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Full Length Research Paper

Design of Virtual Environment for Medical E-Learning

A. M. Riad, Hazem El-Bakry and Samir M. Abd El-razek

Faculty of Computer and Information, Sciences, Mansoura University, Mansoura, Egypt

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This paper introduces a new design for virtual medical environment. The aim is to allow medicine students practice problem-based learning. This is done by simulating a medical consultation, using the current pedagogical methods based on clinical cases and integrating web technology methods. The environment is composed of a set of cooperative platform independent tools that allows students to simulate a consultation at distance on a virtual patient that can be designed easily by the teacher. Using multimedia data exchange, the simulation is more realistic than a face-to-face simulation. Information can be shared between students and teacher in multimedia various forms like text, audio, video, and whiteboard. The concept of case-based learning and the need for virtual environment is presented to support this methodology of learning. In the previous work (Samir et al., 2010), the project was applied at the faculty of medicine in Mansoura University. Here, the design is applied for Egyptian Universities Virtual Environment System (EUVES), a virtual environment for medical e-learning for all medicine students in the Egyptian universities. The system is logically designed to simulate case-based learning methodology, and technically designed upon MedBiquitous specifications for virtual patient.

Keywords: E-learning; Virtual Environment; Virtual Patient; Medical Training; Case-Based Learning (CBL).

INTRODUCTION

Medical learning methodologies have a major interest for CBL. This methodology of learning depends on putting students in a semi-real situation and the objective is to learn how to react in this particular situation (Samir et al., 2010 : Samir et al., 2010 : Samawal, 2007). E-learning is the use of Internet technologies to enhance knowledge and performance. E-learning technologies offer learners control over content, learning sequence, pace of learning, time, and often media, allowing them to adapt

their experiences to meet their personal learning objectives. In different medical education contexts, e-learning appears to be at least as effective as traditional instructor-based methods such as lectures. Students do not see e-learning as replacing traditional instructor-based training but as a complement to it. Developing infrastructure to support e-learning within medical education includes repositories, digital libraries, or virtual environments. Innovations in e-learning technologies point toward a revolution in education, allowing learning to be individualized (adaptive learning), enhancing learners' interactions with others (collaborative learning), and transforming the role of the teacher. The integration of e-learning into medical education can improve the medical learning theory, where educators will no longer

serve mainly as the distributors of content, but will become more involved as facilitators of learning and assessors of competency. The previous project "ClinicSoft" (The final paper of ClinicSoft...) aimed to medical decision support system that can help the physician in the clinical diagnosis, based on the data provided to the knowledgebase. ClinicSoft targets only physicians and doesn't cover the learning process in medical colleges.

Here, we present a new model for medical e-learning, this model is based on virtual patient methodology. The virtual patient provides a semi real environment which can be used for students training and assessment. The teacher will be able to create a medical case represented in a virtual patient, which can be hardly achieved in the real time. These medical cases can be accessed through a web based application that provides a set of interactive multimedia tools that can be used in diagnose any virtual patient. Either in training mode (lectures) which can be recorded and accessed later by medicine students, or in assessment mode which enables the teacher create a virtual practical assessment. Collaborative e-learning is most suitable for clinical case-based learning, which provides a set of communication tools between teachers and students like whiteboards, audio, video, and textual communication.

In the following sections we present the problem of clinical case-based learning. Then we introduce the virtual patient model, its modes, and its standard data specifications. Later we present our model and its proposed functions. Finally, the proposed medical E-Learning system is applied for the Egyptian Universities.

Medical Clinical Case-Based Learning

Medical education is a fast growing field, as almost medical trainers and instructors use most of the available learning methods to achieve their targets. One of the most successful methods is Clinical Case-Based Learning (CBL) which is based on developing a repository of interesting clinical cases that illustrate various aspects of clinical learning. These might include:

- Case notes from a case history.
- Investigations and the results, X-rays, etc.
- Reports written by other doctors.
- Video or audio tapes of patient encounters.
- Information from relevant articles about the clinical condition, treatment options, etc.

These cases can be used as interesting material to encourage students or trainees to learn about a specific clinical condition (McCrorie, 2009). It is seen as interesting and relevant by learners and allows the teacher to prepare and select materials which illustrates specific learning points, because the materials are based on real patients and real resources.

The main goal of medical education, however, is still to produce professional physicians. The new paradigm is based on the "Learning by doing" idea, which is principally based on clinical cases. Problem-Based Learning (PBL) is used during preclinical courses and Clinical Reasoning Learning (CRL) is the adaptation of PBL for clinical courses (Corcos, 2010). The main difference between these methods is that in PBL students analyze clinical cases in several sessions in order to identify the problems and pedagogical subjects for solving the problem; in CRL students simulate a medical consultation to obtain the diagnosis, in only one session. Clinical Reasoning Learning (CRL) is a pedagogical method based on real patients' problems (Kennedy et al., 2010). The teacher will be able to create a virtual patient with specific medical case properties. Then the teacher can simulate a virtual diagnosis, broadcasted to students. Or a group of students can simulate the diagnosis. The teacher helps, corrects and coordinates the students during the simulation.

Medical E-Learning

The nature of medical education requires some specific features in any e-learning system. Some subjects like anatomy and physiology require the students to be able to identify and understand the function of different parts of the body, other subjects like those involving practical medicine require the students to identify symptoms, and examine the patient history. It is not enough to provide the learner with text books and lectures, the learners need to have more details and clarity in order to understand medical subjects well. Therefore, medical e-learning systems must be able to provide the students with the tools to clearly identify and describe different parts of the body including videos and detailed figures; it also must interact with other medical systems to provide students with the medical history of their patients, their X-ray pictures, and their prescribed medicine (Sung et al., 2008). Medical e-learning systems require a higher degree of interactivity than other types of e-learning systems in the hospital to allow the students to focus on some symptoms.

Virtual Patient

Virtual patients allow the learner to take the role of a health care professional and develop clinical skills such as making diagnoses and the correct decisions. The use of virtual patient systems is increasing in healthcare education, partly in response to increasing demands on health care professionals and education of students but also because they allow opportunity for students to practice in a safe environment. There are many different

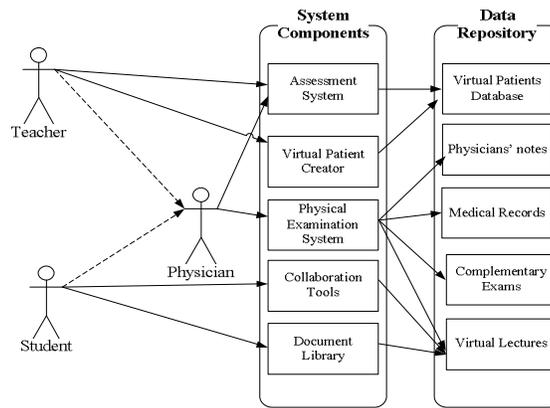


Figure 1. Virtual Patient Model for Medical E-Learning

formats a virtual patient may take. However the overarching principle is that of interactivity - a virtual patient will have mechanisms for the learner to interact with the case and material or information is made available to the learner as they complete a range of learning activities.

A number of different modes of virtual patient delivery have been defined (Ellaway, 2009):

- Predetermined scenario (directed mode)
- The learner may build up the patient or case data from observations and interactions (blank mode)
- The learner may view and appraise or review an existing patient or scenario (critique mode or rehearsal mode)
- The VP may be used as a mechanism to address particular topics (context mode)
- The learner may use a scenario or patient to explore personal/professional dimensions (reflective mode)
- Banks of patients or scenarios may collectively address broad issues of healthcare (pattern mode)

Virtual patients increase the availability of training opportunities for medical students, making them less dependent on actual cases to learn how to handle different situations. Unlike real patients, virtual patients can be accessed on demand and they can be endlessly replayable to allow the user to explore different options and strategies. They can be structured with narratives that represent real situations while challenging the user with a wide range of tasks (Inga Hege et al., 2009). Despite their efficacy virtual patients are still a tangent and prosthesis to reality. They should be viewed as augmenting existing modes and methods of clinical teaching. The European Commission is funding a major 3-years project named eViP (eViP Project Team, "Annual Report", 2009), the project started in 2007 and is due to finish by end of 2010. The project aims to explore the feasibility of repurposing and enriching VP examples in a variety of different ways, and for different purposes

(<http://www.medbiq.org> , Last Accessed on July 29, 2010). The project is developed with cooperation with seven universities and they could implement common technical standards for all VPs in collaboration with MedBiquitous. MedBiquitous Virtual Patients Working Group has developed XML standards and Web services requirements to enable interoperability, accessibility and reusability of Web-based virtual patient learning content (Inga et al., 2009). In 2009 Inga Hege from the University of Muenchen-Germany has implemented the MedBiquitous standards into a learning system named CASUS (Marjorie and Nirenburg, 2009). Another project has been developed in the University of Maryland-USA, Marjorie and Nirenburg has been working on a simulation and a training system the name it Maryland Virtual Patient (MVP). The system gives the user the ability to act as a physician and treats virtual patients with or without a virtual tutor (Jorn et al., 2009). One of the major projects that are working on VPs is CAMPUS. The CAMPUS virtual patient system, developed at the University of Heidelberg-Germany consists of different modules for learning and assessment with VPs (James, 2009). Some projects have a big focus of authoring VPs like VPSIM that has been developed in the University of Pittsburgh-USA on 2008. VPSIM creates an authoring environment for medical educators that require minimal training and stimulated creative case writing (David and Nancy, 2010). Also researchers in the University of McGill-Canada have developed an authoring system to create VPs can be used in the simulation of physical examination, taking history, and ordering the required laboratory tests (Imison and Hughes, 2008).

The Virtual Patient Data (VPD) provides the personal and clinical data that is relevant to the clinical scenario being simulated. The VPD is a bit like a clinical chart, containing data elements and some structure that corresponds to the medical history, physical examination, laboratory and radiology data, and procedure and outcome data. The VPD architecture should be designed

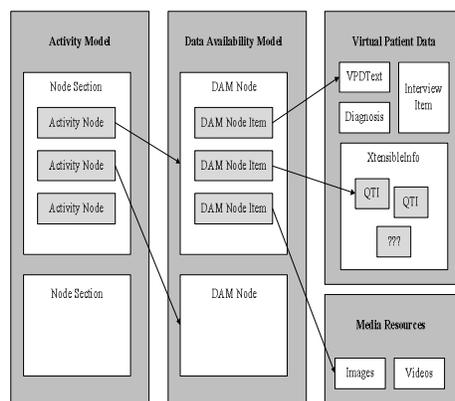


Figure 2. MVP Specification Model.

to enable a flexible approach to how this data is expressed and managed. The Virtual Patient schema includes the following data elements. In most cases, these elements contain sub-elements (Valerie et al., 2009).

- Virtual Patient Data: is the root element. It contains elements that provide clinical and demographic data for a virtual patient as well as metadata.

- Patient Demographics: contains sub-elements that define the name, age, sex, and other demographic characteristics of a virtual patient.

- VPD Text: provides narrative or other descriptive text that is part of the virtual patient data.

- Medication: describes a medication taken by the virtual patient in detail.

- Interview Item: contains sub-elements that describe a single question and response.

- Physical Exam: contains sub-elements that describe a single physical exam and the findings of that exam.

- Diagnostic Test: contains sub-elements that define test results.

- Diagnosis: defines either a differential diagnosis or the final diagnoses intended by the virtual patient creator.

- Intervention: describes a single intervention.

- Organization: contains sub-elements that create a hierarchical structure for the other virtual patient data elements. This hierarchy can then be used by authoring systems importing the data.

METHODOLOGY

After observing some face-to-face CRL sessions and based on our experience on the designing of learning environments in other domains. There is no a general method for collaborative virtual environments; the following methodology is used:

Users and roles identification

Three types of users are identified: teacher, student, and physician.

Tasks list for each role

Teacher will be able to create virtual patients with different medical conditions. These medical conditions could be blood pressure, X-Ray, patient's complaints, etc. then he can play the role of the physician by examining this patient online, this examination will be broadcasted live to students. Students can ask questions, teacher can explain something on whiteboard. A CRL session can be attended online. Students can also play the role of physician in a collaborative form, they can work together, perform diagnosis, write notes, or ask each other. Teacher will monitor this diagnosis, help, or assess the students.

Main functionalities identification

The main components of the proposed model shown in Figure 1 should enable the following functionalities:

Virtual Patient Creator

The teacher should be able to create a virtual patient, by setting the patient properties, upload pictures, or sounds. In order to enrich the medical simulation, we can use some multimedia data, principally medical imagery or photographs. These documents are used to complete the exams and medical record. The images should be physically stocked on the local web server and their URLs on the database. The patient selects a clinical

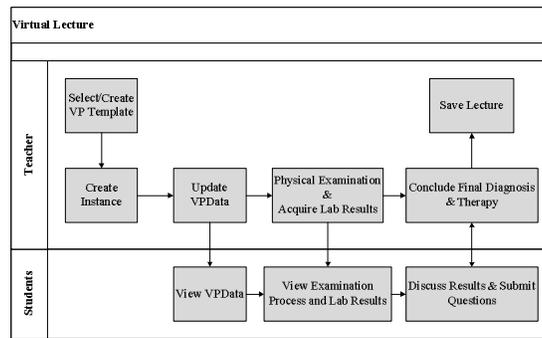


Figure 3. Virtual Lecture Workflow (Marjorie and Nirenburg, 2009)

case, the list of associated documents is updated. He/she can select the documents, and they are sent to all users. Some modifications can be made on images, for example physicians can zoom in/out of them or, write and draw annotations on the Images.

Assessment System

Physician’s notes can be consulted by all group members. The teacher can evaluate their reasoning and send immediately feedback. Physicians can compare their notes with other physicians’ notes. This comparison allows the students to make a self-evaluation and they can learn from their mistakes.

Physical Examination

Pictures and body sounds are used to simulate the physical examination. The patient can have some pictures and sounds in the database. In order to make patient-physician communication easier, a human body image is used to indicate the problems area, for example, the physician can click over the image to ask patient if the area is painful.

Document Library

In order to facilitate the learning process, external resources can be used by students during the session. These resources include e-books, commented or interactive clinical cases, medical images, multiple-choice questionnaires, medical guidelines, medical encyclopedias, human atlases, medical digital libraries and computer-assisted diagnostic systems. The teacher can recommend some sites for consultation.

5. Collaboration tools

Students should be able to share ideas and comments.

Computer tools

Computer tools: to develop this model, a Web Server is needed to stock pedagogical documents and local decision-making systems; a relational database for indexing the local and external resources, a chat server to mediate the user communication, a web browser for accessing pedagogical resources, a sound player to listen to body sounds, and finally, some cooperative tools for sharing information like a graphics whiteboards and a cooperative notepad.

MedBiquitous Virtual Patient (MVP) Specifications

The MedBiquitous Consortium developed the XML-based MedBiquitous Virtual Patient (MVP) data specification. This specification enables the exchange and reuse of VPs across different systems. The following are the main components of the MVP architecture (Sung et al., 2008), shown in Figure 2.

The Virtual Patient Data (VPD) provides the personal and clinical data that is related to the clinical scenario being simulated. The VPD contains data elements and some kind of structure that represents the medical history, physical and technical examination and therapy. The Data Availability Model (DAM) specifies the relation between the VPD and Media Resources (MR) elements to be used in the Activity Model. VPD and MR elements can be used multiple times in the DAM nodes depending on the logical relation between these elements, such as patient history and test results. The Activity Model (AM) encodes what the learner can do and how he may interact with the virtual patient. By creating available paths through content using interconnected nodes and controlling how the user can follow them using a simple rule system, a great variety of patient activities are possible. The AM provides the context in which they are exposed to the learner. Media Resources (MR) like images, animations, videos and audio files associated

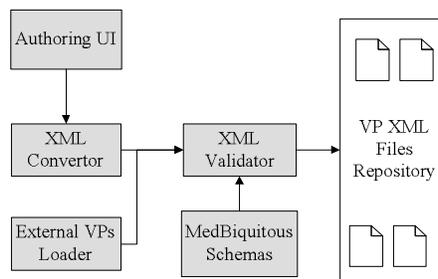


Figure 4. VPs XML Handlers

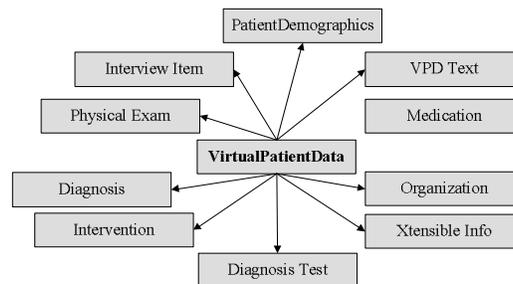


Figure 5. VP data structure elements

with the virtual patient are referenced in the DAM or in the VPD elements. IMS Content Packaging is used to structure media resources within the MVP specification and provide unique identifier for each media resource (Inga et al., 2009).

Principles of EUVES

EUVES is a medical e-learning system for authoring and delivering CBL to medicine students based on MVP standards. EUVES can work as helper tool for medicine professors to demonstrate the diagnosis process for students over the web in a virtual lecture style presented in Figure 3. Professors can select or create a new VP template, these templates are categorized by teacher upon their relevance to subjects. Each VP template contains a complete VP data and media resources, the teacher can create an instance from this template to start performing the diagnosis process on this instance. The idea of creating templates is to “reuse” previously created VPs and make it easier for creating VPs rather than copying files. After creating the instance the teacher may need to change some VP data for more clarification on this case or to add new important information needed for diagnosis like up-normal values for some lab elements, or increase the measure of blood pressure, etc.

All the previous steps are performed “offline” or away of students. Once the teacher finishes his updates on the instance chosen, he can start the virtual lecture. The

virtual lecture items are broadcasted to students over the web, starting with VP data and media resources. Teacher starts his lecture using collaboration tools like audio/video streaming, whiteboard, and performing visible physical examination on the VP instance. The physical examination is performed using a rich set of physician tools, and possibly to acquire some lab results for this VP instance. Each step of the diagnosis process can be opened for discussion by students using a simple chatting tool with the teacher until the teacher reach the conclusion of the diagnosis student can submit their questions and discuss the reasonability of diagnosis. The lecture can be saved to the Virtual Lecturers Library (VLL) and can be reviewed by student later. Another important feature of EUVES is it can be used as an assessment tool for students. Teacher can “setup” the instance as introduced previously, but he will assign the diagnosis process to a group of students who need to collaborate together to conclude the possible diagnosis with guidance of the teacher.

Data Structure of the proposed EUVES

In EUVES, VP's XML data structure is based MedBiquitous VP specifications. This global data structure enables EUVES to integrate with any other VP authoring system by importing VP XML files. An XML package is a set of XML files that represents a single VP. This standardization required implementing two

```
<PatientDemographics id="D009">  
  <CoreDemographics id="C1003">  
    <PatientID> P542 </PatientID>  
    <Name> Adam Ali </Name>  
    <Age> 50 </Age>  
    <Gender> Male </Gender>  
  </CoreDemographics>  
  <DemographicCharacteristic id="154B">  
    <Title> Marital Status </Title>  
    <Description> Single </Description>  
  </DemographicCharacteristic>  
</PatientDemographics>
```

Figure 6. Patient Demographics Example

```
<InterviewItem id="1">  
  <Question>How are you feeling?</Question>  
  <Response>Not very well.</Response>  
</InterviewItem>
```

Figure 7. Interview Item Example

components for building VP XML packages, and another for validating XML files schema before loading in the virtual lecture player as shown in Figure 4 (Marjorie and Nirenburg, 2009).

VP data structure is defined by a root element named VirtualPatientData, which contains the clinical and demographic data for VPs in addition to the metadata. VirtualPatientData element must exist once in a VP package. VirtualPatientData has sub elements defining the data of a VP shown in Figure 5, the existence of any sub element is optional (Inga et al., 2009).

Patient Demographics

The PatientDemographics element contains subelements that define the name, age, sex, and other demographic characteristics of a virtual patient and allows for the categorization or grouping of various demographic characteristics, see the example shown in Figure 6. It consists of two sub elements: Core Demographics which contains the regular demographics, and Demographics Characteristic which contains non-standard demographics.

VPD Text

It provides narrative or other descriptive text that is part of the virtual patient data. It contains A unique identifier for this text that can be used by other virtual patient components to control how the text is used in an educational activity, also it contains an indicator of the function this text serves in the virtual patient. Valid

values are: complaint, history, or problem. VPD Text could contain an xhtml div element that can be used to format how text will be presented to the user.

Medication

Medication describes a medication taken by the virtual patient in detail, including the medication name, dose, route, and frequency.

Medication name defines the name of the medication, possibly referencing a medical taxonomy or vocabulary. Dose defines the dosage of the medication, for example: 10 mg. Route defines the route of administration for the medication, for example: oral.

Interview Item

It describes a single question and response that is part of a clinical history, see the example shown in Figure 7.

Physical Exam

It describes a single physical exam and the findings of that exam. It consists of sub elements like exam name, location on body, actions the virtual clinician takes to perform the exam, findings of the exam for example: normal heartbeat, and the description of the physical exam in more details.

Location on body is defined by sub elements like which part of body, whether it's proximal or distal, right or left, front or back, inferior or superior.



Figure 8. VP authoring Module

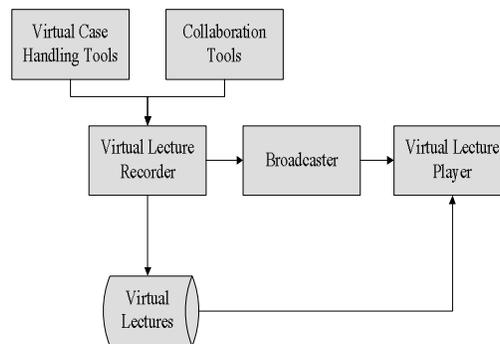


Figure 9. Virtual lecture module components

Diagnostic Test

Diagnostic test defines the test results. It consists of test name, unit to measure this test, result, and the normal value of the test.

Diagnosis

Diagnosis defines either a single differential diagnosis or a single final diagnosis intended by the virtual patient author. It contains the likelihood of the differential diagnosis being correct. Valid values are: high, medium, low, none.

EUVES Modules

EUVES is composed of main four functional modules: configuration module, learning management module, VP authoring module, and virtual lecture module. EUVES

supports three types of users, with different authorization levels: student, teacher, and administrator.

Configuration module

The administrator module manages users, permissions, and lookups. System administrator is responsible for managing users of the system and defining their permissions upon their types.

Learning management module

Professors can access to VPs templates databases and they can create user specific virtual cases. Each teacher has his own set of virtual cases and then he can use these cases in virtual lectures or assessments. Professors also can create new assessments and select students who will perform this virtual assessment. Through this module professors can categorize virtual

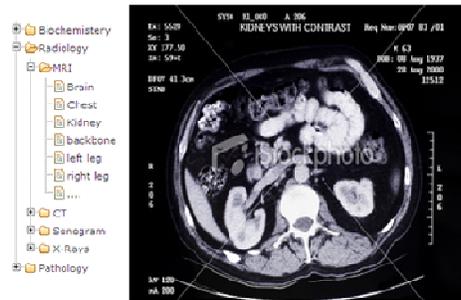


Figure 10. Virtual Activities.

lectures into subjects and can view reports related to each subject like number of virtual lectures, or assessments reports.

VP authoring Module

This module provides a tool for building VPs with a simple user interface for professors who does not need to know about the structure of VP, without help of multimedia developers or designers. Most of VPs created on EUVES are built using VP templates which were developed with assistance of Mansoura Medicine Faculty professors who provided the initial information needed for each case. Based on the MVP specification model, templates contain VP data like text, media resources, diagnosis, some questions and answers. This information must lead to a specific medical conclusion about this VP. All templates are based on the normal template that presents the normal conditions and data for a normal human. Then professors use these templates to define their own virtual cases by updating some information of the template that could makes it easier for students to perform the diagnosis or by making it harder in assessments. Professors can update VP data from a usable web interface shown in Figure 8. VP data in authoring module are categorized into general information, patient history, physical examination, lab tests, diagnosis, and therapy.

Professors use these categories for submitting VP data, which consists mainly of text, boolean, images, and different multimedia formats. History information, physical examination, and lab tests are considered important to solve the case can be marked as required. The amount of time needed to create a single case varies and may depend on the complexity of the case.

Virtual lecture module

This module is main core of EUVES. It manages the CBL concept of putting users in a virtual situation, and starts

to record and analyze their activities for solving this situation. The main components of this module are shown in Figure 9.

The virtual case handling tools are an important component of this module; it manages the VP data and the virtual activities like diagnosis and lab tests. An example of the virtual activities is shown in Figure 10.

Some VP data are visible to users of EUVES, others are hidden waiting for virtual activities to be performed to reveal these hidden information about the virtual case. In e-learning context collaboration tools are very important to help professors and students to share knowledge and for open discussions related to virtual cases like discussion boards, whiteboard, and chatting. Both virtual activities and collaboration activities are recorded using the virtual lecture recorder as a one unit like a video recording for a real lecture. Students can view any recorded virtual lectures from the virtual lectures database. Live virtual lectures are broadcasted to students and viewed using the virtual lecture player, which is a web-based interface that presents virtual case properties, virtual activities, and collaboration activities. EUVES provides another feature which is virtual assessment. In virtual assessments students plays the physician role, and they conclude the final results and therapy plan. Then teacher evaluate these results like the real assessment scenario. Virtual assessment is built on the same components of this module.

Conclusion

Medical e-learning based on CRL is currently used in medical schools throughout the world. Unfortunately the computer support systems available are not adapted for multi-users, and don't have immediately teacher feedback. Our objective is to create a computer tool to allow medical e-learning in collaborative form. In this paper the main features for virtual patient usage in medical e-learning are described. Clinical Reasoning Learning is chosen as a pedagogical role-play format method, because it the best method to simulate the

medical consultation. And Virtual Patient is chosen as design and implementation model for applying the CRL, as it provides extra functionalities that are not used during the face-to-face simulations. Multimedia data allow students to have a more realistic representation of the patient problem than can be represented by a virtual patient. The electronic notepad allows the teacher to assess and send feedback. It also allows information to be shared and compares physicians' notes. Furthermore, EUVES has been presented. It consists of different modules for learning and assessment with virtual patients based on case-based learning methodology. An easy to use authoring system enables the user to create virtual patients based on a defined structure of virtual patient data like patient demographics, interviews, diagnosis, and medications. Building the system on MedBiquitous specifications enables EUVES to integrate with any other system built on the same specifications like eVip by importing and exporting virtual patients XML files. Medicine professors can use EUVES to practice virtual diagnosis and therapy in a virtual lecture, or assess students online. Students can communicate with the lecturer by a rich collaboration tools like whiteboard, and discussion boards. Virtual lectures can be recorded, containing virtual case, virtual activities, students' questions and answers.

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