SUMMARY In medical education, many of computerized Problem-Based Learning (PBL) systems are used into their training curricula. But these systems do not truly reflect the situations which practitioners may actually encounter in a real medical environment, and hence their effectiveness as learning tools is somewhat limited. Therefore, the present study analyzes the computerized PBL teaching case, and considers how a clinical teaching case can best be presented to the student. Specifically, this paper attempts to develop a web-based PBL system which emulates the real clinical situation by introducing the concept of a “time sequence” within each teaching case. The proposed system has been installed in the medical center of National Cheng Kung University in Taiwan for testing purposes. The participants in this study were 50 of 5th grade (equivalent to 1st grade students in a medical school of the American medical education system) students for the evaluation process. Some experiments are conducted to verify the advantages of designing teaching cases with the concept of the “time sequence.”

key words: e-Learning in medical education, e-Learning, cyberworlds for education, computer education

1. Introduction

Recently, many medical schools and centers had adopted a variety of approaches in an attempt to address various problems of the traditional medical training methods. In particular, as the Internet becomes prevailing, one such approach has been to introduce computerized Problem-Based Learning (PBL) techniques [3, 6, 12] using a browser. In the medical field, this approach involves the presentation of clinical cases as a means of learning basic medical and clinical science [2, 5, 7]. Previous studies have confirmed that implementing PBL techniques on computer networks provides an effective training tool for physicians or students in medical schools, and enables these students to acquire the necessary knowledge and experience required to perform accurate diagnoses in their actual clinical practices [3, 10, 14]. The basic three steps of a computerized PBL system within the medical training field are as follows: (1) Students are puzzled and challenged by the patient’s problems that are given all at once. (2) The system will provide some selection types of questions for the students to get more information needed, such as questioning the patients and ordering some laboratory tests. After the students’ selection, the corresponding answers to the questions will be provided so that the students can get more information about the patient’s status. For instance, the system enables the students to select any kind of laboratory tests and provides the answers to them to emulate the real clinical situation. (3) The students can repeatedly interact with the system interactively and work on their ways in an attempt to diagnose and cure the patient’s problem. Current web-based PBL systems do help students’ learning to some extents, they suffer from several serious drawbacks, which degrade their effectiveness as learning aids. For example, they do not truly reflect the typical clinical situation, in which a patient’s condition may evolve over time. This drawback, together with others discussed later within this paper, basically arises from the manner in which the data relating to a particular teaching case is presented to the student.

Consequently, this present study considers how a computerized PBL teaching case should best be presented to the student such that it serves as a truly effective learning tool [16]. The study also discusses the implementation of a prototype system – HINTS (Health Information Network Teaching System), which was developed in the last 10 years and is currently being used to test the approach proposed within this paper. Section 2 of this paper briefly describes the concept of the teaching case template adopted by the proposed system. Furthermore, the background to the most commonly available computer-based or web-based PBL systems [1, 8, 11, 12] is discussed, and their relative drawbacks are analyzed. The adoption of a time sequence concept within the computerized PBL teaching cases as a means of addressing these limitations is also discussed. Section 3 adopts the concept of a time sequence in the presentation formats for medical teaching cases. In order to really demonstrate the idea of the time sequence, we also implement the idea in a web-based computerized PBL teaching case system that allows students to simply use a WWW browser to browse the contents of the system. Section 4 discusses the architecture of the proposed system and its implementation. For this particular study, we select 50 students.
of them for the evaluation process. Section 5 describes the results of our experiments with the proposed system. Finally, we give some brief conclusions of the present study in Sect. 6.

2. Relevant Background

In order to explain how the developed prototype system is implemented, it is first necessary to introduce the concept of the PBL teaching case template. The developed PBL teaching case system is essentially a multimedia CAI (Computer Aided Instruction) system. Generally speaking, such systems comprise three basic models, namely a knowledge model, a student model, and a tutor model[13].

The knowledge model is a database containing the knowledge of specific topics which an expert in that particular domain could reasonably be expected to possess. The data stored within the knowledge model represent the knowledge which is to be taught to the student, and should ideally be stored in an abstract fashion such that the model is capable of dealing with different learning situations in a flexible and intelligent manner. Therefore, the current knowledge model utilizes a number of “teaching case templates”[15] to form an abstract model of the domain knowledge. In other words, the templates outline the main contents of the various teaching cases, and serve as the directories of each case. A typical medical teaching case might well include the following sections: (1) basic personal information such as the patient’s age and gender, (2) a brief case history, (3) reported complaints, (4) results of physical examinations, (5) findings, (6) the diagnosis, (7) relevant cases, (8) discussions, (9) comments, and (10) learning points. The details of all sections of the template can be presented via hypermedia techniques. The authors of the PBL system are provided with the tools required to create a case template or select a case template from an existing case template database, in which each template has a defined name and an appropriate set of titled sections, e.g. History, Diagnosis, etc. as described above. If necessary, each of these sections can be further partitioned into several sub-sections. It is noted that a single teaching case template may be used by many teaching cases of the same type. Each teaching case within the system identifies the particular case template which it uses.

3. The Concept of Time Sequence in a Teaching Case

In many computer-based or web-based PBL teaching case systems[4], [9], [12] as briefly described in three steps before, the student is first presented with basic patient information and details of the patient’s principal complaints. He is then provided with the means to specify the sources from which he wishes to get relevant information to the case, e.g. history taking information, laboratory examination items, etc. The detailed information, as the answer to the selected items, is then retrieved and presented to the student, who can then select whichever information he feels to be necessary to make an appropriate final diagnosis. Once the student has provided his diagnosis, the system will assesses his performance in completing the teaching case.

In this type of computerized PBL teaching case, all of the relevant information relating to a particular case is lumped together within the system. However, in practice, it is far more likely that this information will be accumulated gradually over a long period of time. In other words, conventional computerized PBL techniques do not include the concept of a “time sequence” of events within their teaching cases. For reasons of convenience, this type of teaching case will be referred to as a “lump-teaching case” throughout the remainder of this paper. Although this type of teaching case may be of some value for training purposes, it is nevertheless rather unrealistic, and suffers from the following drawbacks:

1. In many cases, a medical practitioner is unable to make a final diagnosis after the patient’s first visit. Several patient visits may be needed before the final diagnosis can be made. During the on-going course of diagnosis and treatment, the results of the physical examinations, and the patient’s response to the prescribed medicine, may lead the practitioner to consider or to discount various diagnoses. Each stage in the medical decision-making process has its own reasoning and inference procedures. To accurately represent the medical situation described above, and to emulate the associated decision-making processes, it is important that the PBL teaching case presents the various events in an appropriate time sequence. The overall diagnosis and treatment of a patient may well involve a series of treatments and physical examinations, and hence the diagnosis and treatment process can be regarded as a series of events taking place at different points along a time axis instead of happening all at once as described in most of the current computerized teaching cases found on the web.

2. There are some other situations where the concept of time sequence in a teaching case is necessary. For instance, in many actual cases, local regulations may prevent the medical practitioner from scheduling physical examinations at will, or at least not unless the patients are willing to meet the cost of these examinations from their own pockets. For example, in Taiwan, the National Health Insurance Scheme, which is administered by the central government, does not permit a medical practitioner to schedule certain physical examinations until other preliminary tests have first been performed to confirm that the further examination is truly necessary. This policy exists to avoid wasting limited insurance fund resources, and furthermore, to protect the patient’s general health, since some examinations may cause physical discomfort, or even physical harm. Although the example cited above refers specifically to Taiwan, the same situation is common in many other countries which operate similar health insurance poli-
cies, or to cases where private insurance companies will meet the cost of the examination.

(3) From a purely clinical perspective, the physical examinations should be sequenced in such a way that the cheaper, non-invasive, and safer examinations are performed first. The more expensive, invasive and riskier examinations are performed at a later stage in the course of treatment if and when they are called for. In most computerized teaching cases which lump all of the information together, it is difficult to determine whether or not a student is following the correct line of thought in scheduling the appropriate examinations in an appropriate sequence.

The main point of the preceding discussions is that each of the events within a course of treatment occurs at a discrete time, and hence this sequence of events and the corresponding accumulation of the thinking processes should somehow be emulated within the computerized PBL system. Accordingly, the present study incorporates the concept of time sequence in the proposed teaching case system by developing “time-sequence teaching cases” in which each individual event is recorded, and presented, as part of an overall sequence of events distributed along a time axis. Obviously, the time-sequence teaching cases are much difficult for the students to deal with. Therefore, we want to be able to present a teaching case in both the lump or time-sequence formats depending on the students’ sophistication level about the teaching case. We will describe the detailed implementation in the following section.

4. Implementation Issues

The implemented system contains editing tools which allow the authors to edit both the case templates and the teaching case materials. The case templates and the teaching case materials are then stored in appropriate databases. The author has to prepare a teaching case with time sequence events and enters the case into the system using the editing tool. For instance, in a male preterm infant case, he was delivered at 29-weeks gestation. His Apgar score was 1 at one minute and 4 at five minutes after birth. On Day 10, it was noticed he had a mild fever, frequent apnea, bradycardia, etc. On Day 20, the infant exhibited signs of abdominal distension, and subsequently, a bile-stained substance was noted in the nasogastric tube, etc. These and other time sequence events can be entered into the system. In this real clinical case, the patient’s condition changed constantly over time, and it was necessary to order various laboratory examinations and to prescribe appropriate clinical treatments in response to these changing conditions. In this case, the time-sequence presentation format is clearly the most appropriate presentation format.

When a particular case is activated, the relevant data, i.e. the associated case template and the applicable case contents, are retrieved from the databases and made available for presentation processing in accordance with the required presentation format. Regarding the teaching case presentation policy, the implemented system has two databases:

(a) A user profile database which records each individual user’s major (e.g. Internal Medicine) and his level of ability (e.g. “Intern,” “Specialist,” “Medical School Student,” etc.).
(b) A view-rule database comprising the following fields: (1) user level, (2) user major, (3) case template ID, (4) section name, (5) presentation mode (i.e. lump-presentation or time-sequence-presentation), and (6) a switch flag which records how each section of the teaching case should be presented. As will be discussed later, items 1 to 5 are used as indexes to retrieve the appropriate switch flag, which then specifies how the corresponding section is to be presented.

The user profile database must be populated by the system administrator, and the view-rule database by the authors, before the teaching cases can be published on the website. The overall architecture of the proposed system is shown in Fig. 1. It is noted that all of the multimedia documents associated with the various teaching cases are stored in a teaching case database within the system in order to simplify their management.

When a student accesses the web browser and logs into the system, the system will first retrieve that individual’s major and default user level from the user profile database. When the student activates a teaching case for interactive browsing, the system, based on the user’s level and major, the case template ID (stored in the case), and the specified presentation mode, will then determine the appropriate switch flags from the view-rule database such that the data within each section is presented in the appropriate format. As shown in Fig. 2 (a), the system presents all of the section names associated with the particular case template in the form of push buttons on the right side of the screen. Meanwhile, in a sub-window on the left side of the screen, all of the teaching cases which the student can access and browse are displayed in the form of a hierarchical structure. It is
noted that this sub-window can be closed by the student at any time if it becomes necessary to free up additional screen space to display the contents of the current teaching case as shown in Fig. 2(b). When a particular section is activated, the system acts in the same way as a web service application system responding to a web browser's request, and retrieves the appropriate contents from the teaching case database, references the corresponding switch flag, and then presents the contents of that particular section in the required format.

In the time sequence teaching cases, the patients' conditions are changed over time. Therefore, for the outpatient cases, the time sequence events with their associated time stamps are stored in the teaching case database, and are retrieved and presented in terms of 1st visit, 2nd visit, and so on. For the inpatient cases, the time sequence events are presented as Day 1, Day 2, and so on. The same case template is used for each "time slot" (i.e., the 1st visit, the 2nd visit, and so on). For the time sequence cases, after the student gives the tentative or final diagnosis and patient management for the 1st visit, the system will automatically enter the 2nd visit and the same process can be repeated until the conclusion of the case is reached. Then the system will provide the student with a summary to indicate the student's performance, such as how many correct items have been selected by the student and how many have been missed in each section of the case. In other words, the system really emulates what happens in a real clinical setting and the student simply work their way through the complete clinical case. Figures 2(b) and 2(c) show the present illness and family history sections for the second and third visits respectively. The student can select the questions he thinks are critical to the case. The corresponding answers to the questions will be displayed below the questions. He can not simply ask any questions he wishes, due to the difficulty of processing natural language with current technology.

From the discussions above, it can be seen that the switch flag corresponding to each section governs how that particular section should be presented at run time. As a result, a single teaching case can either be presented in a lump-presentation format or in a time-sequence-presentation format.

5. Experimental Results

The proposed system has been installed in the Medical Center of the National Cheng Kung University about one year for testing purposes. More than 150 students ranging from the 5th to 7th grade (equivalent to 1st to 3rd grade students in a medical school of the American medical education system) have had experience in using the system. For this particular study, we select 50 of 5th grade students for the evaluation process. These students have already taken most of the basic medical science related courses and have had enough basic medical knowledge for the clinical diagnoses. Currently, they have many practical training courses in the medicine department. The objective of the courses is to learn the skills of how to face a real patient, order laboratory test, make a diagnosis, and give treatment to the patient. We use these teaching cases in the HINTS to emulate the real cases. The experimental group received a one-hour orientation to the patient simulation software. This session introduced the students to the HINTS interface with another simulation. Students learned to use the software without difficulty.
The learning process is structured according to the seven-jump method. The seven-jumped procedure \cite{16} in PBL is shown in Fig. 3. The first to fifth steps are pre-discussion, and the seventh step is post-discussion. In the pre-discussion (the first classroom lecture for a case), the instructor gave the students some background knowledge about the particular case in the classroom. Then, the students browsed through the case by themselves including reading through the basic information and chief complain sections in the HINTS, specifying which part of the patient body should be examined, what questions should be asked, and what laboratory test should be ordered to get more information and insight about the patient’s status from the HINTS. They went through several patient visits as time went on, and finally gave their final diagnoses for the exercise. The post-discussion is in the second classroom lecture, the instructor and students discussed their results computed by the HINTS and experiences. Table 1 summarizes the student responses to a series of questions posed by the current researchers. The students have also made a variety of comments after using the teaching cases in the post-discussion. The principal results of this study are summarized as the following:

1. All students feel that the teaching cases presented using the time-sequence-presentation format approach better resemble the actual clinical setting, and provide a better feeling for what actually takes place in an authentic clinical environment than the cases presented using the lump-presentation format.
2. All of the students agree that the system can significantly develop their skills for dealing with real clinical cases. Furthermore, when a patient’s condition evolves over time, it is felt that the concept of a time sequence within the teaching case is particularly meaningful.
3. 72% of the students think that if the system limits the number of patient visits a student can have during the diagnosis procedure of a teaching case, it will cause the teaching case to become more interesting and more challenging.
4. The time-sequence-presentation of a teaching case enables the teacher to check whether the student has ordered the appropriate physical examinations at the appropriate stage of the diagnosis process, i.e. from

### Table 1: Results of medical students’ evaluation of the proposed system.

<table>
<thead>
<tr>
<th>Question</th>
<th>Percentage of Respondents % (n=50)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Strongly agree (5)</td>
</tr>
<tr>
<td>Practice can improve the individual learning process?</td>
<td>28</td>
</tr>
<tr>
<td>The use of multiple visits can simulate the real clinical situation?</td>
<td>6</td>
</tr>
<tr>
<td>The operation of the multiple visits cases was easy?</td>
<td>6</td>
</tr>
<tr>
<td>The multiple patient visit cases enable you to learn and trace more about the patients' condition?</td>
<td>12</td>
</tr>
<tr>
<td>The system can improve the capability of the clinical service?</td>
<td>12</td>
</tr>
<tr>
<td>The limited number of patient visits makes the case more interesting and more challenging?</td>
<td>28</td>
</tr>
<tr>
<td>Do you think the time-sequence-presentation case better resemble the actual clinical setting and provide better feeling for what actually takes place in an authentic clinical environment than the lump-presentation case?</td>
<td>36</td>
</tr>
</tbody>
</table>


1-5: pre-discussion 7: post-discussion

**Fig. 3** The seven-jump procedure in PBL.
cheap, non-invasive, and safe examinations during the initial stages, towards more expensive, invasive, and riskier examinations towards the latter stages.

6. Conclusions

This paper has proposed and implemented the concept of a time-sequence in the computerized PBL teaching cases. Experimental results have indicated that students feel strongly about the way in which cases are presented to them. Furthermore, the students have confirmed that the teaching cases are more interesting and challenging when the time sequence concept is used, and that these cases provide a better feeling for the actual clinical environment which they will work within in the future.

References


