
| Expenditure | Last name |
| Activity identification | First name |
| Block identification | Title suffix |
| Faculty identification | Address line 1 |
| Subcode identification | Address line 2 |
| Course identification | Geography identification |
| Expenditure paid | Access to vehicle |
| Expenditure amount | Date of birth |
| Expenditure number | Gender |
| Expenditure date | Graduation year |
| Vendor identification | |

many and which historical features must be explored
by a student before he or she is allowed to proceed to
the physical examination.

Authority for allocation of financial resources for the
curriculum is centralized in the resources subcommit-
tee of the curriculum committee. A working principle
of this subcommittee is to fund projects directed to-
ward special initiatives of the curriculum committee
or specific course initiatives (e.g., a particular lecture,
a problem-based learning case), but not projects
aimed at developing general libraries or catalogs of
learning materials. Priority for funding and develop-
ing each component of MEdIS was handled in this
fashion. This strategy has allowed resources to be di-
rected toward applications immediately used to sup-
port learning within or management of the curricu-


Discussion

The information system that supports the medical education program at the University of Pittsburgh School of Medicine represents a first step toward accommodating learning and instruction needs as well as the administrative and research responsibilities of the curricular environment. Designers and developers determine the needs and uses of the system, not the limitations of hardware or software applications. The methodology for database design was developed from a conceptual schema using an ER model, and it provides an efficient, cost-effective means of maintaining information. Summary data are readily available for review and analysis.

During the initial stages of system development, the implementation of a new curriculum and a rapidly changing environment for academic medicine compounded the uncertainty of predicting information needs and defining strategic components. It was therefore critical that the system readily incorporate new information. The conceptual schema for database development has been critical in supporting these adaptations. As needs and priorities change and as the curriculum evolves, so may the conceptual schema, which, to date, has easily accommodated new entities and relationships.

The current implementation of MEdIS is limited in that a database of curricular content is not yet included. Approaches described in the literature for representing curricular content generally feature human-dependent methods of keyword selection from a controlled vocabulary, for which maintenance is difficult, costly, and time-consuming. A method for the automated recognition of medical concepts in curricular documents did not produce uniformly acceptable precision and recall; nevertheless, its performance on some curricular documents was good enough to warrant further study. It is likely that future improvements in precision and recall will improve the cost-benefit ratio so that maintenance of a curricular content database as an information system component is justified. Ongoing work with the prototype of a national curriculum database supported by the Association of American Medical Colleges may provide additional insights in this area.

Although many of the desiderata described earlier have been realized, development of MEdIS has been hampered by several interrelated factors, including the inability to access information from other systems automatically, the inability to integrate all applications fully, the tendency to use multiple platforms (to take advantage of the platform best suited to a particular task), and time-consuming development of user-friendly graphic interfaces to allow efficient use of the system by clerical workers. Proprietary operating systems and hardware platforms exacerbate the situation. Finite economic resources and political factors also contribute to the problem.

Due to the impediments summarized above, MEdIS is not yet a fully integrated system. Components are developed in Macintosh, DOS, Windows, and UNIX environments and reside on the latter three platforms. Most of the components are maintained within the Office of Medical Education, and the remainder are maintained within other divisions of the dean's area and even within areas external to the dean's area. Although duplication of effort is assiduously avoided, and sharing of data and resources is maximized, incompatibilities and inefficiencies exist. For example, data frequently must be downloaded as an ASCII file from a DOS application, reformatted using UNIX-based editing tools, and uploaded to another DOS application. The costs of such tasks include the time involved and the need for an employee who is familiar with more than one operating system and is skilled in handling data on more than one platform.

The World Wide Web, with its protocols that allow the use of networked information and hypertext, offers potential solutions to many of the obstacles noted above. Web browser and server software is available for most platforms and supports the retrieval and display of text, image, video, and sound files. An implementation of MEdIS on the Web would permit efficient use of the system by employees of varying skills working on different platforms through a user-friendly graphic interface created with standard protocols. A prototype implementation of a clinical information system on the Web has been reported.

Important theoretic and methodologic areas for future research include the representation of curricular content, automated recognition of medical concepts in curricular documents, and automated analysis of curricular content. These activities would facilitate the integration of curricular content across courses and disciplines through such means as automatically identifying unintended redundancies of curricular content, alerting faculty to omissions, and providing an intelligent "assistant" to faculty members who are charged with organizing, teaching, and managing the curriculum.

In summary, a state-of-the-art information system that supports the medical school educational program can afford medical educators efficient access to comprehensive information. Establishment of system com-
ponents on a sound theoretic base increases the ability to handle unforeseen necessary extensions to the information system.

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References