Teaching Files as Learning Modules in Undergraduate Medical Education

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***Abstract*—Teaching files serve the educational process in medicine and especially in the field of radiology in a variety of ways. The most common way is as peer-reviewed archival information resources used as a means for formal professional scientific communication. Only recently interest is shifting towards using digital teaching files to support the undergraduate medical educational process. This paper presents our approach to bridge and technologically integrate the educational environment, where clinical information is consumed, with the healthcare enterprise where clinical data is generated via a novel teaching file authoring environment that supports the creation of teaching files that can be viewed as individual learning modules and can be incorporated into generic learning management systems.**

I. Introduction

There is currently an international trend to involve computers and the Internet in medical curricula as well in continuing life-long medical learning. This increasing employment of new technologies in higher medical education is also strongly related to an emerging trend in education that shifts attention from *teaching* to *learning* [1].

Like many other cognitive domains, medical education can be considered in terms of three levels of increasing complexity and importance: information (i.e. simple facts), knowledge (i.e. information with a purpose), and understanding (i.e. conscious knowledge, achievement of explanation and grasp of reasonableness). Technology can be employed in diverse ways to support different levels of medical education (be it theoretical instruction based on textbooks or clinical practice with one-to-one interaction), mainly by extending the amount and availability of knowledge and instruction as well as the place and duration of the educational process

Supporting the dissemination of medical information is the easiest and most straightforward achievement of information and communication technologies as they have extensively and successfully been used to give quick, easy and cheap access to information sources, such as books, textbooks, atlases, medical and biological databases, research journals etc. Supporting higher levels of the educational process, i.e. knowledge and understanding, is a more complex issue. A major contribution in this area is the creation of digital teaching files for the medical student to practice, together with tools that support continuous self-evaluation and mediate teacher-learner exchange.

Teaching files serve the educational process in medicine and especially in the field of radiology in a variety of ways. The most common way is as peer-reviewed archival information resources used as a means for formal professional scientific communication. During the last few years there has been an increasing interest to develop tools and solutions for digital teaching file creation and management. As a result, nowadays teaching files can be created and managed in a variety of ways, ranging from the very simple word processing documents (with no integration with the radiology enterprise, the web or the educational environment), to more complex integrated approaches, mentioned in the following paragraphs.

There are numerous collections of radiological teaching files on the web. A characteristic case is that of EURORAD (European Association of Radiology e-Learning Initiative, http://www.eurorad.org, last visited on June 2006), which was launched in 1998 as a peer-reviewed teaching file collection by the European Association of Radiology and today it is established as an electronic scientific publication. Digital radiology teaching files have gained such a success on the web, so that special portals and search engines have been built to help with navigation and discovery [2], while it has been already suggested that some sort of academic credit and reward should encourage contributions to teaching file web collections [3].

The need to orchestrate such activities led the Strategic Planning Committee of the Radiological Society of North America (RSNA) to suggest that a Medical Imaging

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Resource Center (MIRC) should be created to facilitate the distribution and sharing of medical images and related information on web, thus integrating local imaging and teaching file repositories on independent sites available on the web (RSNA MIRC, http://www.rsna.org/mirc/, last visited on June 2006) [4]. The project set the first requirements in 2001 and progressed substantially thereafter, and a number of MIRC servers and teaching file repositories and related tools have been developed internationally, e.g. [5]-[9].

Although PACS systems have in theory the potential to create, archive and present radiological teaching files, in practice this potential is not satisfactorily realized [10]. So, a number of different proprietary tools have been proposed to support the process of creating and managing radiological teaching files. Most of these approaches use general purpose software to compile a teaching file and then publish it on the web through a process that is partially (or not at all) automated or integrated, but requires sequential manual data exports and imports among various software packages as well as irreversible data transformations from DICOM to other general purpose formats, e.g. [11].

However, recently there have been attempts for partial [12]-[14] or tight [7]-[9],[15] integration of PACS systems with teaching file authoring tools. The need to integrate teaching file authoring tools directly with PACS has been recently realized by the Integrating the Healthcare Enterprise (IHE) initiative (http://www.ihe.net, last visited on June 2006). Towards this end, IHE has introduced a new integration profile "Teaching File and Clinical Trial Export" that specifies the requirements for a PACS systems in order to support data export for academic and research purposes.

II. Teaching Files as Learning Modules

Existing tools, solutions and initiatives have so far concentrated on enabling the automated creation and management of teaching file repositories on the web with the main purpose to support professional information exchange between peers in radiology and medicine and to provide a means for continuing education for residents and specialists. However, the idea of incorporating teaching files in e-learning environments that support the undergraduate and graduate education has only recently been introduced [5], [16]-[19].

Robust web-server based Learning Management Systems (LMS) are currently used by most Universities to support the structured management of teaching material in higher education, and they have gained success in Medical Schools. A characteristic example is the approach we have adopted in the School of Medicine, Democritus University of Thrace [20] which involves the use of open source technologies and off-the-shelve components to deploy an integrated e-learning environment (Figure 1). The core of the deployment is an open source freely available generic Learning Management System (LMS) which provides the basic infrastructure for the management and dissemination of educational material to the Medical School and Medical Hospital Intranet, thus supporting off-line, on-demand, self-directed access to educational information and knowledge, as structured and distributed by the educators and as provided for in Web resources and local or remote medical databases. The goal of this approach is to bridge and technologically integrate the educational environment, where clinical information is consumed, with the healthcare enterprise where clinical data is generated, and ultimately provide necessary tools and methods to transform clinical data into learning modules to be incorporated into the generic e-learning environment supporting undergraduate

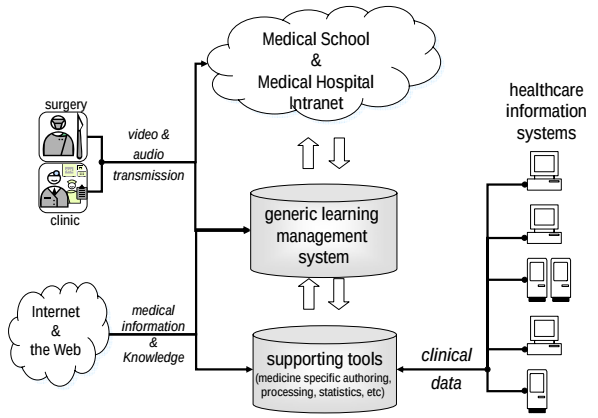

Fig. 1. A schematic overview of the integrated e-learning environment deployed at the School of Medicine, Democritus University of Thrace.

education.

The term LMS refers to a suite of functionalities designed to deliver, track, report on and manage learning content, learner progress and learner interactions, and it can apply to very simple course management systems, or highly complex enterprise-wide distributed environments. LMSs usually support, among other services, back-end connections to other information systems, sophisticated tracking and reporting of student activity and performance, centralized registration, online collaboration and adaptive content delivery.

A key element in establishing reusable, sharable learning objects and adaptive learning strategies in LMSs is the standardizing work of the Shareable Content Object Reference Model (SCORM). SCORM has been designed by the U.S. Government's initiative in Advanced Distributed Learning (ADL, http://www.adlnet.org/, last visited on June 2006) as a set of eXtensive Markup Language (XML) based specifications to define, manage, access and deliver modular educational objects so that they can be easily shared among different learning management systems. SCORM currently provides an Application Programming Interface (API) for communicating information about a learner's interaction with content objects, a defined data model for representing this information, a content packaging specification that

enables interoperability of learning content, and a standard set of meta-data elements that can be used to describe learning content and a set of standard sequencing rules which can be applied to the organization of the learning content [21]. SCORM supports the notion of learning content composed from relatively small, reusable content objects aggregated together to form units of instruction such as courses, modules, chapters, assignments, etc.

Requirements for teaching file authoring solutions that support integration with the healthcare environment and can produce teaching files that can be regarded as learning modules in a generic learning management system include the following: (a) ability to search the entire DICOM information space to identify interesting teaching cases that can serve a particular teaching goal and automatically retrieve DICOM images and related information, (b) integrate with commonly available formats and notions for teaching file distribution in professional radiology practice, e.g. the Medical Image Resource Center (MIRC) specifications, (c) integrate with general purpose learning management systems that support education in higher academic institutions via appropriate e-learning standards, e.g. SCORM, and (d) at the same time offer all functionality as a standalone tool, so that teaching files can be created and managed irrespective of the existence of a fully deployed PACS and/or learning management system.

III. A Novel Teaching File Authoring Environment

To account for the requirements mentioned above, we have developed a novel teaching file authoring environment which is comprised of a teaching file authoring application, a teaching file database, and tools and mechanisms for radiological data discovery and retrieval, as well as for teaching file export in a variety of formats [17]. The proposed teaching file authoring application treats the teaching file as a collection of various fields. Main fields include information on the title and author of the teaching file and some basic information about the patient demographics (e.g. age and sex), the imaging modalities used and keywords. The body of teaching file comprises of the following fields: patient history, findings, diagnosis and discussion, while all images are numbered and can be accompanied by a short description. A typical screen of the authoring application is shown in Figure 1. Once a teaching file has been created, the application supports the additional development of quizzes for self-evaluation and assessment. The author can select any combination of the various fields that comprise the teaching file to form the material for a given question and then construct the question in multiple-choice format. Correct and incorrect answers are defined by the author and comments for each answer can also be included. Typical screens for the quiz authoring are shown in Figure 2.

Teaching file and related quizzes data are stored in a relational database. The schema of this database involves two distinct layers (a) the teaching file related tables and (b) the quiz related tables. It should be noted that although images are stored as raw data, all DICOM attributes are also stored and are available at any time.

Fig. 2. Typical screen of the teaching file authoring application.

For radiological data discovery and retrieval, the authoring application exploits a modular, extensible, multilayer web services environment [22],[23]. At a first level, primary web services act as a wrapper to conventional DICOM image servers, and expose the principal DICOM services of query, retrieve, and store to any other software application or web service over the Internet, using standard XML documents communicated via SOAP messages. Thus, DICOM image data and related information can be discovered, retrieved and maintained in a third party non-DICOM application in its fullness, and through open, standard messaging. At a second level, this primary web service is engaged by collaborating web services that provide functionality specific to research and educational tasks, such as complex queries that combine any DICOM attribute from different levels of the DICOM information

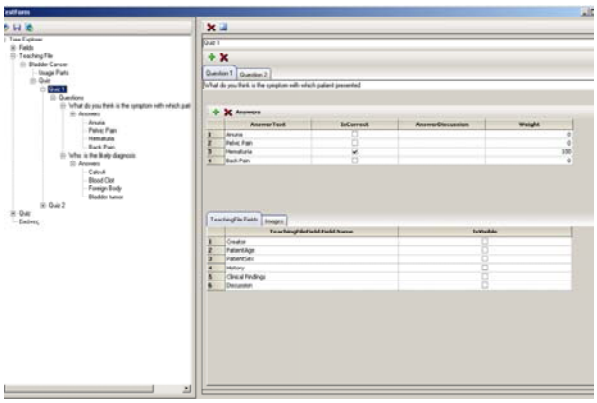

Fig. 3. Typical screen for the creation of quizzes for a given teaching file.

model.

Teaching files can be exported in the MIRC schema for

submission to a MIRC image server. Additionally, teaching files and related quizzes can be exported as SCORM e-learning modules for direct submission to general purpose learning management systems that support higher education.

The teaching file authoring application has been developed in C# using the MS .Net Framework 2.0 (Microsoft, Redmond, USA) and the MS SQL Server 2000 Desktop Engine (Microsoft, Redmond, USA). The collaborating web services have been developed in C# using the MS .Net Framework 2.0 (Microsoft, Redmond, USA) and use the DICOM library DicomObjects 4.1 (Medical Connections, Reynoldston, UK). The SCORM compatibility was tested with the Reload SCORM Player 1.2 (the Reload Project, Universities of Bolton and Strathclyde, UK, http://www.reload.ac.uk/) and with the SCORM compatible, general purpose, open-source learning management system Claroline version 1.7.5 (http://www.claroline.net/) which is used by hundreds of higher education institutions worldwide.

IV. Discussion

This work is part of our efforts to seamlessly integrate clinical data into a generic Internet based e-learning environment that will support undergraduate medical education in Democritus University of Thrace, Greece [20]. The project involves the use of open source technologies and off-the-shelve components to deploy an integrated e-learning environment, based on a conventional e-learning platform to support pre-clinical teaching, tightly integrated with teleconferencing technology for the real-time and/or on-demand transmission from an examination room or the operating theatre to the lecture room, to enhance clinical apprenticeship and provide extended real-world experience. At the core of the project is the effort to develop web service façades for legacy healthcare information systems, in order to extract and communicate educational information using common web standards (as opposed to standards proprietary to the medical environment).

In this respect, the proposed teaching file authoring application and the underlying web service environment is intended to support teaching file creation based on radiological data as discovered and retrieved from clinical DICOM servers, and export teaching files and related quizzes for direct submission to the general purpose e-learning environment that supports undergraduate medical education. This supports and advances the emerging transition from teaching files that support professional information exchange between peers towards teaching files that can be incorporated into the postgraduate medical education as individual learning modules.

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