CASE STUDIES for Dentistry®: Development of a Tool to Author Interactive, Multimedia, Computer-Based Patient Simulations

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Abstract: Computer-based patient simulations have been used to enhance the dental curriculum since the 1980s. This article describes the development of CASE STUDIES for Dentistry® (CSD), a patient case simulation building template, developed at Virginia Commonwealth University, with which authors who have no programming expertise can create realistic, effective, interactive multimedia patient simulations by entering their own information and images into a straightforward, fill in the blanks interface. This program was written with Authorware®, by Macromedia® Inc. Design considerations included emphasis on information collection and analysis, synthesis of collected information, hypothesis proposal and testing, diagnosis, and treatment planning. The program consists of easily accessible interfaces for both authors and students. Authors build simulated patients using typed-in text and their own images. Faculty can build computer-based simulated patients so that students can immediately practice what they learn in class within a simulated doctor-patient relationship. CSD allows building simulations ranging from simple to complex patients in multiple disciplines. Robust feedback and other features allow students to learn both process and content in a self-directed, interactive environment.

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Educators continue to develop sophisticated applications for computers in the learning environment. Computers assist students in their day-to-day learning activities. With the Internet and larger capacity portable media, such as CD-ROM, students can engage opportunities for learning in many venues at almost any time.[1] New applications make self-directed, self-paced study possible and challenge current educational practice.[2] A recent paper by Rosenberg et al.[3] has thoroughly reviewed, compared, and evaluated the results of several studies on the effectiveness of Computer-Aided Learning (CAL) in dental education. Limiting their analysis to twenty-seven randomized controlled trials in dental education, these authors[3] recommended that CAL be used as an adjunct to conventional teaching or as a means of self-instruction. They found that CAL elicited a positive response from students and motivated students to learn. These programs were at least as effective as other methods of learning and carried "value-added"[3] advantages including anytime access and self-paced learning and review.

Computerized patient simulations are a form of CAL. Medical education has a long history with CAL starting in the early 1970s.[4] Today, a MEDLINE search combining just the terms "simulation" and "medical education" garners over 2500 citations. A sampling of medical education's involvement with CAL involves interactive problem-solving software,[5] diagnostic instrument modeling,[6] anatomic process simulation,[7] and simulation of normal and bodily functional examination.[8]

The idea of using simulated patients to illustrate points and provide clinical relevance within the curriculum is not entirely new to dental education.[9-13] Simulations provide direct interaction between a user and a simulated patient who resides (as part of a program) in the computer. Previously reported computer-based patient simulations utilized the most advanced technology of their time. The first successful interactive case simulation program for dentistry was the "DDxTx" program developed at the University of Iowa by Johnson et al.[9] This system solidified the concept that student "doctors" could ask the computer-based, simulated patient a question and receive an answer. Similar interactivity allowed students to gather data from videodisk images of the patient, describe their observations, make a diagnosis, propose a treatment plan, and receive feedback. Hardware consisted of at least two screens, a central processing unit, and a videodisk player. Interactivity was limited due to both hardware and software constraints. Authoring consisted of typing information into a word processor in a very specific format so that an intervening program could interpret the text as commands to the computer. This system is still used extensively at the University of Iowa's College of Dentistry.

Another patient simulation program resulted from the efforts of the Dental Interactive Simulations Corporation (DISC).[14] DISC is a commercial venture that grew out of an attempt by regional dental licensing boards to develop a means to use simulations instead of live patients to test candidates for licensure. Using highly technical, proprietary interactive sequences aimed at the practicing dentist, this program attempts to simulate all aspects of dental practice from patient registration to instrumentation, serial appointments, and record keeping. No information is available about the possibility of authoring with this system.

Because Virginia Commonwealth University School of Dentistry had a need for an authoring system to create patient simulations, and because no other system was commercially available, we developed CASE STUDIES for Dentistry® (CSD). CSD is a patient simulation authoring template with which individuals with no programming expertise can create realistic, effective, interactive multimedia patient simulations by entering their own information and images into a straightforward, fill-in-the-blanks interface. We developed this program with Authorware®, an advanced object-oriented authoring program by Macromedia® Inc. of San Francisco, California.

Design Considerations

In more traditional case presentations that all dental faculty use in their teaching, the common scenario is: a chief complaint, a few symptoms, some history, a picture or two, and the question "What is your diagnosis/differential diagnosis?" or "What would you do next?" Dialog ensues between teacher and student and consists of a number of "what-ifs." Perhaps students ask for more information, and the faculty member gives it to them. Finally, a differential diagnosis and/or diagnosis is established. Then the dialog with the students often switches to treatment, and the faculty member poses another series of "what-ifs" to get to the various treatment options. This Socratic discourse, a valuable tool with advanced students and residents, requires a disease information database, a vocabulary, and familiarity with patient-doctor interchange and the investigative process. None of these are strong suits with beginning students. Before students can appreciate the Socratic case presentation format, they must possess basic biomedical content and patient context knowledge.

The health care context within which biomedical knowledge is used is particularly important. The traditional case presentation is exactly that—a presentation. The conversation is about the patient, not with the patient, and students are not responsible for collecting information on their own initiative by puzzling out what questions to ask the patient, performing examinations, and ordering tests. In a case presentation, the teacher supplies the relevant information. It is assumed the student knows how and where to gather the background information and knows the context within which it becomes relevant. If this is the student's first exposure to the patient-doctor relationship context, a student could be confused as to the source of the case information. Students who readily know the information collection process and have basic disease knowledge within the patient context can benefit from the Socratic case presentation and nothing is lost. If, however, there is no context within which to appreciate the information gathering and processing skills and the need for prior content and context, it is more difficult for a student to discover the process using case presentations. Thus we decided to develop an instrument that could be used to build patients as opposed to cases.

The Design Team

Throughout the software industry, teams develop most application programs. The latest application a customer buys will have the development team listed somewhere in the documentation, and it is not unusual to have twenty to thirty people making up a team. The theory is that nonhierarchical teams work more effectively through the complex iterations and time-consuming gestation of a software program, and they gain strength through shared successes and failures.[15] Our design team consisted of the authors of this paper: LMA, concept designer and content expert; PLA, graphic artist; LH, educational designer; MBH, programmer; and SL, graphic artist.

At the outset, the design team decided to create simulations that would require information gathering, analysis of information, and action based on that analysis. Thus, students would learn the importance of these skills in a patient care context. CSD simulations emphasize: 1) information collection and analysis in a variety of contexts; 2) questions and decisions that require synthesis of collected information; and 3) hypothesis proposal and testing, diagnosis, and planning treatment.

Student Interface

Multimedia, computer-based simulated patients should provide a simple, unencumbered patient-doctor-like context within which students can learn and engage in problem-solving. Adults learn quite effectively when they can act independently, in a self-paced manner, to solve problems in the context of what they will be doing upon completion of their education. Adults also like to receive robust feedback on their progress through learning exercises.[16,17]

Using a multimedia, computer-based simulated patient with a problem, a dental student should be able to practice problem-solving activities such as discovery, observation, ordering/interpreting radiographs and diagnostic tests, synthesis of collected data, hypothesis proposal and testing, final diagnosis, and treatment planning. Accordingly, we established the following characteristics for CSD:

1. Primarily directed toward teaching/learning;
2. Simple, unencumbered, intuitive;
3. As close to live patient interaction as technology allows;
4. Maximum portability and multiplatform;
5. Unrestricted access to simulation features (example: users can take a radiograph any time they wish, even if not indicated, like life); and
6. Fosters decisionmaking, critical thinking, and mentoring.

Authoring Interface

The other side of patient simulations is the authoring system. Faculty who teach should create the patient simulations because they can integrate cases smoothly into the structure of their curricula and develop the nuances in difficulty and similarity necessary to produce effective cases in a series. We devised the following characteristics for the CSD authoring system:

1. Direct, intuitive, esthetically attractive;
2. Requires minimal new and unfamiliar skills;
3. Self-entry of data and images through a template;
4. Accommodates data and scenarios from multiple disciplines;
5. Emphasizes the variety of skills required in a patient-doctor relationship;
6. Authoring interface visually similar to the delivery environment; and
7. Allows standardization and a spectrum of difficulty levels.

With CSD, the author builds a patient on the computer with whom the student will interact. The student doctor interacting directly with a patient is the context. The author teaches by writing feedback and constructing questions and answers that emphasize important content, discuss key issues, clarify context, and explain concepts. This constitutes the mentoring function of CSD simulations.

The student receives no information up front except for the chief complaint and some demographics. Just as with a live patient, the completed patient simulation contains all the vital information to make the diagnosis and plan the treatment. The student must discover the information and put it together by asking questions, performing examinations and tests, ordering and interpreting radiographs, etc. Thus the student's initial patient-doctor interaction begins with having to elicit problem information from the patient. The student works through a simulated patient independently, learning to gather and sort information, generate and test hypotheses, draw conclusions based on evidence, and finally synthesize a diagnosis. Through this independent learning, the student can discover what works while developing a comfortable problem-solving style of his or her own. The simulation environment forgives mistakes and reduces the tendency to mimic the teacher who may have a different style altogether.[18] Students also learn some content knowledge. Primarily, however, they learn a structured thinking process and a pattern for problem-solving. Not only must the student decide what to do, but whether to do something. Decisions must be made at every point. All the options for information gathering are available to the student all the time, just as in real life.

Prompting occurs through feedback. Independent learning builds confidence and eliminates the confusion that arises when the "expert" is trying to instruct the "novice" or the "novice" is trying to please the "expert."[16] In face-to-face instruction, experts may have difficulty understanding that they reason differently from novices, and this interferes with the means of and expectations during instruction interactions. Novices, on the other hand, want to please their expert instructors and often try to say what they think the experts want to hear rather than saying what they believe at the time. Mentoring through feedback during interactive computer sessions can create a climate in which novices are more willing to take risks with their own thought processes.

CSD System Description

The elements listed on the right of the screen (Figure 1) form the organization scheme of CSD simulations. Chief Complaint, Med/Den History, and Diagnosis elements are self-evident. Physical Exam includes: Head and Neck exam, Intraoral exam, Percussion exam, Electric Pulp Test, and Hot/Cold exam. Old Records includes: Old Radiographs, Old Images, and Old Data. Diagnostic Tests includes: Biopsy, Smear, Hematology, Chemistry, and Culture. Treatment Plan allows students to prescribe medication and plan treatments in Periodontics, Restorative, Surgery, and Endodontics, refer patients, and establish follow-up. This simple, uniform, friendly interface contains brief instructions on screen at all times; detailed instructions are available at the click of a mouse. The students never have access to editing functions.

This organization plan is familiar to most clinicians as a derivative of the scientific method:

1. Frame the problem.
2. Gather information.
3. Propose hypotheses (one or more) to explain the cause.
4. Test each hypothesis to include or exclude.
5. Choose the strongest hypothesis on the basis of evidence.
6. Take appropriate action to solve the problem.
7. Evaluate the action as a solution to the problem.

The progression through a simulation can be thought of in several phases, although these are not formal divisions of a CSD simulation:

1. Phase 1—chief complaint, external head and neck exam, intra-oral exam
2. Phase 2—vitality testing, radiographs, and old records
3. Phase 3—hypothesis proposal (differential diagnosis)
4. Phase 4—testing the hypothesis (biopsy, lab tests)
5. Phase 5—diagnosis
6. Phase 6—treatment plan

After phase one data gathering, there could be a pause to prompt the student to propose initial hypotheses for the problem. In order to minimize interruptions in the student's progress through the case, however, the decision was made to postpone examining possible causes of the problem until after the second phase of data gathering.

Once the data has been gathered for the first and second phases, the student then pauses and develops a Differential Diagnosis. The rubric we use is to present a mixed list of correct and incorrect hypothetical causes from which the student chooses all the relevant causes that belong in the differential diagnosis. Authors must build in feedback for each hypothesis (both correct and incorrect). Students receive the feedback instantaneously after they make a choice. This enables them to evaluate their reasoning process immediately. The concept of ongoing maintenance, constant revision, and testing of a differential diagnosis list in the clinician's mind (in real clinical situations) is explained on the differential diagnosis screen.

Once a differential diagnosis is determined, the student tests each hypothesis in phase four by performing, if necessary, one or more Diagnostic Test(s) (Biopsy, Smear, Hematology, Chemistry, and Culture). Feedback, questioning, and discussions with students are used to emphasize that in real life the hypothesis testing may go on for several rounds and still may not lead to a clear diagnosis. CSD simulations can be authored so that this first round of hypothesis testing leads to a clear diagnosis, or it is possible to end up with several plausible diagnoses. Our reasoning here is that we wanted to include the

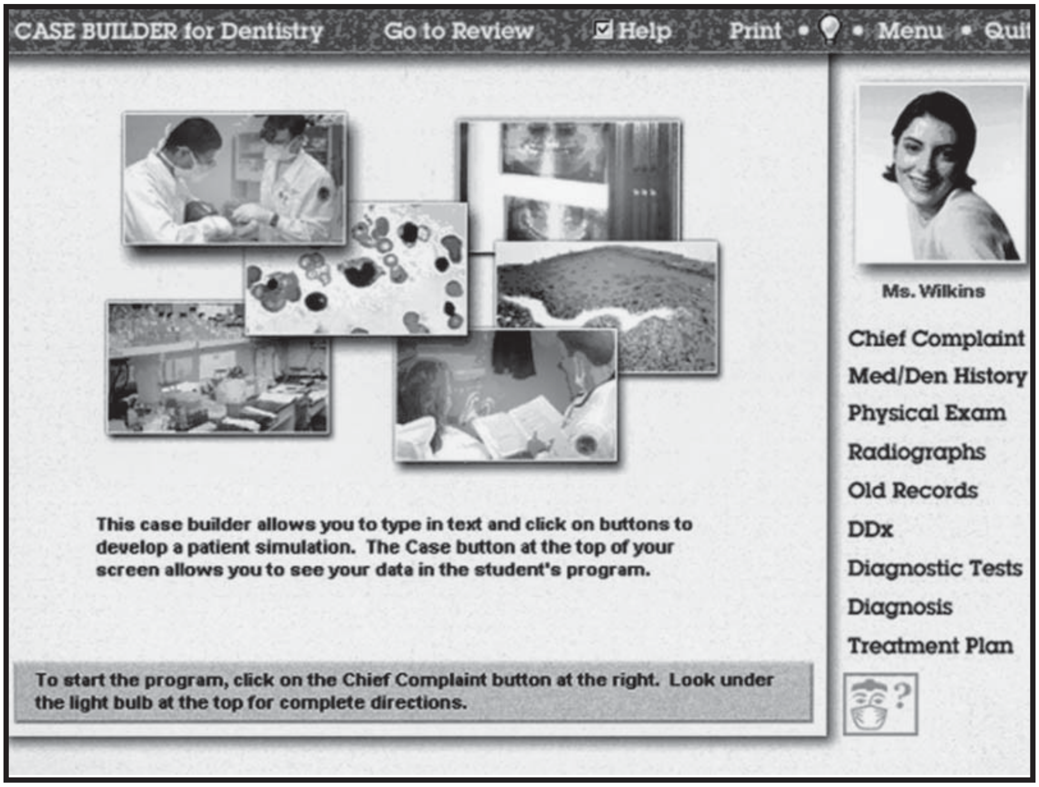

Figure 1. The organization plan for a CSD Simulation appears and remains in the right-hand column of the screen throughout a simulation session.

means for authors to build cases that range from unambiguous to some degree of ambiguity.

Phase five is the Diagnosis. This is accomplished by the student typing the diagnosis decided upon in phase four into a specific box on the screen. Typing a diagnosis that has just been determined a few moments before is a deliberate educational reinforcement of the phase four hypothesis testing result. The student intellectually establishes the diagnosis in phase four and types the diagnosis in phase five.

The final phase is to determine treatment for the patient's problem. The student must first decide which of the treatment categories (Prescription, Periodontal Treatment, Restorative Treatment, Surgical Treatment, Endodontic Treatment, Referral, Follow-up) is/are appropriate and then choose the correct treatment from within the category. The author designates which treatment category(ies) is/are appropriate for the patient. Treatment can be a single category or involve several or all of the categories. The author builds multiple-choice questions and feedback into each treatment choice to explore the reasoning or basis for the student's decision. Authors describe the treatments using text (in endodontic treatment, referral and follow-up) or a combination of text and images (Periodontal Treatment, Restorative Treatment, Surgical Treatment). In the Prescription option, the student chooses the medication(s) of choice, which the author has supplied, then types the correct prescription(s) on a pad provided by the program. Referral can be used for at least two circumstances: a referral to a specialist (dentist or physician) for treatment or to another kind of aid or care, such as for evaluation of a psychosocial problem.

Data and Image-Handling

CASE STUDIES for Dentistry is accompanied by a fully illustrated manual. CSD consists of three programs: Builder.exe, Review.exe, and Student.exe. All three of these programs draw their text and images from two data folders, one labeled "Images" and another labeled "Cases" (Figure 2). Student.exe can function independently and therefore can reside separately on the simulation disk that students use. All three programs have similar interfaces and screens, so both faculty and students interact in a common, familiar environment (Figure 3).

Builder.exe is the authoring program (Case Builder). The author enters text (data) into appropriate blank spaces on a builder screen (Figure 4). Periodically, the author can see how the simulation will appear to the student by seamlessly switching between the Builder and the Review program (this routine is explained in the manual). All the data for a case, entered through the Case Builder, goes into a separate, numbered subfolder inside the main "Cases" folder (Figure 5). The builder program automatically creates a numbered subfolder within the main "Cases" folder for the text of each new case (data).

Builder.exe also creates named subfolders inside the main "Images" folder for the images used in each new case. The author prepares images according to format, size, and naming conventions outlined in the CSD manual and loads the images for any one

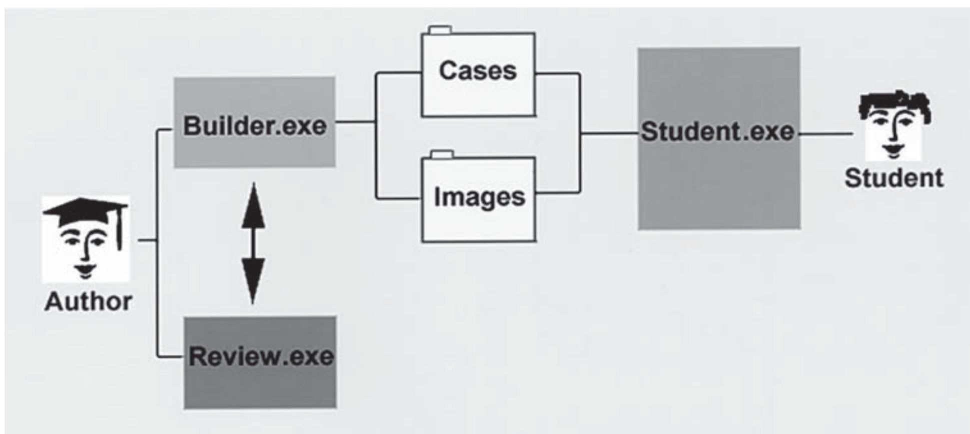

Figure 2. The data-handling scheme for a CSD Simulation

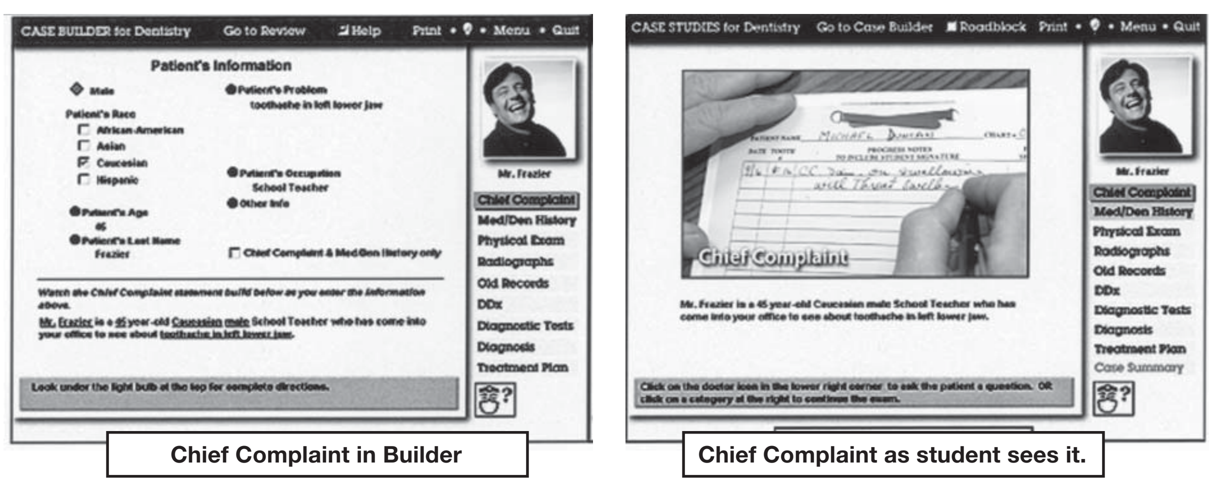

Figure 3. Note the common design features for the authoring screen on the left and the screen the student sees on the right.

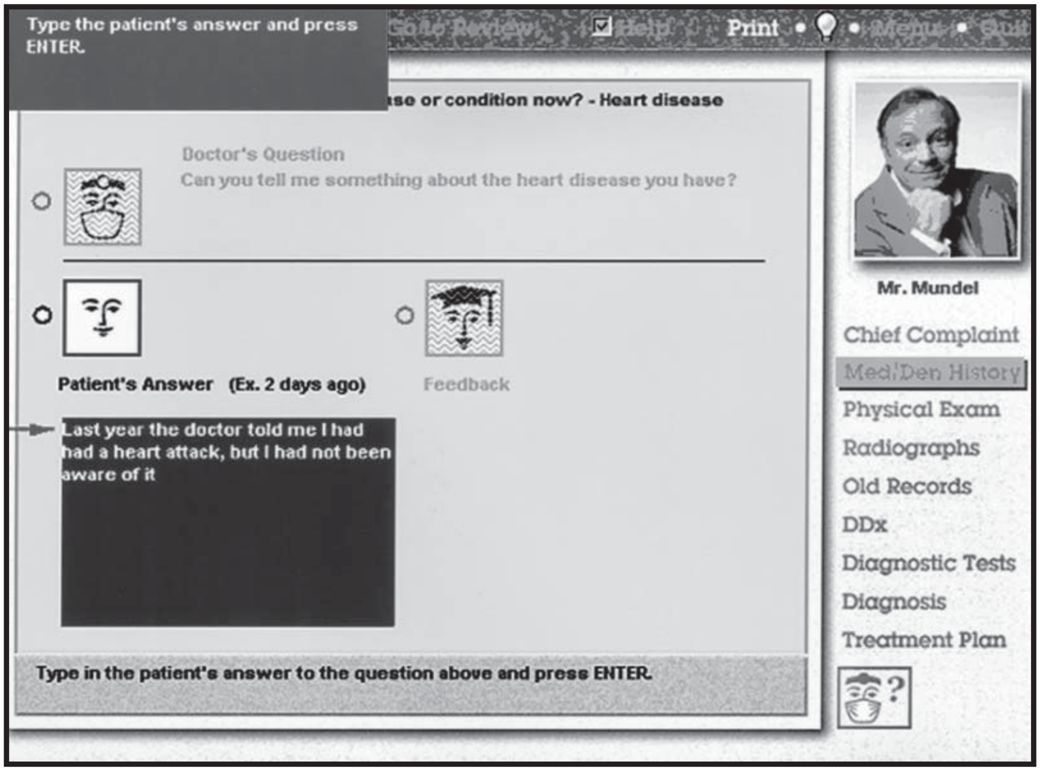

Figure 4. Note the generous space for text entry in the box under "Patient's answer."

case into its individual, named subfolder (Figure 5). When completed, all data and images for a case reside within the "Images" and "Cases" folders. These two folders are then burned to a CD-ROM that contains the Student.exe program and several supplementary files. This CD-ROM can contain up to ten CSD interactive patients.

Notable Features of Case Studies Simulations

In every CSD simulation, a patient photograph from a database of photographs based on gender, age, and ethnicity appears on every screen to remind the user of the presence of a patient. Separate icons identify the doctor, the patient, and the mentor and clearly identify text that comes from each source. The dialog feature allows the student to ask the patient questions, receive answers from the patient, and view the mentor's feedback regarding the question or the answer at many points during the information gathering phases of the case.

The student communicates directly with the simulated patient. An author can write up to six questions to ask the patient with answers and feedback at any point in the simulation development where dialog questions are allowed. For example, an author is building a simulated patient who will have "diabetes" in the medical history. At that point, he or she can write up to six questions with answers and mentor feedback. Then when a student uses that particular simulation, he or she can ask the patient about the history of diabetes, evaluate the patient's answers to the questions, and view feedback written by the author regarding the question or the information the patient provides in the answer. This is the vehicle for the student to obtain information from the patient about their "diabetes."

The author writes the dialog questions and their answers, multiple-choice questions and answers, and

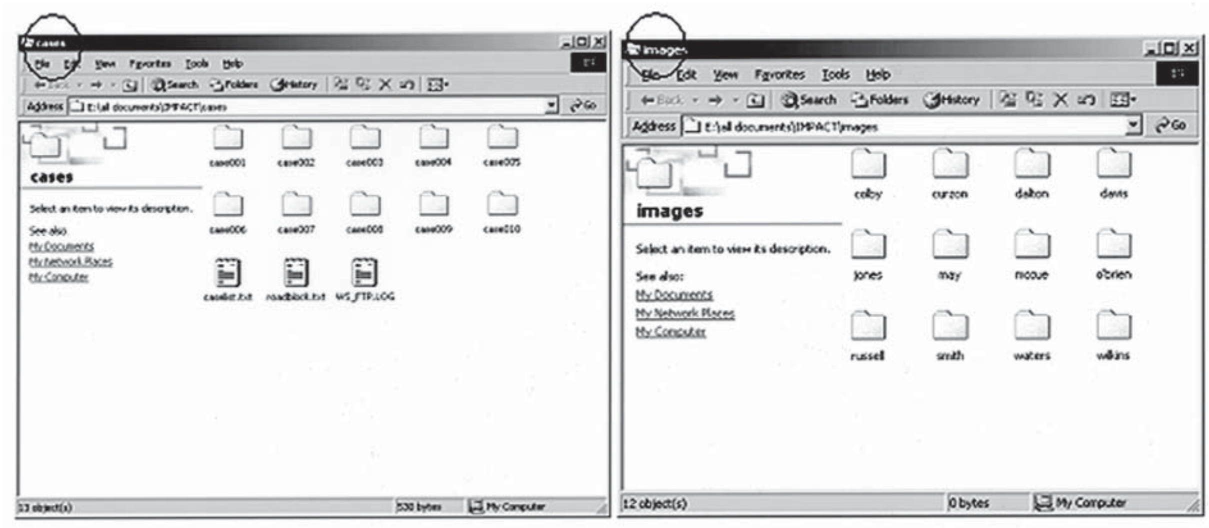

Figure 5. Note the subfolders in the main Cases folder on the left and the subfolders in the main Images folder on the right.

all feedback for every case. We have built in a core of common questions that the author is free to use for many items in the medical history; however, authors are under no obligation to use them. There is no database of answers or feedback controlled for random use by an algorithm-driven program. The absence of "canned" responses and feedback gives the author infinite capability to customize each simulation. One patient, for example, can be authored with several degrees of difficulty for different student populations.

Authors can write multiple-choice questions that the student must answer at strategic times in the simulation. This feature becomes a dialog between the faculty author and the student. For example, the author might want to ask the student to explain observations from the intraoral exam or to justify a decision the student has had to make in the treatment plan. Questioning is part of the mentoring function of CSD cases.

Authors can build in generous feedback at all points during a simulation. The author writes feedback for every question-answer dialog between student and patient, every answer in multiple-choice questions, and every time the student makes a decision or choice, orders a test, or chooses a treatment. Feedback guides, hints, gives advice, corrects, suggests better ways, asks thought-provoking questions, and gives the benefit of experience and mature judgment to novice students. Feedback is the major teaching, mentoring feature of CSD.

Some authors build into a case more information than is necessary to make a diagnosis. As with live patients, the student doctor must sort through interesting but unnecessary information and cull what is relevant to find the cause of the patient's problem. Simulations provide a safe, forgiving environment where mistakes teach and the patients never tire and are always ready for more.

A final notable mentoring feature in CSD is the "Case Summary." Case Summary is a text file that sequentially maps every student choice, finding, question asked, or answer given as he or she progresses through a CSD simulation from Chief Complaint to completion of the Treatment Plan. The Case Summary prints automatically when the student has completed a case or if the student quits a case midway through. The student cannot alter this document. The Case Summary can serve as a basis for faculty and student discussion or evaluation of the student's handling of the case.

Lessons Learned

One of the issues when trying to simulate a human interaction with a computer is that one quickly realizes the complexity and versatility of human interaction and how overly simplified and rigid the computer simulation must be to accommodate the electronic environment. Simulating the differential diagnosis process is a good example of this. The fluidity and versatility of the differential diagnosis list that the clinician keeps testing and revising during problem-solving are well understood. The development team elected not to reproduce this action because in the Authorware® environment there was no way to represent continuous, evidence-based review of a list without extensive time consumption and distraction from the rest of the case.

Each CSD computer-based patient is intended to be an educational tool to reinforce and integrate content into the dynamics of a simulated doctor-patient relationship. The primary goal for CSD simulations is to teach students an orderly process for dealing with a patient who presents with a problem within the practice context. As a student practices, a blueprint for problem-solving emerges that can be applied to any simulated or live patient. Working through CSD cases will help students build confidence as they complete more cases.

Delivering and testing for mastery of specific content were not primary goals in developing CSD. There is no doubt that students using CSD cases learn some content. The amount of new content a student can learn from a case depends on the complexity of the case, the nature of the content, and the level of the student. Learning content, however, remains a secondary aim for CSD cases.

Development takes time and patience. CSD was designed, written, intermittently tested, evaluated, rewritten, and tested again with faculty and students over a period of approximately five years. We evaluated clarity of intention, navigation, text, images, instructions, color scheme, interface design, and the program's ability to hold the user's attention. We learned that the maximum length of time a simulation could take to complete was thirty minutes. Evaluations reinforced the feedback function and the realistic context that CSD created for students to practice diagnostic skills. Faculty regarded the open, intuitive, and flexible authoring aspects of the CSD system as desirable features. Feedback to the developers from both faculty and students strongly supported the intended use of this tool for teaching.

The software has been used for three years in the second-year dental course in Oral Pathology. At the beginning of the semester, students receive a CD containing ten CSD simulations. During the semester they are required to treat all ten patients on the disk. They are tested and graded after each case by software that resides on a departmental website. They also visit the website to complete their evaluations. The scores on the ten quizzes count as 10 percent of their grade in the course. Our analysis of this three-year experience and the formal evaluations is currently being completed.

Future versions of CSD will expand and improve the system's flexibility and broad applicability. An evolving web-based authoring and delivery tool is certain to be developed before long. We will continue to make authoring interactive multimedia patient simulations easier and more versatile.

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