Tutorial Software for Clinical Chemistry Incorporating Interactive Multimedia Clinical Cases

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We have developed computer-based clinical case histories incorporating multimedia elements to aid the learning of medicine in a problem-based manner. Topics have been developed in the specialty of Clinical Biochemistry but the approach used is suitable for any branch of clinical medicine. Each topic has material aimed at medical students and also postgraduate candidates for professional examinations. A browser program is also incorporated. Emphasis is made on interaction through the case and modeling of real-life decisions in diagnosis and treatment. Advantages of the program are self-paced learning, assessment of understanding, feedback, and emphasis on deep understanding of the basic physiological and biochemical processes underlying clinical problems.

To aid the education of medical students and postgraduates working for professional examinations, we have developed a series of multimedia computer programs, based on encounters with patients who have real clinical problems. The material has been developed to support the change in education away from teaching and towards learning, and to provide material for students’ use that is complementary with existing course material (1). The programs are designed to be interactive, and students can control their own pace of use.

The project is supported throughout the UK, with all academic heads in the country being involved in the educational design. Authors of the cases are experts in their particular field, and editorial input allows a consistent approach. We have developed 10 topics in this project; each topic includes an undergraduate case, aimed at medical students and pathology trainees, and a postgraduate-level case history, aimed at those studying for final professional examinations (2). In addition to the two clinical cases, we have developed a browser module for each topic, which can be accessed from within the cases and also as an independent program.

The programs include images of patients and diagrams of physiological processes, animation of control mechanisms, and videos of patient examinations.

These can all be activated by mouse-operated “hot” words within the text on screen, and much of the background material, for which viewing is optional, can also be accessed this way.

We have decided to use case histories, because these are illustrative of classic or common disorders and can be explored in an interactive manner. The programs and the interface, in particular, have been designed to be presented clearly, and the interaction used within the cases and the access to background material provide opportunities for deep learning. No other existing resource coordinates the various components of a clinical case and presents them to the student in an integrated manner.

Educational Design

Learning a diagnostic skill and clinical management in medicine is ideally suited to a problem-based approach and has been used extensively in medical student education in tutorial form (3). The presentation of a clinical case history requiring reasoned decision-making helps the student to apply knowledge in a realistic situation, thus aiding the development of deep understanding of the subject. To allow this, the problem models the complete clinical course of a complex medical condition from the presentation of the patient to a primary care physician to the referral to a specialist. The natural course of a condition is presented in a logical manner, with decisions required from the student over the diagnosis, diagnostic tests, and treatment regimens. Such an approach, integrating learning across disciplines, such as biochemistry, physiology, endocrinology, pathology, pharmacology, and clinical medicine, encourages a wide view of medicine, which is essential for a professional approach to live patient encounters. The integration across disciplines also reduces the artificial barriers between disciplines and departments.

In addition to the realism provided by the accurate modeling of a clinical case, students can, in some modules, enter laboratory data of their own into a simulation program, to determine the effect of alterations on complex physiological processes. Such processes ordinarily are cybernetically regulated by homeostatic feedback mechanisms; however, pathological conditions can significantly alter their balance and are important in the clinical presentation of many diseases. Many of the physiological processes have many variable inputs, and knowledge of their interaction is vital for deep understanding of pathophysiology.

Successful learning can be stimulated by ensuring that students take some responsibility for the learning
process. This is achieved within the program by allowing the student the choice of whether or not to use background material. This is particularly important if the student is to review the case at a later session. Learning is also fostered by the ability to print out material from the case, to act as tutorial material or revision notes. The program is designed to be used as and when the student chooses, and sessions can be terminated at will. Such self-pacing of learning is particularly important for students studying in a curriculum that is constantly expanding.

Analysis of the subject matter and good communication significantly add to the learning process. Initial enablement of the project was achieved by widespread demonstration to all academic heads in Clinical Biochemistry throughout the UK. Ownership of the project was acknowledged, and all teaching hospitals throughout the country were asked to provide learning objectives, especially for the undergraduate-level cases. This widespread consultation process has aided consistency throughout all the cases developed. Learning objectives are subtly incorporated into all cases by emphasis on key points and providing frequent summaries throughout the case. Learning objectives for each of the cases are explicitly shown at the end of the case. Emphasis on learning objectives is provided in numerous assessments at key stages in the case, which are designed to test understanding of important concepts, together with students' assimilation of relevant background information. Assessments are of two types: multiple choice, in the traditional format of a stem and any of five assertions following the stem being correct or wrong, and single-choice questions provided throughout the case. Instant feedback is given on the correct answers, with explanation of both right and wrong choices. An assessment program running through the case collates the running score, which is presented at the end. Students can store their responses (together with the questions) on disc, either as a personal record or to be sent to an assessor. Alternatively, they can transmit their responses as a file via networks such as the Internet. Hence, the programs can be used either for self-testing or for examination purposes. Additionally, the programs may be used in a distributed manner and have distance-learning potential (Table 1).

**Clinical Case Design**

All cases follow a traditional format and are divided for convenience within the program into five stages.

**Stage 1. Summary of patient history.** This describes how the patient finds him- or herself in need of medical care and includes information on the patient's history. Often, this begins with a primary-care consultation, which then progresses to referral to hospital as an outpatient, as in one of the cases in the Thyroid topic, where a patient presents with symptoms of thyroid overactivity. Some cases are admitted as emergencies directly to hospital.

**Stage 2. Clinical assessment.** Here, clinical findings are described and illustrated with still photographs of physical signs and, where relevant, a video recording of a patient's examination. A working differential diagnosis will usually be made at this stage.

**Stage 3. Biochemical assessment.** The student will be reminded of any laboratory tests available so far and will be given the opportunity of requesting further diagnostic tests. Only the results of the requested tests are revealed to the student, who is then asked to make a definitive diagnosis, after answering multiple-choice and single-choice questions. Only one of the three possible diagnoses is correct; for example, in a complex case of hyperthyroidism presenting in early pregnancy in a woman who has had a recent history of severe vomiting and who is taking iodine supplementation, the possible diagnoses include iodine intoxication, hyperemesis gravidarum, or Graves disease.

**Stage 4. Diagnosis and treatment.** The student's selection of definitive diagnosis is allowed to proceed in a realistic manner. The wrong choice may have been made, but the student will not know this yet and will continue to answer relevant questions about the diagnosis chosen. If the wrong diagnosis was made, then the patient deteriorates in some way—worsening either as a natural consequence of the disease, e.g., delay in diagnosis of hyperthyroidism leading to a worsening clinical condition and increasingly abnormal results for thyroid function tests, or because inappropriate treatment was given. Obviously, the clinical cases have to be chosen very carefully so as to allow plausible alternative diagnoses. If a wrong choice is made, this fact is eventually revealed, after which the student is provided with some management choices: e.g., in hyperthyroidism, to treat with surgery, medication, or radioactive iodine.

**Stage 5. Summary/case resolution.** The student is shown the resolution of the case, based on the patient's management. A summary of key learning points pertinent to the topic is presented.

**Student Assessment**

Many questions are posed throughout the case (Fig. 1) to ensure interaction and also to test understanding.

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**Table 1. Educational benefits of the tutorial program.**

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Description</th>
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<tbody>
<tr>
<td>Involvement by academic community</td>
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<td>Learning objectives incorporated</td>
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<td>Consistency of material</td>
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<tr>
<td>Unique presentation of material otherwise unavailable at a single source</td>
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<td>Problem-based cases to model realistic clinical situations</td>
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<td>Interactive format</td>
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<td>Self-paced learning</td>
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<td>Material usable outside timetabled course</td>
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<td>Responsibility of student's own learning</td>
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<td>Simulation models to help deep understanding</td>
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<td>Integration across disciplines</td>
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<td>Exploration of outcomes, with education of wrong or harmful decisions</td>
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<td>Performance testing by assessment program</td>
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<td>Suitability for learning, both locally and internationally</td>
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The explanation requested, Fig. 2. Interactive case computer program. Structures of the clinical case computer program.

The linear sequence of the case is shown by the vertical series of boxes on the left, starting with Patient History and ending with Resolution of case and explanation. Throughout the case, the Interactive Case Manager monitors each student's progress and performance, provides explanation and help when requested, and acts as a link to background information.

Software Design

One of the main objectives in designing the software was to engage students' attention; this is achieved in a number of ways. Screens have been designed to be simple and uncluttered, and graphic artists have been employed to design relevant images that complement the cases, rather than distract from them. The interface is designed to be used intuitively, with little need for help screens—a property that is important for educational continuity within the cases.

Interaction is used extensively to provide continual stimulation, and the need to perform tasks, i.e., by using a mouse, ensures concentration (4). Interaction is also brought about by the necessity to answer questions, activate video and animation sequences, and operate "hot" words that access either images or background material in a browser program.

The clinical case is designed in a traditional linear sequence, moving from clinical presentation to treatment and resolution (Fig. 2). Attention is concentrated on the clinical case by allowing access to background material as an option that can be activated by the use of buttons. Exploration of the background information may be made at will, but the point within the case at which exploration starts is easily regained, thus avoiding unnecessary distraction. This background material can also be accessed independently of the clinical case, thereby allowing review without having to repeat the

of this project. This will be supplemented by direct interview of student users. International evaluation has also been arranged in North America, Europe, and Asia.
whole case. Within the browser program, background information is structured to allow exploration of material relevant to a particular topic. Thus, for both clinical conditions and laboratory tests mentioned in the clinical cases, information is divided into logical sections; e.g., for laboratory tests, information is presented within the following sections: overview, indication, principle, laboratory procedure, and interpretation. The browser program also allows free text search of chosen terms and acts as an electronic index.

The whole program is implemented in Toolbook (Asymetrix, Bellevue, WA) (5) and runs under Windows 3.1 (Microsoft, Redmond, WA). The computer requirements are: 486, 33 MHz personal computer; 8 Mb random access memory; color graphics screen; hard disk drive; mouse; sound card; and double-speed CD-ROM drive.

The software has been tested on numerous sites to ensure that it performs in a logical manner and that educational objectives, such as cumulative scoring of responses, can be performed accurately and the results stored.

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References