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USER INTERFACE DESIGN AND EVALUATION FOR A MEDICAL TESTING AND TRAINING SYSTEM

By

Stephen T.C. Chow, B. Comm. (Hons.)

A thesis submitted to
the Faculty of Graduate Studies and Research
in partial fulfillment of
the requirements for the degree of

Master of Management Studies

School of Business

**Carleton University
Ottawa, Ontario**

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Thesis Co-Supervisor

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May 15, 1997**

Abstract

Computer aided instruction (CAI) system has an increasing impact in education. One of the critical reasons for this is the user interface since CAI is used in teaching and training. There are two main approaches to the interface development -- the system-centered and user-centered development approaches.

This thesis examines the two approaches. The user-centered approach is adopted to Intelligent Multimedia Medical Diagnostic Aid (IMMELDA), a CAI system for medical training and testing. The research results include the advantages and disadvantages of this approach. Solutions for problems encountered in this research are also recommended.

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1. Introduction

Information technology (IT) has been successfully introduced in the education field from corporate training centers to schools. In the education community, educational institutions have implemented IT in their curriculum. For instance, Dalhousie University's School of Business Administration (Halifax, NS), through the Course Development Project, has integrated information technologies in its courses.

Computer aided instruction systems (CAIs) have also been used in medical education for the training and teaching of nurses, medical students, technicians, doctors, surgeons, and hospital administrators. For example, at Boise State University's Department of Nursing, an interactive computer program was developed to provide learning experience on the technical aspects of injections (Otterness and Fountain, 1993). Through the computer, students learn about the types of equipment needed to prepare and give an injection and are tested on the knowledge needed to select the correct equipment.

An important and integral part of CAI is the user interface. A good interface can enhance the way people use CAI to perform tasks. Sukthankar et al. (1993) state that a good interface helps to support and communicate information visually and to expedite the process of learning abstract concepts. A well designed, graphical user interface allows for easy management of displays as well as providing effective visualization tools which convey information about the domain of learning.

The continued positive contribution of IT to products and services in general and to education specifically, is directly related to:

1. how effectively the technology meets the user's real needs in the context of use; and

2. how efficiently and effectively the user can utilize the full benefits of the technology (product interface) (Belden et al., 1993 Page 230).

From the users' point of view, the capabilities of the system are -- to a large extent -- determined by the user interface (Hanne and Hoepelman, 1990). The process of designing and constructing the interface is critical to building systems that satisfy users' needs.

This thesis examines an approach to interface development, testing, and implementation for a CAI system. The domain of application is medical education and the system would be used for testing and training medical students. However, both the applied approach and testing techniques can be generalized and used in interface development and testing in other domains. This specifically includes development of CAI systems for education in business and management. It is hoped that the results of the study allow us to determine the specific users' requirements with respect to the CAI system under consideration which will facilitate the process of system development, implementation, and deployment. Furthermore, this research gives insight into and addresses problems related to the development and testing of interfaces for CAI systems in higher-level education and training.

The background for this research is discussed in Chapter 2. Chapter 3 describes the patient simulator. Chapter 4 describes the procedure of the experiment. The analysis and its results are discussed in Chapter 5. In Chapter 6, the conclusions based on the data analysis are discussed. In additions to the conclusions, considerations for future research are included in that chapter.

To avoid redundancy and confusion, people who were involved in the research are identified throughout this thesis as follows. The author is referred to as the researcher.

The physicians were Drs. Steven Rubin and Rakesh Chaturvedi¹. The developers included Drs. Gregory Kersten, Stan Szpakowicz, and Janse Tolmie². The programmer was Terry Copeck³. The case writers were Dr. Tolmie and the author.

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³Terry Copeck is a programmer at the University of Ottawa, Ottawa, Ontario.

2. Literature Review

This chapter defines CAI and examines different types of CAI. Then, the user interface, the approaches to its design and testing are discussed.

2.1 Computer Aided Instruction

Computer Aided Instruction (CAI) can be defined as the use of computers in teaching. It allows for the presentation of questions, request for answers, and recording and evaluation of the student's progress (Brisebois et al., 1991). CAI can be applied to a wide variety and range of learning and training tasks in various domains. It has been applied to such disciplines as medicine (Greenberg et al., 1993), biological sciences (Thonney, 1993), engineering (Loucks, 1993), and language training (Davies et al., 1993).

Other terms which are associated with CAI include: computer aided learning, computer aided teaching, computer assisted teaching, computer-based learning, computer-based education, computer-based learning systems, computer assisted training, computer aided training, and computer-based training. In this study all these systems are referred to as CAI.

To understand the similarities and differences between various types of CAI systems, as well as what types of CAI systems can be used for training and education, it is useful to review them. The next section describes five types of CAI systems.

2.2 Types of CAI

In general, CAI can be divided into five types: (a) drill-and-practice programs, (b) tutorials, (c) instructional games, (d) simulations, and (e) problem-solving programs (Barker, 1987;

Duffield, 1991). In this section, each type will be briefly described and illustrative examples presented.

2.2.1 Drill-and-Practice

Drill-and-practice systems are used by students to develop automatic reactions, speed, and accuracy with previously learned verbal information, motor skills, and intellectual skills. These systems are used to elicit a response from the student and provide immediate feedback (Barker, 1987). Drill-and-practice systems focus on the proper and effective use of learned material by providing exercises and tests to subjects.

For example, both Respiration Acoustics Laboratory Environment (R.A.L.E.) and Breath Sounds and Heart Sounds & Murmurs (Pelech, 1990; Pelech, 1992) are drill-and-practice systems which are used to teach about human breath, heart sounds and murmurs (a continuous or periodic heart sound). Users can choose the types of sound to listen to and review the text for the subjects. After that, the user can practice through two types of exercises. One involves case studies that present different types of sounds for one specific medical case (e.g., all the relevant sounds for a pregnant woman). The other type is a quiz in multiple choice format. For example, users listen to a heart sound and five classifications of the sound, from which the users are required to choose the one that best describes the sound.

2.2.2 Tutorials

Tutorial systems are designed to introduce and teach new skills and to present and explain new material. Tutorials often provide guidelines to facilitate the comprehension and memorization of the new material. Similar to drill-and-practice systems, tutorials also

allow students to practice through exercises and provide feedback in response to their answers.

Clinical Pheumatology (1993) is a window-based tutorial system which consists of two main modules, the learning module and the review module. Each module is accessed from a different menu. The Main Menu allows access to information about seven medical areas: Osteoarthritis/DJD, Rheumatoid Arthritis, Crystal-Induced Diseases, Serronegative Arthritis, Connective Tissue Diseases, Infectious Arthritis, and Miscellaneous Conditions. Each area contains rich textual and audiovisual material allowing users to study them in detail. For instance, an image of a patient's infected hand is presented together with written and spoken narrative.

The second menu is the Board Review. This menu allows for self-testing on topics from the seven areas. The testing is similar to a multiple-choice scenario; given an image, the user has to choose correct descriptions from those provided by the system. Then, Clinical Pheumatology gives a detailed narrative explanation of the image.

The Interactive Physiology - Cardiovascular System (Marieb and M.J. Branstrom, 1994) is a multimedia tutorial system used to study the human cardiovascular system in which the material is divided into units. The study of each unit is preceded by information about learning objectives and expectations. First, the system indicates to the user the goals of the unit and what the user needs to know, and then illustrates the materials. This system uses the audio materials to explain the content of each unit accompanied by full color animation.

The Physiology - Cardiovascular System also incorporates quizzes that allow the user to test his/her knowledge of the cardiovascular system. The quizzes are in three formats: multiple choice, linking items, and puzzles. Answers to the multiple choice questions are given in terms of diagrams (i.e., electrocardiogram) or sentences. In the linking items

format, users are asked to match the words with the definitions. In the jigsaw puzzle format users are asked to arrange the correct pattern of, for example, an electrocardiogram (ECG).

Both the drill-and-practice and tutorial systems share similar characteristics. They emphasize direct instruction rather than discovery. These systems present topics from the intended teaching area and provide exercises which are tied to the learning materials. Each exercise has only one correct solution or answer, exercises are simple, and there is no training of problem solving skills.

2.2.3 Instructional Games

Instructional games are designed to teach students through competition. The competition may be against the computer, another player, or be based on improving one's own performance. The competitive nature of instructional games is often combined with other types of CAI. For instance, many simulations include varying degrees of competition. In order to provide motivation and allow for additional practice instructional games include real graphical images, videos, and digitized audio outputs.

An example of an instructional game is "TriplePlayPlus! Spanish" used to aid learning Spanish (Syracuse, 1994). This system uses more than 50 interactive comic strips and games. Students learn more than 1000 words and phrases, as well as complete conversations. Using the microphone provided, the student speaks to the computer which in return evaluates the user's response and indicates if the answer is correct and whether pronunciation is acceptable.

The major difference between games and drill-and-practice programs is that there is more than one path to reach the solution for the games. Games usually present students with the

initial conditions and then alter those conditions based on the student's response. There may be several correct solutions or multiple paths to one correct solution. Moreover, the users are in control of the interaction in these programs. Users choose which clues to ask for, which conditions to change, and which paths to pursue.

2.2.4 Simulation Systems

Simulation systems replicate, though in a simplified form, real-life situations, that provide students with problems they may encounter in reality. They allow students to experience problems which, if they were encountered in real life, would be too costly, dangerous or difficult to solve by novices without proper training (Duffield, 1991; Harasym and McCreary, 1987).

The "Scientific American Medicine Discotest" (1984) is a text-based patient simulation. Patient management problem case simulation is designed to assess certain aspects of clinical problem solving. After the user receives the initial case data, she has the opportunity to obtain more information in order to undertake diagnostic studies and procedures, to prescribe therapy, and to make other decisions regarding the simulated patient. In each section, users may be asked to select one, or more than one, response. Furthermore, during the management process, users can review their responses at any time.

The responses are not limited to ordering clinical tests or examinations. Sometimes, the simulated patient will ask questions regarding the risks of the therapy, whereby the user has to choose an appropriate response. For each response or selection, users may get a positive or negative score. The total score depends on the sum of the scores assigned to the choices the user selected. Scores are decomposed into two categories: management decision and data collection.

There are several features in this approach that enhance a user's ability to master the knowledge. The multiple choice questions that follow each patient's management problem are designed to enhance comprehension of the material presented in the case simulation. There are a total of 20 questions for each case. At the end of the case, the system lists what the user has done appropriately and inappropriately. Some relevant references are also presented with respect to each particular case.

Simulation systems vary with respect to how closely they represent reality and settings must be realistic in order to be useful. For example, flight simulators used to train pilots include films of airports and a replica of a cockpit. On the other hand, genetic simulations, contrary to nature, might allow the user to manipulate one gene at a time while holding all the others constant. In this case, the users can observe the effect of altering one specific gene without being distracted by any compounding effects from other genes (Duffield, 1991).

2.2.5 Problem-Solving Programs

Problem-solving programs, like simulations, are based on models (Duffield, 1991) which represent an issue or problem. However, in a simulation, the model is given *a priori*. Problem solving programs focus on the selection and application of an approach (method) to formulate or solve a given problem, while simulation is used to represent dynamic problems in a changing environment to teach actions and reactions. There are many overlapping areas between simulation and problem solving programs, such as having several paths to solve a problem.

The Dynamic Modelling System (Cox, 1986) is used to help students build models, formulate hypotheses, test models, verify theoretical underpinnings, and test models with practical examples. Each model is created or chosen by the user and can be studied after its

initial creation. For example, a student builds a particular model representing the growth of a rabbit population, chooses the variables and their values, and then investigates the relationships between them.

Simulation systems and problem-solving programs are used frequently for teaching and testing analytical and decision making skills. They possess the following advantages over other systems (Harasym and McCreary, 1987):

1. They closely approximate reality allowing an increase in the transfer of knowledge and skill from the learning environment to the real world;
2. They allow for time condensing thus enabling events which normally take days, months or even years, to occur in a few seconds, minutes, or hours;
3. They protect the learner, equipment, and environment from unnecessary risk and damage;
4. They maximize the quality of learning by using information about the learner to alter the task to match the learner's needs; and
5. They allow for the development of complex knowledge and skills in an efficient and cost effective manner.

All CAI systems discussed in this sections have one thing in common; an interface is used to communicate with users. Integral to any CAI system is the user interface; a poorly designed interface will degrade the theoretical advantages listed above. Many CAI systems lack a good interface which is a large and important element in any interaction between the user and the system (Allan and Walraven, 1986). The user interface defines the dialogue that can occur between the user and the computer and determines how well the application is capable of providing an environment for experimentation, testing, review, or modelling (Bergeron, 1989).

The next section describes what a user interface is and then outlines the approaches for interface design, development, and testing.

2.3 User Interface

Interface is defined as the medium which the computer system uses to interact with people (Martin et al., 1991). The user interface is the component of a computer system that allows two way communication between the system and its user. Additionally, the interface may be required to manage and display other types of information, such as graphics or video images. Common input mechanisms, or devices that enable this communication can include the keyboard, mouse, and touch- or pen-based screens. Output devices that convert information from within a system into some form perceptible by users include audio, printer, visual display, and video outputs (Galitz, 1993; Maddix, 1990; McGraw, 1992; Rubin, 1988).

It is essential that the user interface meets the needs of those using the system and that it does not impede or limit the user but enhances and facilitates user interaction with the system. Shneiderman (1986) recognized the importance of the user interface and stated that a good user interface design provides the following benefits to a system and its users:

- increased user acceptance of system prototypes and the final production system;
- increased frequency of use of the system;
- decreased user error rates;
- decreased user training time; and
- increased speed of user's performance.

2.4 User Interface Design

Two main approaches have been proposed to interface development (Martin et al., 1991; McAlindon, 1992; Turban, 1993). Figure 1 shows the system-centered development approach. Figure 2 shows the user-centered development approach. Both are comprised

of three phases with design being the first phase. This research emphasizes the design phase through to the testing and evaluation phase of both approaches.

Figure 1. An overview of system-centered development approach

Other guidelines most commonly used for interface design will be discussed in addition to the two approaches.

Figure 2. An overview of user-centered development approach

2.4.1 System-Centered Approach

Traditionally, a team of computer system developers takes responsibility for the design and implementation of a system and invites user involvement to the degree and in the form they deem appropriate (Damodaran and Eason, 1981). The reasons developers seek user involvement is to ascertain the users' domain knowledge and to reduce their resistance to change. In order to develop the system, developers require user participation for understanding the domain expertise. Furthermore, users' involvement is needed since many systems have been rejected or poorly utilized because users felt the system was being imposed upon them (Martin et al., 1991; Turban, 1993). Thus, by involving users in

system design, the possibility that the system will be rejected due to the resistance to change can be significantly reduced.

The technical considerations, rather than the user's perspective, are central in the system-centered design approach. The following are specific problems encountered when this approach has been used (Belden et al., 1993):

- developers have a different set of judgment criteria than end-users;
- because technology developers know the internal workings of the system, they use technical vocabulary to communicate with users, when in fact the user's vocabulary is different;
- what is intuitive to the developers is not intuitive to end-users;
- developers become attached to their projects leading to their own resistance to change; and
- the systems and devices require training and manuals.

Because of these drawbacks, the system-centered approach is often inappropriate in user interface development. To alleviate these drawbacks, a more comprehensive approach has been proposed namely, the user-centered approach.

2.4.2 User-Centered Approach

The user-centered approach focuses on end-users' needs. Therefore the aim of the system design is to meet those needs effectively (McAlindon, 1992). Total system function is crafted so that it meets the requirements for effective user learning and efficient user access to that function (Karat and Bennett, 1991). The user interface may have little to do with the technology behind this interface. The complexity of the actual process often exceeds the users' cognitive abilities. A good interface can hide its complexity from the users thus allowing the users to concentrate on performing their tasks (Belden et al., 1993).

The design of an effective user-centered computer interface requires consideration of the variables influencing the user's ability to acquire and process information. The ability to acquire and process information is directly related to the users' attitudes, abilities, and experiences. For example, if the target population of system users is medical professionals, it is unreasonable to assume that this group can understand the domain of the system besides medicine (i.e., computer science).

Figure 3. Analyzing the overall task (McAlindon, 1992)

As shown in Figure 3, the properties of the user interface are meant to match with the variables influencing the user's ability to acquire and process information.

The task of user interface design is a complex and highly creative process which blends intuition, experience, and careful consideration of numerous technical issues (Preece, 1993). It consists of five distinct stages, each with specific actions that must be performed. The steps and actions are illustrated in Figure 4. A designer must first determine the target population of the system users and analyze what types of tasks users perform and how they perform those tasks. Designers have a much better chance of preparing high-quality design alternatives and make better user-related decisions if they use the information obtained from the prospective users.

Figure 4. The process description (based on (McAlindon, 1992))

In Figure 4, after the target population (users) is determined, the tasks involved in the system should be determined. Task analysis provides information about what tasks the user performs. It can be obtained through consultation with users about their work and observation of users at work. Then requirements analysis specifies what the system should provide in terms of functionality.

It would be unreasonable to expect users to come up with design ideas from scratch. Users cannot, and should not, develop interface designs because they lack appropriate technical knowledge. However, they can identify designs they do not like or criticize those that will not work in practice. It is, therefore, imperative to obtain user involvement. This requires that suggested system designs are presented in a form users can understand.

Interface products are the result of an interdisciplinary effort (Craig, 1991; Erickson, 1990). An interdependence between designers and users must evolve so that user interfaces can be both usable and effective. The collaborative relationship between user and designer is required because each has significant and distinct contributions to make (Craig, 1991).

During the evaluation stage, the role of the users remains important. Users, as evaluators, can ensure that the designers make reasonable, user-oriented, choices (Lanning, 1991). If the evaluator determines that a design decision is inappropriate, the designers can go through another iteration and gather more or different information, prepare new alternative designs, select, present and evaluate new alternative designs, and then finally evaluate the new decision.

There is a very similar approach to user-centered design -- participative design. The major difference between these two approaches is the level of user involvement. While a user-centered design focuses from the start on users and tasks, participative design starts with users as members of the design team (Damodaran and Eason, 1981; Wilson and Clarke, 1993).

It is difficult to manage a design process if the population of users is diversified because a large number of users will be required to participate on in the design team. The involvement of large numbers of potential users of a system in its development is not recommended (Hix and Hartson, 1993a). A few carefully chosen representatives of each appropriate class of users, even a single representative, can provide designers with invaluable information. Moreover, users need considerable help to understand different kinds of knowledge within the design team (Damodaran and Eason, 1981). Users may not

have enough technical skills to work with designers, programmers, developers, domain experts and others as team members.

In user-centered design, the user is consulted in an iterative manner. This means that the user is not only consulted initially but at every development phase and at every iteration of evaluation. Users will be asked to help designers understand what tasks the users need to perform, how often the tasks are performed, conditions under which those tasks are currently being performed, and so on. Designers consider accurate information about users and their environment during each design activity.

The user-centered approach is more comprehensive than the system-centered one. It can provide appropriate channels to gather user requirements and use those requirements to construct the interface design thereby establishing a set of guidelines.

2.4.3 Guidelines

The purpose of user interface guidelines is to enable the development of usable, consistent applications that conform to designated conventions. The guidelines list well-known principles for user interface design which can be used for the interface development process. However, guidelines vary in content. Some enumerate general principles while others explicitly specify interface detail. Two examples are shown in Tables 1 and 2.

• Use a simple and natural dialog• Provide an intuitive visual layout• Speak the user's language• Minimize the user's memory load• Be consistent• Provide feedback• Provide clearly marked exits• Provide shortcuts• Provide good help• Allow user customization• Minimize the use and effects of mode changes• Support input device continuity

Table 1. A set of short guidelines (Karat, 1994)

In Table 1, a general set of guidelines is shown. These 12 guidelines were compiled from heuristics used by Nielsen and Molich (1990), the International Standards Organization (ISO) working paper on general dialog principles, and the IBM CUA user interface design principles.

User-Centered Design	System Messages
Practice user-centered design.	Use user-centered wording in messages.
Know the user.	Use positive, nonthreatening wording in error messages.
Involve the user via participatory design.	Use specific, constructive terms in error messages.
Prevent user errors.	Make the system take the blame for errors.
Optimize user operations.	
Keep the locus of control with the user.	Anthropomorphization
Help the user get started with the system.	Do not anthropomorphize.
System Model	Modality and Reversible Actions
Give the user a mental model of the system, based on user tasks.	Use modes cautiously.
Consistency and Simplicity	Make user actions easily reversible.
Be consistent.	Getting the User's Attention
Keep it simple.	Get the user's attention judiciously.
Human Memory Issues	Display Issues
Account for human memory limitations by giving the user frequent closure.	Maintain display inertia.
Let the user recognize, rather than having to recall, whenever feasible.	Organize the screen to manage complexity.
Cognitive Issues	Individual User Differences
Use cognitive directness.	Accommodate individual user experiences and differences.
Draw on real-world analogies.	Accommodate user experience levels.
Feedback	
Use informative feedback.	
Give the user appropriate status indicators.	

Table 2. A set of comprehensive guidelines (Hix and Hartson, 1993a)

In Table 2, the set of guidelines is very comprehensive and covers many different facets that may be considered when designing a user interface. For any guideline to be properly applied it must be tailored for each design situation. For example, a general guideline could be to “provide feedback” to the user about the system’s actions. This general advice could be made more specific in different graphical user interface designs. In hypermedia navigation, users can be informed about the transition that takes place when they move from one area of the screen to another (Nielsen, 1993c).

The use of guidelines should not be viewed as a substitute for careful testing or consideration of the user’s needs and limitations during system development (Kaye et al.,

1993). According to Tetzlaff and Schwartz (1991), guidelines are a difficult source material for the effective ratification of design. Design guidelines are not strict rules to be blindly followed. They provide flexible guidance and help establish design goals and decisions, but they require interpretation and must be tailored for a particular design situation (Hix and Hartson, 1993b).

2.5 Interface Development

As shown in both Figure 1 and 2, the design phase precedes the interface development phase. In the system-centered development process, a traditional approach is applied to interface development. In contrast, a prototyping approach is used during the user-centered development process. Each interface development approach is examined in this section.

2.5.1 Traditional Approach

The traditional approach is to build a complete interface. After the user requirements and needs are established and the design specifications are approved, a fully functional interface is developed. The interface consists of all the necessary functions for the users to perform their tasks in the normal work environment. Of course, such an interface requires significant time and effort to build.

The advantage of this approach is that a clear and fully functional interface can be presented to the users. Such an interface is tested by the users; users can see all the functions provided by the interface and point out what features they like and dislike. According to the results of the testing, the developers and designers can make appropriate changes.

On the other hand, the fully functional interface causes a major drawback, specifically, the tremendous amount of time and effort required for system improvement. It takes time and effort to make any substantial changes. It is risky to assume that the first interface is

satisfactory. In some cases, if users do not like any part of the interface, it may have to be re-built and all the up-front time and effort invested are wasted. It is almost impossible to get a user interface right the first time; therefore, this approach is not recommended for interface development especially in systems that have multiple types of users.

2.5.2 Prototyping

User interface development is based on user evaluation. The information obtained from the evaluation is required before time and effort are invested in the detailed design and in the system's implementation (Hartson and Boehm-Davis, 1993). To obtain a preliminary design which can be tested and evaluated, prototyping methodology is used (Martin et al., 1991; Thimbleby, 1990).

Prototyping is used to save the time and expense required to develop a system which can be tested with users. This system development methodology encourages user participation and involvement in the development process and it allows developers to observe user's behavior and reactions to the prototype. It facilitates the definition of the system's requirements and specification, particularly in relation to the identification of user needs. It also allows for feedback which can be used in system design (Harker, 1991). Prototyping is considered to be the key to supporting the formative evaluation and iterative design process (Hix and Hartson, 1993a).

The completeness of a prototype depends on what the prototype will be used for (Bury, 1984; Wagner, 1990). If the task is simply to explore different screen layouts, then no functionality is required behind the screens, and the prototype should include static screen pictures only. On the other hand, if the designers wish to explore issues concerning the dynamic aspects of the user interface, then it is necessary to have some demonstrable functions tied to the screens. For example, if the user is expected to swap disks to

complete a task, then the functionality for ejecting and requesting disks should be integrated into the prototype.

Prototype development should emphasize task coverage more and efficiency less (Nielsen, 1993c). For example, it will not matter how much disk space the prototype uses since it will only be used for a short period. Similarly, test users may accept slow response times which would not be acceptable in their interaction with a production system. Of course, efficiency measures of the user's performance will be invalid if the prototype slows them down. Thus, inefficient prototypes are better suited for early evaluations of interface concepts than for the measurement studies.

In brief, the functionality of the prototypes will be stressed and developed in the early evaluations. In later evaluations, the efficiency of the prototypes will also be emphasized as well.

Prototyping can be accomplished with some programming tools. On a Macintosh operating system, HyperCard™, SuperCard™, and SmethersBarnes Prototyper™ are often used by developers for interface development. Asymetrix's ToolBook™, VisualBasic™, and ObjectScript™ are personal computer (PC) based prototyping tools which run under Windows 3.0™. A user interface tool kit is a library of callable routines (code modules), used by programmers, for implementing interface features (Hix and Hartson, 1993b; Holsapple et al., 1991).

2.6 Testing and Evaluation

As shown in both Figure 1 and 2, the testing and evaluation phase follows the interface development phase. Both system-centered and user-centered approach include testing and development phase. Both testing and development phases have user involvement.

For the system-centered approach, there are three types of testing activities: unit testing, system testing, and acceptance testing (Laudon and Laudon, 1994). Unit testing consists of testing parts of the system while system testing tests the functioning of the system as a whole. Acceptance testing involves users in testing the system.

For the user-centred approach, the process of interface development is iterative (Hartson and Boehm-Davis, 1993; Hix and Hartson, 1993b; Nielsen, 1993a). Iterative development of user interfaces involves steady design refinement based on usability testing. It involves setting objectives, designing to meet the set objectives, and testing and measuring representative users on the prototypes (Preece, 1993; Shackel, 1991). The process is repeated as needed. Generally, interface designers complete a design for a part of a user interface and then test it with the representative users. After the problems which users encounter are determined, the designers resolve these problems in a new prototype. Then, they test the interface again to ensure that the problems have been solved and debug any new problems introduced by the changed design. The iterations continue until the results satisfy the objective(s).

2.6.1 Setting Usability Goals

Goals are the results we want to achieve. They are defined prior to the system development process. In the interface development process, they constitute a set of usability goals and serve as a basis for communication among developers and between developers and users (Nielsen, 1993c). The goals need to be explicitly stated in order to ensure that all members of the development team understand and share them.

Usability goals include the measurement of user learnability, efficiency, memorability, error rate, and satisfaction. They provide quantitative and measurable targets for designers to work on (Wiklund, 1994). An effort is made to use quantitative usability goals which

are easy for designers to measure and compare. For example, a measure may be the time required to complete a task of creating and adding a column of numbers in a spreadsheet. A goal may be that 75% of the users perform this task in less than ten seconds and that all users complete this task in less than twelve seconds.

Some goals may not be easily quantified in terms of time or number of tasks. For instance, one of the usability goals may be user satisfaction. In this case, a rating scale is used with the goal being that at least 75% of users give the system a score between 4 and 5 on a five-point scale of satisfaction.

Usability goals can be set for new versions of existing systems or for systems that have a clearly defined market competitor. The minimum acceptable usability might be to equal or exceed the current usability level by a given percentage, and the target usability goal could be derived as a significant improvement level. For new systems where there are no similar or competing systems, the usability goals may be difficult to set. One approach is to define a set of sample generic tasks and ask several usability specialists about possible goals for these tasks.

Usability goals can also be used for publicity (Rideout and Lundell, 1994). Managers or marketing personnel may use usability goals as a benchmark to show how much they have improved from the previous version, or to compare the proposed system with those of the competition.

Usability testing plays a vital role in the iterative design process. Usability testing is used to evaluate the design, determine problems, and obtain suggestions for interface improvements (Nielsen, 1993b). During each iteration, some of the changes made may fail to solve the usability problems. A revised design may even introduce new problems

(Bailey, 1993). Therefore, using usability testing during the iterative design process allows designers to monitor the results of the iterations.

It is costly and time consuming to make significant changes when the design process is well advanced. Design decisions made early in the process, such as requisite functionality, choice of platform, and software architecture, can affect the usability of the system. If effective evaluations are carried out early in the design, then problems can be discovered before making a significant investment in system development. If the problems are discovered at the early stages of the development process, they will be less costly to repair and, therefore, have an increased likelihood of being resolved.

The outcome of the development process is the prototype. The prototype is used for testing and evaluation. Different testing and evaluation methods are discussed next.

2.6.2 Formative vs. Evaluative Testing

There are two main types of testing: formative and evaluative (summative). Formative testing is done to help improve the interface as part of an iterative process. It is used early in the design process to learn which detailed parts of the interface are good and bad, and how the design can be improved. Developers use it to address users' needs, and ensure that the system has high usability. Formative testing is essential to ensure that an evaluative test will succeed.

Evaluative testing is an evaluation of design after it is completed or nearly completed. It is used during field, alpha or beta testing, or to compare one product to another. Field testing involves bringing an almost completed interface to the user; a prototype is set up in the normal working environment and tests are conducted. The aim of these tests is to obtain qualitative data (Hix and Hartson, 1993b).

Alpha and beta tests are methods of evaluative testing. An alpha test is the in-house testing of a software product by the vendor prior to its release for beta testing. Beta testing of a software product takes place in a normal work environment prior to its release to the public (Long, 1991).

With the formative testing method, additional costs relating to the lengthening of the development process are incurred because of the involvement of end-users. However, there are also significant benefits that result from the use of both formative and evaluative testing (Ravden and Johnson, 1989), including the following:

- reduction of user training time and costs;
- decrease in support costs, due to fewer and less significant difficulties (one such example is the cost of servicing a customer-support call. If the installation program for a word processing software package is easy to use, it can reduce significantly the number of customer calls regarding the installation program);
- decrease in amendments, modifications and revisions made immediately or soon after system implementation;
- increase in the efficiency and utilization of computer resources;
- increase in the developers' awareness of the users' needs and their ability to communicate with the users; and
- increase in user understanding and acceptance of the role, functions and limitations of the implemented system.

2.6.3 Testing Issues

Usability testing (which is a kind of formative testing) is comprised of four stages (Hix and Hartson, 1993b; Nielsen, 1993c):

1. preparation;
2. introduction;
3. testing; and
4. debriefing.

Preparation is both necessary and critical. In preparation for testing, the tester should make sure that the facility is adequately equipped. All the test materials, instructions, and questionnaires need to be available. All files needed for the test tasks should be restored and any irrelevant files should be removed from the system.

During the introduction stage, the experimenter gives a brief explanation of the test purpose, namely to evaluate the interface and the system not the user. The experimenter assures the user that the results are confidential and will not be shown to anyone in a form allowing for the identification of an individual user. The general procedure for the test is also described. If a consent form is required, the experimenter should ask the user to sign it during this phase.

Following the introduction, the user is given written instructions. The experimenter asks the user whether there are any questions regarding the procedure, the test instructions, or the tasks. If any training is required, the experimenter provides it before the beginning of the test. Regarding the tasks, they should be as representative as possible of the tasks that users will encounter once the system is implemented. The tasks should also reasonably cover the most important parts of the user interface.

After the test, the user is asked to fill in the questionnaires. During the debriefing, the experimenter should thank the user for their help and time. User is also asked for any comments she might have about the system and any suggestions she might have for improvement.

2.6.4 Testing Instruments

In order to properly evaluate the user interface, data about the interface has to be collected. There are various methods for generating and collecting data to evaluate the user interface. These methods include questionnaires, follow-up interviews, and “thinking aloud” protocols.

Questionnaires are commonly used for studying the users’ subjective satisfaction, assessing the manner in which the users use systems, and determining features they particularly like or dislike (Hix and Hartson, 1993a; Nielsen, 1993b; Rubin, 1988; Thimbleby, 1990; Waterworth, 1992). A questionnaire may contain closed or open-ended questions. Closed questions typically provide several options for the user to select from (e.g., “Have you ever used a typewriter?” with two options - yes and no), a number of closed questions which solicit data with the use of a step scale (which is a graded series of intervals that are usually numbers or adjectives). Open-ended questions are used to solicit comments and remarks about specific aspects of the system and its interface (e.g., “What did you like least?”).

Follow-up *interviews* are used to elicit users’ comments and opinions after testing. Interviews are well suited in exploratory studies because they are more flexible and allow the interviewer to react to the interviewee’s comments. However, interviews are time consuming and require greater involvement from the testers than questionnaires. Interviews typically include many open-ended questions and the users are encouraged to

answer in detail. For instance, the interview might include a general question such as “What did you like best about the interface?”.

The *verbal protocol* method, also called the *thinking aloud* method, has traditionally been used in psychological research (Ericsson and Simon, 1984). However, it is increasingly being used for the evaluation of human-computer interfaces (Nielsen, 1993c). The main advantage of this method is the wealth of qualitative data which can be collected from a fairly small number of users. However, researchers need to be aware that the “thinking out loud” process increases the users’ effort and time required to complete the tasks. Therefore, this method is not appropriate for testing the system’s efficiency.

Verbal protocols help to uncover users’ working knowledge and assumptions. This allows for not only determining potential usability problems but also providing an understanding as to the occurrence of specific incidents or difficulties (Hix and Hartson, 1993b). It may also be used to determine what information or knowledge a user was missing that would have allowed the user to successfully complete a task.

The “thinking aloud” method involves one test user interacting with the system at a time and performing a given set of tasks while being asked to verbalize her thinking process (Nielsen, 1993c). When users verbalize their thoughts, an experimenter can observe not only how they interact with the system, but also determine the underlying reasons for the user’s actions. This insight into a user’s thought process can help pinpoint the interface elements that pose difficulties, are misunderstood, or do not allow for effective interaction.

A variation of the thinking aloud protocol is *constructive interaction* which involves two users interacting with the system at the same time (Hackman and Biers, 1992). This test situation is considered more natural than the thinking aloud method, because people are accustomed to verbalizing when they try to solve a problem together.

Another variation of the verbal protocol is *retrospective testing* which involves videotaping (with the user's consent) the testing session. Following the taping, the experimenter and user jointly review the tape (Nielsen, 1993c). It allows the experimenter to stop the tape and question the user in more detail without interfering with the test. The drawback of retrospective testing is that it prolongs the evaluation process. This method, therefore, is not suited if the users are difficult to recruit or if they cannot participate in testing for an extensive period.

Reports from the literature indicate that, simulation systems are widely used in CAI to impart problem solving skills. User interface is an important and integral part of CAI. To develop a usable and effective interface, this research followed the user-centered approach to the interface design process.

The approach was applied to the development and testing of the user interface for a specific CAI system, Patient Simulator. The next section describes the theoretical model behind Patient Simulator, the history of the system development, and the benefits and problems of the system.

3. Patient Simulator

The Patient Simulator is a simulation-type CAI system under development for the diagnostic and treatment skills training of medical students. The unique aspects of the system include its methodological basis and use of artificial intelligence (AI) technologies for simulation of sequential decisions. The initial version of the prototype was developed by Kersten, MacDonald, Rubin, and Szpakowicz (1993). The aim of the system is to provide students with an opportunity to solve medical problems; by conducting case management in a simulated environment (Kersten et al., 1993; Kersten et al., 1994; MacDonald, 1993b). In this respect, the Patient Simulator has features of problem solving CAI systems; it requests users to solve problems by formulating and testing diagnostic hypotheses suggesting solutions which “cure” the patient’s sickness.

Patient Simulator is an adaptation of the Negoplan system for the purpose of computer aided instruction in the medical domain. Negoplan is a system for the simulation and support of sequential decisions and is based on a restructurable modelling methodology (Kersten et al., 1991). This section discusses the methodology underlying both Patient Simulator and Negoplan and describes Patient Simulator and its development history.

3.1 Restructurable Modelling

Restructurable modelling is a methodology proposed by Kersten and Szpakowicz (1994a) to represent dynamic decision processes involving several entities and is characterized by an evolving structure. Decisions are made in a given setting or situation. A situation explicitly represents entities at a given time. In the present implementation of restructurable modelling, three interacting entities are distinguished: the agent, the other participants, and the decision environment. The entities and relationships between them constitute the

“world”. The progressive sequence of simulated situations reflects the evaluation of the decision process.

The agent can determine the relevant entities, interpret their actions and reactions to their decisions, and prepare for subsequent decisions through the development of the decision problem’s representation. The other participants respond according to the agent’s decisions and also make their own decisions independently. The environment, the broader context in which the agent makes decisions, influences the behavior of the agent and the other participants.

There are several mechanisms currently implemented in restructurable modelling. Since problem representations may require different solution procedures at different times, the mechanism for solution procedures is separate from the representation of the agent and the problem. A set of decision alternatives can be determined by applying solution procedures to elements of problem representations. The agent’s ability to select, in a given situation, one decision from many feasible alternatives is provided. Following the actions and reactions of other participants and the environment, the agent is required to assess the appropriateness of the current problem representation. This assessment may lead to the use of modification mechanisms to restructure the current representation so that a new representation takes into account the new situation obtained. In addition, control mechanisms are provided to select appropriate choice, modification, termination and other mechanisms required to simulate decision making.

The problem is represented in terms of a hierarchical structure consisting of facts or goals and their decomposition. The hierarchical decomposition of goals is interpreted as implication and represented by a rule:

$$\text{goal} \leftarrow \text{subgoal}_1 \ \& \ \dots \ \& \ \text{subgoal}_k$$

The truth value of the goal can be determined from the truth values of subgoal_1 & & subgoal_k . Using logical reasoning, each predicate can be assigned a logical value, *true* or *false*. The values *true* and *false* describe a goal as “achieved” and “not achieved” respectively. A predicate with a logical value is called a metafact.

Metafacts are used to represent decision alternatives and to interpret actions and reactions of the other participants and the environment. The creation of new metafacts, changes in their status, assignment of additional meanings to them, are needed with metarules. A metarule’s general format is:

$$\text{triggers} ==> \text{effects}$$

A trigger is a conjunction of metafacts required to reason about the effects.

A set of rules describing the hierarchy of the decision problem at a given moment in time is called the problem decomposition graph (PDG). A solution for the decision problem is denoted as a Goal Solution (GS). GS is composed of the metafacts which, at a given moment, represent instances of the actions which the agent should undertake to solve the decision problem. The evolution of a decision process may require a change in its representation and the creation of a new PDG. The change may include redefining the initial goal’s hierarchy, adding new goals, or considering additional issues while making a decision. A transformation of the problem representation is modelled by restructuring metarules written in this form:

$$\text{triggers} ==> \text{modify}(\text{rule}_1, \dots, \text{rule}_p)$$

Restructurable modelling has been implemented in the Negoplan system (Kersten et al., 1991; Szpakowicz and Kersten, 1993). Negoplan was initially developed to assist negotiators by representing and simulating negotiation processes. Negoplan has been

applied to a variety of decision-making situations including union-management negotiation (Matwin et al., 1989), negotiation with a hostage taker (Kersten and Michalowski, 1989), disaster management (Michalowski et al., 1991), and negotiation in distributed artificial intelligence (Kersten and Szpakowicz, 1994b). One of the most important applications is in medical education. The specific requirements which had to be met in applying Negoplan to medical education resulted in a substantial modification of the system, especially the interface, which resulted in the Patient Simulator.

3.2 Description of Patient Simulator

The Patient Simulator has been developed in collaboration with Carleton University, the University of Ottawa, and the Children's Hospital of Eastern Ontario (CHEO). The purpose of this system is to provide medical students with cases of patients having different symptoms and requiring diagnosis and treatment. The advantage of this system over other traditional training methods (i.e., multiple choice examination) is that it enables them to develop their problem solving skills by learning from their mistakes without any detrimental effects since they will not be using human subjects. Furthermore, the restructurable modelling methodology behind Patient Simulator allows for a dynamic decision-making environment for the student, as the patient's condition is always changing. The capability of such dynamic modelling provides Patient Simulator with unique characteristics that allow for a realistic simulation which is not common in other patient simulations.

Three entities are distinguished in the Patient Simulator. (1) The patient is, in the Negoplan notation, the agent who discloses certain symptoms. (2) The physician (student) analyzes the situation, makes a diagnosis, and prescribes a treatment. (3) The environment is an amalgamation of all elements external to the patient and the physician. For example, in a

student training session, the scores assigned to the student's diagnoses will be presented in the environment.

To obtain the interactions between the physician (student) and the patient, medical cases were developed. At present, there are three cases all of which involve the gastrointestinal system: (a) viral infection of the intestinal system, (b) bacterial infection of the intestinal system, and (c) bacterial infection of the neurological system. These cases were developed through the problem-oriented approach (Chow and Tolmie, 1995). Using the problem-oriented approach, common symptoms for a set of sicknesses are presented to the student. The student then has to decide how to proceed with the case. The case unfolds for the student as she applies actions to the patient. For instance, diarrhea and vomiting are common symptoms for patients who have a viral or bacterial infection of the intestinal system. The simulated patient will be indicated as having such symptoms. The student has to apply general examination procedures and check the patient history in order to obtain more information regarding the case.

There are two ways of selecting a case in Patient Simulator. Instructors can specifically select a case for the student training session. At present, to start a training session, the instructor selects one of two biological systems (intestinal or neurological systems) and then picks one of two infections (virus or bacteria) for the chosen biological system. The case is then presented to the student. Alternatively, if the instructor chooses the random function in Patient Simulator, the system will randomly select the biological system and the infection for the training session. The random function is used for random case selection. After the function is chosen, Patient Simulator randomly selects one of the four cases to start the training session.

For each scenario, actions are available for case management including tests, examinations, and treatments. Some actions, such as general examinations, may provide more information about the patient to aid in diagnosing the sickness. Some actions, such as administering antibiotics, may change the condition of the patient. The changes in the patient's condition are shown through changes in the patient's symptoms. For example, high body temperature drops as the patient's condition improves. The parameter associated with fever will change to reflect this fact. Some of these parameters can be randomly generated to simulate closely a real life patient's situation. One example is the percentage loss of body weight. Two patients who both have viral intestinal infection may have different percentages of body weight loss. Students who re-visit the virus of the intestinal system case will face different patient conditions.

As the student works through a medical case, Negoplan dynamically represents the implications of the clinical decisions involved in case management. Whenever new information becomes known and the student selects the actions, the model is modified and a new representation of the problem emerges. The case management terminates when:

- the student makes a correct diagnosis and selects an appropriate treatment;
- the selected actions are clearly inappropriate in a given situation. For example, intravenous rehydration is *not* the correct treatment for a viral intestinal infection patient. If intravenous rehydration is selected, the process terminates and the student is informed why;
- the patient's condition leads to death.

3.3 Technical Specification

Patient Simulator runs on Macintosh computer platforms. On the Macintosh platform, it requires at least 5 megabytes of random access memory (RAM), 2 megabytes of disk space, and a color monitor. The system is programmed in AAIS Full Control Prolog.

3.4 Benefits of Patient Simulator for Students and Physicians

The aim of Patient Simulator is to provide students with a system for building and enhancing their case management skills. An important feature of the system is that it separates cases (which describe particular illnesses or problems) from other components of the system.

Simulation of medical cases allows students to experience situations which they may face in the future and provides students with the environment in which they have to use their problem-solving skills, especially diagnostic and treatment skills. The students can work at their own pace, select cases which they need to practice, and repeat the selected case many times.

Patient Simulator represents a flexible solution to the problem of improving knowledge acquisition through a wide selection of cases. It can be used for self-study or in conjunction with textbooks. The student is also free to practice at almost “any time and place” since the system can be installed on a personal computer (Macintosh). In addition, the system helps students to become familiar with the computer environment that they will experience when they start to work in hospitals, clinics, and research laboratories.

Another objective is that the system becomes a valuable testing tool for medical educators. In the earlier years of medical school, students are typically tested on their knowledge

through multiple-choice or written essay questions, laboratory quizzes, and term papers. All these tools are used for testing medical facts rather the ability to use these facts in diagnostic and treatment skills. After installing a scoring system, Patient Simulator can also be used as an evaluation tool. During the case management process, each action chosen by the student will be assigned a score depending on the appropriateness of the action. The total score will be summed up at the end of the session and will be compared to the “perfect” or standard score.

With respect to the medical faculty, the computer simulation program can be a useful tool for demonstrating to students how to approach clinical problems. Rather than faculty relying solely on costly clinical practice set-ups, the system can be used to reduce the expense while yielding similar results.

Furthermore, physicians can use the system to continue their own medical education. They can review their own problem-solving approaches to a variety of diseases. When there is a new case management practice for a particular disease, it can be loaded into the system and made accessible to practitioners for their own use.

3.5 Development of Patient Simulator

The original idea for the use of restructurable modelling for a patient simulation system came from Aggarwal (1992). The results of that study included the conceptual model and the initial prototype for the patient simulation system. In 1993, the development of Patient Simulator was carried out by MacDonald (1993a). The focus of the research was to study how restructurable modelling could be used to simulate medical decision making, medical case representation, and the development and testing of cases. The last version of Patient Simulator developed by MacDonald was version 4.

The interaction between the student and the simulated patient in version 4 was through dialogue boxes. Students simply used the mouse to click twice on the action(s) that they wanted to perform; that action(s) was (were) selected. An action can be represented by the request for a medical test, an examination, a treatment or even contacting a specialist. Alternatively, they could click on the “Select” button to select the action(s). After closing the menu, the action(s) would be executed.

Information was organized in windows. One window with the title ‘Patient’ contained information about the patient. At the beginning of the system-user interaction it contained only the visible symptoms of the patient. As the case management process continued, the information about the patient would be updated. The other window with the title ‘Student’ represented the history of actions. It showed the actions selected by the student as well as those selected during the testing session.

Table 3 shows the ‘Patient’ window after the first three steps of the user-system interaction.

SICK INFANT	
true:	diarrhea(0) dry mouth(2) on previous treatment(1) refusal to eat(0) vomiting(0) age(13 months, 2) behaviour(normal, 2) blood pressure(low, 2) bowel movement(normal, 1) diet(no change, 1) family(no similar symptoms, 1) fever(38, 2) fontanel(ok, 2) head size(normal, 2) irritability(neutral, 0) pulse(high, 2) skin(normal, 2) loss of weight(8, per cent, 2)

Table 3. Clinical information display

In table 4, 'True' notation indicated that the user selected the correct actions and the conditions of the patient were listed. The last number after each patient's condition represented the stage of the simulation process. For example, 0 represents the initial stage of the patient. "diarrhea(0)", "refusal to eat(0)", "vomiting(0)", and "irritability(0)" are the initial symptoms of the patient. 1 represents the patient's reaction to the first action selected by the user. "on previous treatment(1)" and other conditions with the number "1" are the result of a general examination which was selected by the user. As the user further performs more action, the number increases.

Three medical cases were written from the domain of pediatrics (in an emergency room environment). However, the complexity of these cases was limited. Simulated patients would not be included in any kind of accidental injury, such as a car accident. The cause of the illness could be a virus, or a bacteria but not multiple causes or psychological reasons. Version 4 which employed Negoplan version 2.1g had been tested using these three cases.

The initial testing was conducted by MacDonald (1993a) and continued by this researcher. The system had been evaluated by two physicians from CHEO: Dr. Jeffrey Turnbull and Dr. Steven Rubin. Version 4, summarized in Table 4 with the medical cases was also tested by MacDonald and 12 selected business and medical students. Both testing and the preliminary evaluations proved the validity of the approach and its potential in medical education. However, some areas required further improvement, mainly the user interface and the efficiency of the system.

	MACDONALD (Version 4)
NEGOPLAN VERSION	2.1g
MEDICAL CASE	Three
	Easier to write and debug
	Random case selection and random selection of Some parameters
START UP PROCEDURE	Complicated
GRAPHIC	Window-based
WINDOWS	Predefined
INFORMATION PRESENTATION	All clinical information under 'True' notation
PROMPTS AND QUESTIONS	Default
HEADINGS	Default

Table 4. An overview of the states of Patient Simulator in 1993

3.6 Weaknesses of Patient Simulator

Patient Simulator as of 1994 was not deemed by either the users or domain experts (physicians) as appropriate for effective teaching and training. One of the major difficulties users had with the system was that it was difficult to follow the information provided by the system (MacDonald, 1993). An improper interface reduced the speed of the users'

performance due to a high user error rate. Users also required much more time to get used to the system which substantially increased the amount of training time. Due to the poor interface, physicians were not able to test the system with a larger number of medical students.

In order to overcome these weaknesses, the user interface had to be re-designed. In addition, with a good user interface the users would be able to focus on the particular case and experience no difficulties with the system's behaviour. This would allow the domain experts, together with the developers, to better assess the system's effectiveness in self-study and testing and also allow them to focus their attention on possible improvements to case formulation, increased case complexity, and the addition of features to further increase the accuracy the simulation of real-life situations.

In order to truly reflect the capability of Patient Simulator, it was re-named to IMMELDA in 1994 and this name is used in the reminder of this study. IMMELDA stands for Intelligent Multimedia Medical Diagnostic Aid. The development and testing of IMMELDA's interface and the construction of knowledge bases used in case management are the foci of this research.

4 Methodology

4.1 Purpose of the Study

The main purpose of this study was to select and, if required, modify a methodology which is appropriate for the design and refinement of IMMELDA's interface. Thus, the practical implications of this research include an enhanced and tested interface.

The objectives of this research were the following:

1. to develop instruments and processes for the identification of the interface problems, difficulties, weaknesses, and areas for improvement;
2. to select design principles from the existing literature and adapt them to a particular CAI system;
3. to test and evaluate research instruments for the implementation of the customer-centered approach;
4. to evaluate the interface development process for the medical training system; and
5. to assess the applicability of the customer-centered approach to CAI in medicine.

The main research questions were the following:

1. What are the advantages and disadvantages of the user-centered development approach for the development of the user interface and evaluation of IMMELDA?
2. How does one determine users' perceptions of the system and its usability?
3. What are the main characteristics of the system that are attractive to its users?

The usability of the system can be measured in terms of user learnability, efficiency, error rate, and satisfaction. One of the issues considered would be the relationship between the interface and the use of the system for self-study.

4. What is the appropriate development process and the level of involvement for the domain experts and users?
5. The work on IMMELDA and its interface have broader implications for other problem solving systems. Would the system be useful for business education?

This study applied the user-centered development process to the design of the user interface and the evaluation of the system based on the advantages of this approach identified in the literature review. Usability testing was applied to evaluate the system as a whole as well as the user interface alone.

The entire research process is depicted in the Figure 5.

Figure 5. The original research process

The goal in developing the user interface was to achieve a high level of usability for the system allowing for effective and efficient learning, high performance, low error rates, and high user satisfaction.

Due to time constraints, the intensity of case development and technical difficulties, the research process was adjusted. The original research process shown in Figure 5 has been modified. The actual research process is shown as Figure 6. The details of this research process are discussed in Chapter 5.

The field testing and the follow-up data analysis phase were not performed as outlined in the earlier research plan because of several reasons. Time constraints made it impossible to perform field testing. Technical difficulties were also encountered. Audiovisual materials (real medical images) could not be obtained because there was no support from the physicians to obtain them. Furthermore, it was difficult to recruit students for testing.

In addition, interface prototyping required not only a focus on the interface but also significant modification of the knowledge base (the medical cases). Users often cannot distinguish the presentation method from the content. It seemed as though the presentation method was not obvious compared to the content of the case. Thus some requests required changes in the case representation and even the case representation in a knowledge base. In order to build medical cases, a modified case development process was followed.

4.2 Case Development Process

Significant modifications of the knowledge base (medical cases) were required to follow a case development process. As shown in Figure 6, case development is comprised of five phases: Interviews with the physicians, Documentation, Case Programming, Testing and Evaluation, and Case Implementation.

To build a medical case, domain experts (physicians) were interviewed to gather the necessary knowledge. First, physicians were asked to provide a general description of the case. With an overall idea of the case, physicians were asked to unravel the details that the student should follow. They determined the history and initial symptoms of the patients, all the necessary tests, examinations and treatments, the correct diagnosis, as well as the possible incorrect tests, examination, treatments, and diagnosis.

As more cases were developed, the scope of cases was emphasized. The selection of cases became significant. Cases were selected in order to fit in with the problem-centered approach used in IMMELDA. With this approach common symptoms for a set of diseases were presented to the student. Then the student had to decide how to proceed with the case in order to filter the correct diagnosis from the differential diagnoses⁴.

After the information was received through the interview, the researcher documented the information. The documentation laid out all the details of the case and included:

- initial symptoms of the patient;
- history of the patient;
- necessary and inappropriate tests and examinations;
- necessary and inappropriate treatments;
- correct and differential diagnosis;
- explanatory messages when an inappropriate test/examination/treatment is selected; and
- changes of patient conditions within the case.

The purpose of the documentation was to ensure that there was no confusion among physicians, the researcher, and developers regarding the case. Furthermore, the documentation was used as the case specification for next phase - case programming.

⁴Differential diagnoses refers to the medical tests and examinations performed to eliminate the set of possible diagnoses so that finally one prevailing diagnosis remain.

As the case specification was prepared, developers and the researcher coded the case. It was written in a special programming language (Kersten and Szpakowicz, 1990; Matwin et al., 1989) which was executed by Negoplan. After developers and the researcher debugged the case, the case was shown to physicians for testing and evaluation.

During testing and evaluation, physicians used the case along with the documentation. Physicians went through the case to pinpoint any typographical errors, to add any necessary tests/examinations, or to change the condition of the patient. Provided that physicians were satisfied with the case, the case implementation phase followed.

In the case implementation phase, the medical case was used with the interface prototype developed during the interface development process. The researcher used the medical case along with the prototype for user testing. Within the interface development process, when medical-case related problems were found in the problem identification stage, they were brought back to the case development process for further improvement. The details of the interface development process are described in the next section.

Figure 6. The modified research process

4.3 Interface Design and Prototyping

The design phase was based on the results of tests, experiments, and discussions with the domain experts. These led to the formulation of changes and modifications to the interface. Further discussions and analysis of data allowed the researcher to determine design specifications.

The design began with the existing user interface of IMMELDA. Initially, senior medical students in third or higher years were the target users of IMMELDA. Since the purpose of IMMELDA is to provide treatment and diagnostic skills training, only senior medical students were deemed to have sufficient medical knowledge to use the system.

Users, the medical students, through their interaction with the system, performed two major tasks: they (a) made patient diagnoses and (b) prescribed treatments. To perform these tasks they analyzed the patient's situation as presented by the system.

The researcher designed the prototype of the screen. The aim was to explore several different screen layouts. For example, a sketch of the system windows was illustrated through a drawing program. Through illustration and discussion, the researcher and developers established a clear idea of the screen layout. After the design of the user interface was obtained, a prototype was developed.

An improved interface was designed based on the results of data analysis from user testing. With the data from the tests, the domain experts (physicians), developers, and the designer (researcher) met to discuss test results and to determine the necessary changes for subsequent iterations. Collected, processed, and analyzed data was used for several decisions made by the domain experts, the developers, and the researcher. These decisions included: the priority of recommendations, the time frame for system improvement, and the

next testing schedule. The researcher and developers assessed the applicability of the recommendations in terms of technical aspects. After finalizing the recommendations, the development team, including the developers and the researcher, prioritized the list of recommendations and then implemented them in the next prototype.

Based on the results of the design phase, the programmer developed the prototype. Once the prototype was completed, testing and evaluation of the system prototype had to be performed. Before the new prototype could be tested for usability, it was tested by the developers and the researcher. Such testing ensured that the prototype was fit for user testing. Following this step, the new prototype was tried by users to determine if there were any usability problems in the system. The details of the testing and evaluation phase are discussed in the next section.

4.4 Testing and Evaluation

Evaluation is central to the continuous improvement of the interface. Deliberate and thorough attention to early and continuous user feedback is essential to developing good user interfaces. Based on the review of the literature, usability testing was performed for testing and evaluation. The details of the testing process are discussed next.

The testing instruments comprised questionnaires, thinking-aloud protocols, and usability testing. Each of these elements is described in the following sub-sections.

4.4.1 The Questionnaire

Development of the questionnaire was based upon models in three studies (Nielsen, 1993b; Rubin, 1988; Waterworth, 1992) which also involved the development and testing of either CAI or user interfaces.

Since the purpose of testing was to elicit users' comments, the questionnaire included not only quantitative but also qualitative measurements. The questionnaire comprised the following sections: user-computer interaction, graphics, case management, and educational aspects. The first two sections elicited the user's level of satisfaction with the interface, and the last two sections were used to obtain opinions on the system as a whole. In addition, each section of the questionnaire provided space for the participants to write additional comments. The complete questionnaire is shown in Appendix F.

4.4.2 Subjects

For testing, third year or higher medical students were the primary participants. Subjects were recruited through both the University of Ottawa's Department of Medicine and Montreal Civic Hospital. Physicians who were involved in this research came from CHEO and Montreal Civic Hospital.

The domain experts, physicians, also participated in the testing process but mainly during the case development process. The participation of physicians helped to ensure the validity of IMMELDA especially in terms of the clinical information and the reality of the simulation in the case management process.

Two groups of subjects were targeted to use the system. One group consisted of students who would participate in most or all of the tests. This would allow for the obtaining of information about improvements made and for measuring incremental user satisfaction. The second group would have consisted of students who tested the system only once. This would allow for the assessment of novice difficulty with the system use. Unfortunately, the researcher could not recruit enough subjects to participate in a second testing due to their busy schedules. As a result, the subjects only tested the system once throughout this research.

4.4.3 Sample Size

The sample sizes required in usability research are very small. Figure 7 indicates the cost-benefit ratio as a function of sample size (Nielsen, 1993c). The optimal number of users is between 3 and 6 from the perspective of cost benefit for each test.

Figure 7. The pay-off ratio (how much larger the benefits are than the costs) for user tests with various numbers of test users (Nielsen, 1993b; p174, Figure 18).

Nielsen (1993b) and Virzi et al. (1993) have found, repeatedly, that five users can identify approximately 80% of the existing interface related problems. Virzi et al. (1993) also note that the most severe problems were turned up easily and quickly. This is due to the fact that usability tests are focused on finding major, obvious problems for which small groups are sufficient. It is also for this reason that traditional statistical analysis is not applicable.

Due to the very small sample size reliability is a potential problem. However, most major problems become obvious in a well-designed usability test, even with a very small sample size. Hence the design of the test, and not the sampling technique or sample size, is a critical factor to its success.

4.4.4 Ethics Review Process

Before recruiting the subjects and conducting the testing, the entire proposal (including the testing instrument, recruitment and sign-up sheet, and the informed consent form) underwent review by the Carleton University Ethics Committee (see Appendix A). The purpose of this review is to ensure that all the participants are treated in accordance with the ethical guidelines of the researchers' organization. Since the primary principal investigator is a Carleton University student and the subjects are students from the University of Ottawa, approval of both the Carleton University Ethics Committee and the University of Ottawa Ethics Committee was obtained.

4.4.5 Conducting Tests

When the expected number of subjects was recruited, the testing commenced in the laboratory environment. The four stages of usability testing in this research were: preparation, introduction, testing, and debriefing.

Preparation included arranging the test room, setting-up the prototype and the testing instruments. During the introduction stage, the experimenter gave a brief explanation of the test purpose to the subject. The general procedure for the test was described. After understanding the purpose and the procedure of the test, subjects were asked to sign the consent form. Following this, the testing started. During the test, subjects were encouraged to verbalize their thoughts. Since the thinking-aloud method was used, only one test user at a time was allowed to use the system. This method facilitates an understanding of what each subject is doing with the interface and why. This insight into users' thought processes can help to pinpoint interface elements that cause misunderstandings so that these elements can be redesigned.

Such an approach contrasts with the techniques used originally to study problem solving whereby users were asked only to “think aloud”. This is to avoid the possibility of the experimenter influencing the user’s behavior. There are three reasons to adopt this more relaxed approach (Nielsen, 1993c; Wright and Monk, 1991): (i) the more natural the procedure the easier it will be for the evaluator to learn and to use; (ii) allowing the evaluator to ask questions maximizes the possibility of identifying and correctly interpreting critical incidents by providing the necessary intentional context; (iii) putting the users on an equal footing with the evaluator and allowing them to ask questions encourages them to be critical and so maximizes the detection of breakdowns.

During the thinking-aloud test, the experimenter did not express any personal opinions or indicate whether the user was doing well or poorly. The experimenter made non-committed sounds like “uh-huh” to acknowledge comments from the user in order to keep the user going. Also, to keep the user going, without leading her, the experimenter asked questions such as:

- What do you think?
- What are you thinking now?
- What do you think this message means?
- If you do “such-and-such”, what do you think will happen next?

The researcher refrained from helping the user, except when the user encountered severe difficulties. Whenever the researcher provided help, notes were taken on when the users needed help and what difficulties they encountered.

After the testing, the researcher organized the notes and the questionnaires. All the results from the testing were used in the next phase -- data analysis.

4.4.6 Data Analysis

The quantitative data obtained from the questionnaires was presented as descriptive statistics. For each question, the total pattern of the users' responses was determined.

After the total pattern of the results had been obtained, the analysis began with the explanation for the pattern. The analysis also explicitly stated which usability goals were met, and which were not. The results led the team to either accept the software, or determine the necessary changes to be implemented for the next iteration of the prototype.

The qualitative data elicited from the questionnaire and verbal protocol was transcribed into the recommendations for the next iteration. Qualitative data can point to features of the design that will cause problems for users and will often suggest what sort of redesign is necessary. The data was used to formulate recommendations for the redesign of the system.

After the data analysis was completed by the researcher, the results of the evaluation were used for problem identification which led to the user interface design phase.

4.5 Field Testing

Field testing allows for testing a completed interface under the user's actual environment, the result would then be evaluated to determine the next stage. If the testing results indicate that minimal changes are required, there would be refinement on the prototype followed by the continuation of the process through the deployment stage. However, when significant changes on the prototype are required, the testing results of the evaluation would be used for another iteration in the interface development process.

As discussed earlier, the field testing, and subsequent phases, were not completed. The refinement and deployment phases were not within the scope of this research.

In the final phase, this study concluded with a summarization of experience gained from the study. This summarization included the design specification, the description of the prototyping process, all the results of the testing and evaluation, and the description of the implementation process which was the complete interface implementation in IMMELDA. The next section describes and evaluates the development process.

5. Results and Analysis

During the research, a total of three iterations of the activities shown in Figure 4 were performed. In this chapter, each iteration is explained in terms of problem identification, user interface design, prototype development, testing and user evaluation, and data analysis phases within the interface development process (see Figure 4). At the end of the chapter, an overview of the states of the 1993 Patient Simulator and 1995 IMMELDA (prototype III) is shown to conclude this chapter.

Table 5 summarizes the number of subjects who participated in the testing that took place for all three iterations.

PROTOTYPE	NO. OF SUBJECTS	EXPERIMENT SITE
Prototype I	6	University of Ottawa
Prototype II	5	Montreal General Hospital
Prototype III	5	University of Ottawa

Table 5. Number of subjects who participated in the testing

5.1 Prototype I

Prototype I was developed to rectify some of the weaknesses of Version 4 of Patient Simulator. The major improvements were from the clinical information presentation and the addition of multimedia capability. The process of the first iteration is discussed next.

5.1.1 Interface Development

Problem Identification

The problem identification stage is to discover the design directions for the new interface or to identify the problems in the existing interface of the system. IMMELDA was in the latter situation. According to MacDonald (1993), IMMELDA was not deemed by either the medical students or physicians as appropriate in effective teaching and training. One of the major difficulties users had with the system was that it was difficult to follow the information provided by the system.

In order to clarify the problems, one of the domain experts who is also involved in the IMMELDA project went through the simulation with the researcher and pinpointed the problems and difficulties.

User Interface Design

After several discussions with the physician and developers, the new interface design was produced. The changes in the new design included: (i) removal of the stage number beside the medical information; (ii) removal of the irrelevant prompts and questions during the management process; and (iii) addition of visual and audio material samples.

Development of the Prototype

The approval of the development team for the design changes was then obtained. The programmer and developers built the prototype based on the results from the design stage.

Testing and User Evaluation

The user testing for the prototype was held at Room 2137, Medical Education Resource Centre, Guindon Hall at the University of Ottawa from October 17 to October 28, 1994. The testing involved two experimenters and six subjects. Each session took forty-five to sixty minutes per subject. At least one medical case was tested and evaluated per session. All cases were randomly selected by the computer. During the testing session, the subjects were asked to verbalize their thoughts. Participants talked about what they did and why they did it. One experimenter observed the participant's actions and took notes on all the verbalizations from the participants. After testing, each participant filled in a questionnaire. The questionnaire is shown in Appendix F.

5.1.2 Data Analysis

This section presents the subjects' positive and negative comments from the testing session including those from the questionnaire, and then suggests remedies in response to the comments. Participants' demographic information and comments are also included.

Subject Characteristics

All six subjects were third year medical students in the Faculty of Medicine, University of Ottawa. None of them were in any area of specialization. All subjects were in the age range of 23 to 27. There were four males and two females. Of the six subjects, three considered themselves as novice computer users, two as intermediate computer users, and

one as an expert. All but one of the six participants had used computer assisted instruction before.

Comments

Generally, subjects liked the system from the aspect of the medical case, the presentation, and the potential of the system. For example, the last question (27 - "In general, did you like using the system?") in the questionnaire was asked to obtain an overall opinion towards the system. Four out of six subjects gave the "Like" rating, and one gave the "Like Extremely" rating. One gave the "Neutral" opinion. All subjects also provided lots of comments during the testing session as well as completing the questionnaire. The balance of the data analysis will be followed according to the section headings on the questionnaire used.

User-Computer Interaction

All six subjects were in favor of the interaction with the system except for the clinical information provided. Five subjects considered the complexity of the system neither simple nor complex, and one subject rated the complexity of the system simple. Five out of the six subjects rated either "Like Extremely" or "Like" using the mouse as an input device. One subject gave the "Neutral" rating and commented "use a keyboard instead of mouse or have an easy-to-use mouse." This subject seemed unfamiliar with the mouse as an input device, and had a problem with using the mouse. Therefore, using a mouse as the only input device did not seem to be a problem in this experiment.

However, some subjects had difficulties working with the information in windows during the session. When the dialogue box was hidden under "Sick Infant" and "Student" windows, some subjects were unable to get it back. The experimenter had to help to get the dialogue box in front of the two working windows.

Regarding the clinical information in the two working windows, one subject considered the clinical information to be difficult to understand. Three subjects gave “Neither Easy nor Difficult” rating. Only two said that the clinical information is easy to understand. Furthermore, two subjects rated the amount of information given as mostly inadequate, and expressed the view that more clinical data is necessary (e.g., sex). In fact, three subjects who said the amount of information given is mostly adequate commented that they would like more quantitative data (e.g., blood pressure) and qualitative data (e.g., a picture of the patient).

Even though clinical information was already presented (i.e., blood pressure), subjects commented that the information could be more readable and better organized. First of all, the age of the patient should be under patient history rather than general examination. The organization of clinical information should be in order with respect to the human body (i.e., from head to toe) rather than in alphabetical order. For example, the vital signs should be presented together: pulse, temperature, respiratory rate, and blood pressure. In addition, instead of presenting low blood pressure, the actual blood pressure measurement should be given.

Graphics

All subjects considered the layout of the screen either “Average” or “Good”. However, subjects expressed concern that the “Student” window was not useful and took too much space on the screen. The “Student” window displayed what student had selected and had not selected actions for the case management; the subjects stated that this information was not helpful in case management. Moreover, as the “Sick Infant” window displayed more clinical information, the dialogue box covered the patient information when the menu appeared. Some subjects even had difficulty locating the dialogue box when the dialogue

box was hidden under the two working windows. This suggests why subjects said the “Student” window should be removed or reduced in size. Removal of the “Student” window or reducing its size would help ensure that the dialogue box would not hide some of the information in the “Sick Infant” window.

Although there were no relevant pictures or movies for the medical cases available, the graphics related questions were considered appropriate to solicit opinion about the current graphics. These questions were intended to elicit the opinion about the necessity of the pictures. During the testing session, a few commercial software pictures and movies were presented to show the capability of the system. The experimenter asked the participants about the idea of including pictures and the movies.

All six subjects responded that pictures or movies would be a good idea during the testing session. In the questionnaire, three subjects rated the pictures “Very Useful”. Two subjects did not give a rating; they wrote down that the actual pictures were not available. One subject rated the pictures and video clips as “Somewhat Useless”. One commented “the picture didn’t add a whole lot to my learning as is, although I think they could be a good learning tool.”

Case Management

One subject “Liked Extremely” the way the case was brought up and one “Liked” it. The other four subjects had a neutral opinion about bringing up the case. Three subjects rated “Undecided” regarding the accuracy of the medical information. One stated that a student cannot judge whether the information was accurate or not. Regarding the patient’s initial symptoms, subjects said that they were too simple. In real life, the patient tells the physician about her conditions rather than providing the information in point form.

One subject mentioned that, in some cases, the order in which symptoms occurred with a patient is important. For example, “if abnormal bowel movement occurred before vomiting the patient may have cancer”, and “if vomiting occurred first, bacteria may be present.” The subject therefore suggested that the symptoms might include their temporal occurrence.

In terms of case management, four subjects gave a “Somewhat Realistic” rating to the exercise (simulation session) and one rated “Undecided”. One subject even rated the exercise as “Somewhat Unrealistic”, and stated “cases were not presented in that way in medicine and more information about the patient should be included.” This implies that improvement in the content of the clinical information is necessary.

All the subjects stated that the termination message was too vague. Although all six subjects indicated that they could understand the message, the messages are not detailed enough. One subject expressed concern that the system was unable to tap into educational material behind the case. The system should not only provide what the user did incorrectly during the case management process but also the reasons why. Furthermore, one subject stated that he would like to proceed with a case even if a mistake was made.

Educational Aspect

Overall, all subjects considered the system a useful tool to learn diagnostic skills. Five out of six subjects rated the system either “Mostly Appropriate” or “Very Appropriate” for both teaching diagnostic and treatment skills, and one subject rated “Undecided”.

All six subjects rated either “Definitely Yes” or “Yes” to using the system as a self-evaluation tool for diagnostic skills. However, three subjects thought the system was not “Very Appropriate” for group study, and one “Undecided”. Only two subjects considered the system “Very Appropriate” for group study. This indicates that, at present, group

study is not the direction to head with the design of the system. Five out of six subjects selected “University” and “Home” both as their preferred place to use the system.

5.1.3 Problem Identification and Recommendation

To respond to the subjects’ comments, eight recommendations were formulated to improve the system.

1) Provide a short instruction page or manual for using the system

A short instructional manual could provide medical students with information on how to start the simulation. The suggestion was to simplify the IMMELDA user manual. The simplified user instruction would be limited to 2 pages, and include the steps involved in running a simulation. It was important to make the 2 page manual easy to read so as not to “scare” users. One subject commented that if there was a long manual, no one wanted to read it.

Additionally, a short written instruction could be put into the system. Users could get a help screen that indicated how to proceed with case management. Such help functions should not be under the Apple icon menu as was the case with Negoplan. People, even Macintosh users, might not know the help function was hidden under Apple icon menu. One suggestion was to explicitly add a menu item called ‘Help’ beside the ‘Data’ menu. Another suggestion was to use one of the Negoplan icons as a button to activate the help function.

2) Present a short description of the patient condition instead of the four initial symptoms

A short description of the patient could provide a more realistic clinical environment for the medical students. The given initial symptom was shown in point form (see below).

true: _____ stage 0 _____
 diarrhea
 irritability
 refusal to eat
 vomiting

Subjects stated that in the clinical environment the patient told the physician about her condition in a paragraph form (or sentences) rather than in point form. Such presentation of initial patient's condition could not simulate the actual interaction between the patient and the physician. Therefore, a short, written description of the patient condition could simulate closely the clinical environment. The short description of the initial contact with the patient should be written by physicians.

In addition to the written description, the patient's introductory paragraph could be presented by the audio output. For instance, someone could read out the paragraph as the patient's parent informs the physician about the condition of the patient. Reading out the paragraph could be done by the physicians or the researchers.

3) Enhance the content of the termination message

Enriching the termination message could enhance the applicability of the learning environment. One subject commented that he could not learn anything from the termination message (see below) except that she requested an incorrect specific test. If the system could not provide an explanation of his incorrect action, he would not use the system at all because of the inability to learn from mistakes. An example of a termination message was shown as below.

Terminated because of :

This is the incorrect specific test.
Please consult the specialist.

All six subjects stated that they could clearly understand the message but it was too scant. Therefore, the termination message had to be improved. Domain experts (physicians) had to provide appropriate texts for termination messages. Only physicians could provide the level of detail and content that should be included in the termination message.

4) Modify the format of information presentation

a) Change the format of side-printing

Under the side-printing format, if a medical student selected two actions (i.e., patient history and general examination) to be performed simultaneously, the results of two actions would be presented as follows:

———— stage 1 ————
 dry mouth
 no previous treatment
 age(13 months)
 behaviour(normal)
 blood pressure(low)
 bowel movement(normal)
 diet(no change)
 family(no similar symptoms)
 fever(38)
 fontanel(ok)
 head size(normal)
 pulse(high)
 skin(normal)
 loss of weight(8, per cent)

Such a presentation introduced a serious problem. Subjects had problems locating which piece of information came from the general examination or the patient's history. All information lumped together caused confusion in interpretation. To reduce such confusion, the following presentation format was suggested.

———— patient history ————
 no previous treatment
 bowel movement(normal)
 diet(no change)
 family(no similar symptoms)
 ———— general exam ————
 dry mouth
 age(13 months)
 behaviour(normal)
 blood pressure(low)
 fever(38)
 fontanel(ok)
 head size(normal)
 loss of weight(8 per cent)
 pulse(high)
 skin(normal)

- b) Allow case authors to arrange the order of metafacts

The following shows the order of general examinations results:

———— general exam ————
 dry mouth
 age(13 months)
 behaviour(normal)
 blood pressure(low)
 fever(38)

fontanel(ok)
 head size(normal)
 loss of weight(8 per cent)
 pulse(high)
 skin(normal)

Provided that the case author was free to arrange the order of metafacts, the clinical information could be shown as the end-users prefer. Case authors could arrange the metafacts into the rule base according to the users' preferences.

The outcome of the new order of metafacts was shown as follows:

————— general exam —————
 fever(38)
 pulse(high)
 blood pressure(low)
 head size(normal)
 dry mouth
 fontanel(ok)
 skin(normal)
 behaviour(normal)
 loss of weight(8 per cent)
 age(13 months)

Such a presentation of the information could satisfy the need of end-users (medical students). The vital signs were shown together, and then the other information was in the "head-to-toe" order.

c) Remove the "true" and "false" notation

The notation of "true" and "false" should be eliminated. All six subjects commented they had no clue as to what "true" or "false" stood for. Furthermore, the "false" notation sometimes made the subjects think that they had done something wrong such as selecting an inappropriate action. Thus, removal of the "true" and "false" notation was considered necessary.

d) Use the user's language to present information

To make the information easier to understand, the clinical information should be presented the way users read. For example, the reading of the blood pressure should be given such as 80/50 rather than the objective judgment (i.e., high, normal, low). In real life scenarios, physicians read the measurement from

equipment or from the test results, and then made a judgment. Moreover, presenting such readings not only simulated real life environments but also tested the medical students' ability to judge readings.

The primary input for changes in clinical information should come from the physicians. Physicians provide the knowledge on what kind of information could be presented more "clinically". This included specific terms used to describe symptoms, tests, and others. Here are some of changes that were suggested by the subjects:

- "sugar" should be changed to "glucose";
- "blood pressure (low)" should be changed to "bp(130/70 mm of Hg)"; and
- the use of some clinical symbols, for example, Rx, %.

5) Change the size of working windows

Changing the size of the working windows would reduce the cumbersome feelings that the students experienced with the windows. The following diagram shows the suggested organization of the windows.

Figure 8. A suggested organization of the windows

All the patient information was kept on the left hand side of the screen, and the information regarding the student was on the right hand side of the screen. The position of the dialogue box did not cover the patient information anymore. Also, this presentation clearly showed to the student all self-relevant information: the action he/she selected, the options from the menu, and the current score for the management of the case.

6) Hide unnecessary functions/menus from the end-users

During the testing, one subject's case session was forced to terminate because the subject selected an unnecessary option (Go to Prolog) under the control menu. Moreover, the 'Show Fact Tree' command under 'Tracing' menu gave the complete goal representation of a Negoplan case. Although such commands were useful for case authors or system developers, these options might provide a student with the correct answer if they were available in the training mode. If a student selected the 'Show Fact Tree' command, she knew the problem of the patient right away. Since the 'Options', 'Tracing', and 'Control' menus were used by case authors or system developers rather than end-users, these menus should be masked .

7) Get real pictures and movies

Since all subjects were happy and excited about the audio and visual capabilities of the system, it was deemed necessary to get the actual pictures and movies relevant to the test and treatment. For instance, a picture of an infant could be shown during the patient introduction and could enhance the sense of interaction between the physician and the patient. One subject said, "It sometimes makes a difference how the patient appears or presents herself to you." The supply of pictures or movies had to rely on the physicians' support.

8) Develop the aid and scoring system

During the experiment, all six subjects indicated that the system should allow for an aid such as references to the textbook and a performance evaluation function such as a scoring system. To develop the aid and the evaluation system, physicians would play an important role in formatting the content of the aid and the structure of the scoring system. For instance, physicians had to decide the marking scheme for

a case management session. Case authors and physicians should, together, design the aid and scoring system. On the other hand, case authors and system developers should design the physical implementation of the scoring system and other aids.

Based on the testing results, the researcher concluded that the medical cases developed did not reflect the clinical situations. Consequently, changes had to be made on the medical cases. To build the medical cases, the case development process (see Figure 6) was followed. Within the case development process, there are five stages: (1) Interview with the physicians, (2) Documentation, (3) Case Programming, (4) Testing and Evaluation, and (5) Case Implementation.

First, physicians were asked to develop a typical medical case for the simulation. The purpose of the case is to represent the real-life clinical situation as closely as possible. After obtaining detailed information about the case, the researcher put it into a document that presented the case as shown on the screen.

The researcher and developers then wrote the case according to the documentation worked out with the physicians. Because of the requirements from the physicians, the existing method of writing cases was no longer effective and efficient. Developers used the new method to write the cases. The medical cases were tested thoroughly by the researcher and developers to ensure that there were no bugs. After the testing, the researcher presented the case to the physician. The physician was asked to pinpoint any errors and suggest any necessary changes that had to be made on the case. If the case was fine, it was used for interface design and development.

5.2 Prototype II

Prototype II was developed based upon the findings of the first iteration.

5.2.1 Interface Development

Problem Identification

According to the data analysis from the first iteration, one of the major problems was understanding the clinical information presented by IMMELDA. Thus, it was necessary to refine the presentation of the clinical information. Users also encountered difficulties due to the position or size problem of the windows.

User Interface Design

After several discussions with the physician and developers, some problems were not considered serious enough to be addressed in the next design. The changes required in the new design included: (i) increasing the amount of clinical information; (ii) changing the presentation of the medical information; and (iii) adding realistic medical images.

Development of the Prototype

The final agreement on the design was obtained with developers and the new prototype was built. Three new cases were added into this prototype. More items were added into the Help menu.

Testing and User Evaluation

Prototype testing was held at the Surgical Teaching Laboratory, Montreal General Hospital on July 18, 1995. The testing involved five subjects, one experimenter, one developer and one physician. Each session took between twenty-five and thirty minutes per subject

because of time constraints: each participant could only spend half an hour on the experiment. One medical case was tested and evaluated. During the testing session, the subjects were asked to verbalize their thought processes. Participants talked about what they did and why they did it. The whole testing process was tape recorded with the participants' consent. After testing, each participant completed a questionnaire.

The questionnaire (see Appendix G) used was slightly altered from the one used in the first iteration for several reasons. Due to time constraints, each participant could only spend half an hour on the experiment. In order to satisfy the time constraint, the questionnaire was shortened and rearranged. The Subjects' Characteristics section was removed, since participants' information was obtained before the experiment.

5.2.2 Data Analysis

In this section, the subjects' comments arising from both the testing session and the questionnaire are presented, and then suggestions and remedies in response to these comments are documented. All five subjects had either completed their second year or were enrolled in the third year at the Faculty of Medicine, McGill University. Three of them considered themselves as novice computer users and two of them as intermediate computer users. Three participants had used computer assisted instruction before and two had not.

Generally, subjects liked the system and provided a lot of encouragement and constructive comments. The rest of the data analysis is presented according to the section headings on the questionnaire.

User-Computer Interaction

All five subjects rated the use of the system as “simple”. Regarding the clinical information, subjects considered the clinical information easy to understand and the amount of information adequate.

However, there was a difference of opinion on the options in the dialogue box. Some subjects did not agree with some of these options. For instance, one subject stated that the option “hospitalization” is not clear. He thought that since the case takes place in a hospital, there is no reason to select hospitalization. (and because he did not hospitalize the patient, he received the penalty - session terminated). There were also some ambiguities in the definition of the options, such as “general tests”, and “specific tests”.

Moreover, some subjects had difficulties working with windows. When the dialogue box covered the “Patient” and “Case Management History” windows, some subjects did not know how to read the information in the “Patient” window. Similarly, when the dialogue box was partially occluded by the “Patient” window, it took a while for the subject to get back to the dialogue box. Two subjects suggested that the window should be “tiled” instead of “cascaded” with the title so that the windows could be easily accessed.

Subjects also pointed out problems with the Help menu and the help function. One subject commented, “Help menu is useful but its position on screen does not make it clear that Help belongs to the program and not to the computer system.” Another student also commented, “Instructions should be clearer regarding how to select the options, what are the options, how to use the system.”

Graphics

Compared to other sections of the questionnaire, the graphics-related questions had relatively high scores on the five-point scale. All the subjects favored the layout of the screen and the pictures presented. However, there were some concerns regarding the control of the pictures. The picture was presented as a window and the subjects had difficulty accessing it. This is consistent with the comments regarding the windows in the previous section.

Case Management

Subjects gave average score ratings (3.25 out of 5) on the way a new case was brought up. One subject did not answer the question. They would have preferred an introductory page on the screen before the case starts because they were not clear what role they played in the system and what they were supposed to do.

There was a mix of opinion on the reality of the case management. Two out of five subjects gave it a rating of 2 on the 5-point scale. The remaining subjects gave ratings of 4 and 5 respectively. The two subjects that gave the low scores did not agree with the procedures built into the case management - perform general tests before any specific tests. They argued that, in “real life” many of the options selected can be done at once, and it is unrealistic to do them in a linear, step-by-step fashion. Accordingly, one of them also gave 2 out of 5 on the next question - “is this system appropriate for teaching diagnostic skills to medical students” - and the other gave three. However, the remaining three subjects gave four points on the five-point scale to this question.

Consequently, the score for the question, “teaching diagnostic skills” to medical students is slightly lower than the one, “teaching treatment skills” to medical students. Furthermore,

there were some concerns about the way the session was terminated. Subjects would like to go on with a case if a mistake was made.

Regarding the accuracy of the information, there were some typographical errors and chronological order problem in the clinical information. During the testing sessions, some subjects suggested that, instead of showing all the patient history and general examination results at once, they could be categorized and requested accordingly. For example, the patient history could be divided into present, past, and family history. Certain history will be shown only if the student requests that particular history.

5.2.3 Problem Identification and Recommendation

In response to the subjects comments, six recommendations were proposed to improve the present version of the system.

1) Move the dialogue box

The dialogue box consistently produced difficulties for the students in both first and second round of experiments. Students did not know how to get back to the dialogue box after reading the information on the working windows. Therefore, moving the dialogue box was necessary to eliminate these difficulties.

2) Increase the accessibility of the pull-down menu

A Help menu was perceived as a useful feature to provide more information and explanation. However, it was difficult to access. It was under the Control menu (one of the drop-down menus). The suggestion was to put the Help menu beside the Data menu (another one of the drop-down menus).

3) Provide brief instruction for using the system

Instructions for users on how to start the simulation were deemed necessary. This could be one page long, describing how to select an item, what the options are, and so on. The rationale was that one page of instructions should be easy to read, and users would not be “scared” away by a manual.

4) Refine the presentation of clinical information

Since there were some typographical errors and the chronological order problems with respect to the clinical information, refining them could be done by the physician. The physician needed to go carefully through all the information presented in the case and pinpoint the errors to correct them.

5) Provide a short introduction

A short written introduction should explain what the student’s role is, where the case takes place, and what they are expected to do. This would alleviate the problems for students who are not clear what they should do. This would require less time and effort than creating an introductory screen for the system as suggested by the students.

6) Reduce the number of termination paths

All subjects who succeeded in the case management, except one, disagreed on certain procedures in the case management process. Some even were frustrated when the session terminated; they wanted to go back to discover where they made the mistake and continue to work on it.

In addition, Dr. David Fleischer⁵ stated that there were too many termination paths in the system that can frustrate the students using the system. In case management, there is more than one way to handle the patient. Since the students cannot argue

⁵Dr. David Fleischer is the Associate Dean of Medical Informatics at the Montreal General Hospital. On July 18, he reviewed IMMELDA and provided some useful comments.

with the computer if they do not agree with the results shown by the system, the system should not just terminate the session but attempt to explain the reason and let them recover from the mistake.

In response to the students' and Dr. Fleiszer's comments, certain metarules would be changed so that the case would continue rather than end abruptly. Changes would be done with the physician's help to ensure that correct medical expertise is built into the system. In brief, students would be informed if they made a mistake and then they would be allowed to continue the session. The proposal for termination metarules included incorrect interim treatment, incorrect selection of contact specialist, and the incorrect procedures for general examination, general tests, and specific tests.

5.3 Prototype III

Prototype III was the last iteration in this research and was developed based upon the findings of the second iteration.

5.3.1 Interface Development

Problem Identification

According to the data analysis of the second iteration, users encountered difficulties interacting with the system due to the position of the dialogue box. As a result, repositioning of the dialogue box was a top priority. Users also had difficulties accessing the help menu.

User Interface Design

The changes in the new design included: (i) repositioning of the dialogue box; (ii) reduction in the number of termination rules; (iii) repositioning of the Help menu; and (iv) refinement of the clinical information. Although pictures associated with the cases were necessary, the physicians could not provide the pictures or X-rays due to technical difficulties and the

policy towards patient confidentiality. Instead the sample X-ray and pictures not related to the cases were used.

Development of the Prototype

Due to the time constraints and the availability of the students, the required changes on the simulation were quickly implemented. The new prototype was built for testing and user evaluation.

Testing and User Evaluation

The user testing for the prototype was held at Room 2137, Medical Education Resource Centre, Guindon Hall at University of Ottawa from August 8 to August 13, 1995. The testing involved one experimenter and five subjects. Each session took forty-five minutes per subject. One medical case was tested and evaluated. After testing, each participant filled in a questionnaire which was the same questionnaire used in previous prototype testing II (see Appendix G).

5.3.2 Data Analysis

All five subjects were enrolled in the third year at the Faculty of Medicine, University of Ottawa. Of the subjects, two considered themselves as novice computer users, two intermediate computer users, and one as an expert. All five participants had used computer assisted instruction before.

Subjects liked the system and perceived the system as a learning aid. They also provided a lot of encouragement and indicated that the system could be applied as a self-evaluation tool or for performance evaluation or group study and used at a university, library, or hospital. However, further improvement in the system was deemed to be necessary.

User-Computer Interaction

There was a mix of opinions on the amount of clinical information and understanding the information. Some subjects suggested that the social history of the patient should be included while one commented that the information was excessive. All subjects indicated that a larger font should be used for information display.

In this test, subjects did not experience the difficulties with the dialogue box and the help menu as in the previous two tests. Regarding the Help menu, most subjects suggested having more definitions and explanations in the help and a tutorial of the system. Since the system would be used as a learning aid, those help functions would increase the usefulness of the system.

Graphics

Although there were no actual case-matched pictures, all subjects indicated that pictures would be helpful for the case management and simulation of real life cases. Subjects also suggested that an audio-visual introduction of the system would be useful and nice.

Case Management

Most subjects gave either 3 or 4 on the 5-point scale on the reality of the case management. Similarly, the range of the score for the question, “teaching diagnostic skills” was between 2 and 4. Students explained that a medical student often learns different management skills depending on which staff doctor she is with. Therefore, they did not quite agree with some case management procedures in the case and would have liked to see more explanation in the event of an incorrect action or step.

Since the case used for the testing did not really require treatment, the score for the question, “teaching treatment skills” was much lower than the one, “teaching diagnostic skills”. Students believed that physicians will ensure the accuracy of the information because physicians were involved in the system's development.

Although prototype III was the last iteration in the research, it did not anticipate that prototype III is the last prototype for IMMELDA. In fact, there are further improvements required for the system, such as to incorporate the actual pictures and add a tutorial. Because of the time constraint, prototype III was the final iteration of the research. Table 6 summarizes the major case and interface changes for each prototype.

	CASE CHANGES	INTERFACE CHANGES
Prototype I	<ul style="list-style-type: none"> • Introduce new method to write the cases 	<ul style="list-style-type: none"> • Use stage number as the heading • Add audio and visual capability • Remove irrelevant prompts
Prototype II	<ul style="list-style-type: none"> • Re-design the case development • Add three new cases • Add explanation messages • Add more items in the Help menu 	<ul style="list-style-type: none"> • Use test name as the heading • Add help button in the dialogue box • Add Help menu • Enlarge the patient information window • Rename the windows • Re-position pictures
Prototype III	<ul style="list-style-type: none"> • Reduce the number of termination rules • Add more items in the Help menu 	<ul style="list-style-type: none"> • Move the dialogue box • Help menu more accessible

Table 6. An overview of the case and interface improvement

5.4 Overview from Patient Simulator to IMMELDA

Since the development of the first four versions by MacDonald in 1993, the medical system has been further improved. At the end of 1995 the IMMELDA prototype III began using Negoplan version 2.3k. The major changes relate to the start-up procedure, graphics,

information presentation, and speed. The changes and improvements made in IMMELDA are illustrated in Table 6.

In the early version, users had to go through several obscure steps before they could select a medical case. The user needed to answer two questions: "Load a file to customize your environment" and "Load 'setup' automatically?". Depending on the answers of these two questions, the user had to select a few files before actually selecting a medical case. In the current prototype the start-up procedure is significantly simplified. Users can easily initiate interaction with IMMELDA and either immediately select a medical case or have the case randomly selected for them.

Further improvement was made to the error recovery procedure in the pop-up menus. In Patient Simulator Version 4, if a user did not select any item and closed the menu, the system went into a loop and the user could not continue or quit the program. At present, if a user does not select an item before closing a pop-up menu, the same pop-up menu will re-appear automatically.

The dialogue heading for each dialogue box has been refined. In Patient Simulator Version 4, the default heading was used (i.e., 'Select the actions you want to perform') regardless of the set of options provided. Now, case writers can customize the dialogue heading for each pop-up menu. For example, if a dialogue box includes a set of diagnostic options, the heading is under 'Select diagnosis'.

Within the current windows-based interface environment, multimedia capabilities have been developed. Presentation of clinical information has been modified in response to the request of the two domain experts and preliminary tests conducted in 1994. IMMELDA is now able to present clinical information through both audio and visual output. For

example, a picture of an X-ray can be displayed. It is also possible have “education related” sound (e.g., professor's speech) to be played over the computer speaker.

The method of presenting the clinical information has been changed. To illustrate the changes, Table 7 shows the differences between Patient Simulator and IMMELDA for the first three steps of the user-system interaction.

Patient Simulator	
true:	diarrhea(0) dry mouth(2) on previous treatment(1) refusal to eat(0) vomiting(0) age(13 months, 2) behaviour(normal, 2) blood pressure(low, 2) bowel movement(normal, 1) (.....)
IMMELDA	
presenting complaint:	55 year old female presented with on set of severe shortness of breath (SOB) last 2 days runny nose, cough and sputum production last 4 days history of past illness: dyspnea: - patient states that she has this shortness of breath (SOB) last 10 years and this SOB increased in last 3 years (.....)
general exam:	sick, anxious looking lady suprasternal in drawing/use of sternocleidomastoid and intercostal retraction afebrile blood pressure(140/70 mm of Hg) (.....)

Table 7. Clinical information display in Patient Simulator and IMMELDA

The new information presentation separates the clinical information from the test or examination selected by the user. This significant improvement provides the system with

the flexibility to modify the information display; the case writer may change and adapt the display according to the particular requirements which was not possible in the previous versions of the prototype (The particular requirements were provided by the students and the physicians). The presentation should begin from present complaint, personal history, family history, followed by the results of tests. If the result of action(s) should be displayed according to the test or examination, the information display will follow the name of the test or examination.

Related to information presentation, two questions which did not provide any useful information in terms of case management, and, in fact, were misleading for the test users, were removed. These questions are needed if the system is used for decision support but not for training and education. These two questions are: “Are you satisfied with generated position” and “Are you willing to change your goal tree”. The present version (or prototype III) allows for customization of the interface for a specific purpose. In IMMELDA, the two questions were removed. Table 8 summarizes the states of the Patient Simulator of 1993 and IMMELDA of 1995.

	PATIENT SIMULATOR (Version 4)	IMMELDA (PROTOTYPE III)
NEGOPLAN VERSION	2.1g	2.3k
MEDICAL CASE	Three	Six
	Easier to write and debug	Packets
	Random case selection and random selection of Some parameters	No changes
START UP PROCEDURE	Complicated	Simplified
MEDIA	Text, windows	Audio and visual capability added
WINDOWS	Predefined	Customized
INFORMATION PRESENTATION	All clinical information under 'True' notation	Clinical information under test/exam
PROMPTS AND QUESTIONS	Default	Irrelevant prompts removed and replace with appropriate questions
HEADINGS	Default	Customized
ADDITIONAL FEATURES	N/A	Help button and menu added Explanatory messages added

Table 8. An overview of the states of Patient Simulator of 1993 and IMMELDA of 1995

6.0 Conclusions

The main objectives of the study were: (a) to develop testing and evaluation instruments, to identify the interface weaknesses and areas for improvement, and to elicit information regarding them; (b) to select the design principles from the existing literature and adapt them to this research; (c) to test and evaluate research instruments for the implementation of the customer-centered approach; (d) to evaluate the development process for a medical training system and; (e) to assess the applicability of the user-centered approach to CAI in medicine.

6.1 Summary of Experience: Problems and Solutions

This section will present a summary of the experience gained from the study. The problems encountered in the study will be discussed and the solutions will also be presented. The section will also answer the main research questions listed in Chapter 4.

This research depends heavily not only on the responses from the test users but also the availability of the technology (i.e., multimedia) and programming resources. Therefore, some of the questions could not be fully addressed; however, the research components were.

The user-centered development process was used to develop the user interface and evaluate IMMELDA. Based on the feedback received from the students and physicians, IMMELDA has been significantly improved over previous versions.

Throughout the research, the set of guidelines in Table 2 was also followed. Since the set of guidelines is very comprehensive, during the three interface development iterations the

focus was only on user-centered design, consistency and simplicity, feedback, system messages, getting the user's attention, display issues, and individual user differences.

The first research question referred to the advantages and disadvantages of the user-centered development approach. It was found that solely focusing on users' needs can lead to continuous interface development iterations as users learn and make mistakes with the system. Focus on users' needs is, thus, a major disadvantage, as the interface from the process may satisfy the users but may not provide the best learning experience for them.

An advantage of this approach is the findings of the routine of the general physician which is outlined below:

- interaction with the patient;
- examining the patient's medical, family, and social history;
- ordering tests to further examine the patient;
- hospitalizing the patient if necessary;
- producing a final diagnosis;
- giving interim treatment(s) to the patient; and,
- referring the patient to other specialists if necessary.

All of these activities were simulated by IMMELDA. Another advantage of the user-centered development approach is the possibility to cater to the users' needs as that is the main focus of the approach. Also, the interface of IMMELDA has been enhanced. The windows are organized in a way that allows for easy access. The depth of the medical cases has been increased and more details regarding a patient's history, conditions, tests and examinations have been added.

This research also found that medical students and physicians disagree with the procedure in IMMELDA when they made unrecoverable errors. If they make a mistake, they prefer to go back to the step preceding the mistake and try again. This explains why they do not like the simulation session to end when they perform incorrect procedures. Students also dislike the negative feedback such as “this treatment is not correct”. When students obtained the message from the system stating that their actions are illogical but were given no explanation, they were frustrated and questioned why. Accordingly, IMMELDA incorporates a new feature, namely explanatory feedback. Every time a user selects an illogical test/examination, the system presents a message to explain why it is not logical to perform the action. The system does not allow the user to continue unless a correct action is selected.

Regarding question 2 on how one determines users’ perceptions of the system, this research found that applying a user-centered approach with usability testing can explore users’ perceptions of the system and its usability. Users’ perceptions surfaced through the experiment as they verbalized the details of interaction between them and the system. Through the questionnaires quantitative measures of the system’s usability were also taken.

The main characteristics of the system that were attractive to the users, as referred to in Question 3, were the multimedia feature and case-study format. During the experiments, the medical students were impressed by the capabilities of IMMELDA for showing audio-visual materials such as X-rays. The medical students indicated that it is important to visualize some of the patient information. Significant portions of the patient information are indeed presented in visual (or audio) form (i.e., X-ray or heartbeat) in actual clinical environments.

Throughout the research, minor procedural differences were found between hospitals. Students in both the Ottawa General Hospital and Montreal General Hospital explained the general procedures of patient care during the experiments. There are differences in the procedures such as the availability of a test result. This information can be helpful for the further development of IMMELDA, especially if IMMELDA is aimed at being a learning aid for medical students across Canada.

The participation of developers (Drs. Kersten and Chaturvedi) as observers in the experiment was also found to be critical. Problems which are not obvious to developers can be found through observation. One good example is the position of the dialogue box which allows the user to select appropriate actions. The dialogue box was in the middle of the screen and covered part of two windows which were behind it. Users did not know what to do in order to read the information in the two windows. As the developers were already familiar with the system, they knew that simply clicking on a window would make it appear in front of the dialogue box. Although the problem with the position of the dialogue box was found in the first testing, developers were not convinced that it was a problem, until they saw users struggling with the dialogue box in the second testing⁶.

Throughout this research, the general procedures of the physician, the characteristics of the system that users found attractive and the unobvious characteristics of the users were discovered. The participation of developers in the experiment as observers was an important element in the user interface design process.

⁶During the testing, Dr. Kersten and Dr. Chaturvedi were surprised that users had difficulty with the dialogue box.

Different kinds of difficulties were also encountered. Based on the researcher's experience, some issues should be addressed if the development process is to be repeated.

Physicians who were involved in the IMMELDA project are like the researcher who went through a learning curve for the system development. The researcher learned a lot as the research progressed. Similarly, the physicians gained experience as the project progressed. At the beginning of the research, the physicians were not clear as to how they would like the system to work or how it could be developed. Between two design meetings, the physicians' requests were often contradictory. Such a learning process should be recognized.

In the first testing (prototype I), all students commented that the clinical information in the case was inadequate and unclear. As a result, the amount and quality of clinical information was improved in the next two prototypes. In the last test, students had mixed opinions regarding the clinical information. At this stage, students may not be the best people to judge the information as they may not know what they want. Physicians should have the responsibility in deciding the clinical information for each case.

The research found that students did not like to learn from a mistake which led to the death of a patient. Although the death of a patient is not common as a result of physician care management, inappropriate actions can definitely jeopardize a patient's life. Under the user-centered approach, end-users' needs are the focus. However, removal of a possible patient's situation (death as a result of inappropriate action) from a system causes the simulation to become utterly unrealistic. What students like may not be the best learning experience. If one of the goals of a CAI system is to simulate the real life patient-physician interaction, a trade-off between the preference of the students and the realism of the simulation should be made.

This implies that the user-centered approach should be carefully applied as there may be situations where users have to learn through their mistakes. If the user-centered approach is uncritically used, the focus of users' needs will be the major disadvantage of this approach.

The research process was centered around the students' needs and wants. This is, indeed, the disadvantage of user-centered approach. The problem is also that for the users to be familiar with the system, its training method, and so on for a period of time. One half hour experiment does not provide enough time. Some users should not only test the system and answer questionnaires but also participate in the development process. The selected users should be responsible to provide solutions to the problems found in the system.

Question 4 referred to the appropriate development process and the level of involvement of the domain experts and users. Some users, as just discussed, should be part of development process and provide solutions to develop the system. It also was found that physicians should play major role in interface development. Physicians are the domain experts to provide medical expertise and they are also one kind of users who use the system to aid in their teaching. Physicians should be responsible for making decisions on what features or characteristics of a system should be used.

Other difficulty encountered in this research is that there was not much support from the physicians in obtaining audio-visual materials and assisting in recruiting students. Although different hospitals had been approached, it was still difficult to obtain pictures through the departments in the hospital. This may be due in part to the need for maintaining patient confidentiality.

On the other hand, lack of student support could be attributed to recruitment problems and a lack of interest. At times students were recruited at an inappropriate time (i.e., close to

examinations or summer term) or the recruiting notice failed to reach all the potential students.

Having to work with busy physicians' and students' schedules was problematic. During the summer, it was relatively difficult to recruit students even though they studied three terms a year. A lot of students went on exchange programs in the summer. The exchange program provides the students with the opportunity to go to other cities (e.g., Toronto and Montreal) or other countries (e.g., Germany and England) and study medicine for one term.

The final research question referred to the usefulness of the system for business education. Although a business simulation is not developed, the work on IMMELDA and its interface can be applied to other problem solving systems. IMMELDA is an adaptation of the Negoplan system for training. It simulates a patient's behavior in response to a physician's actions. Negoplan also allows for the representation of external entities which contribute to the behavior of the simulated entity. Thus, it is possible to use the Negoplan system to simulate a business environment, (i.e., a company as the simulated entity, the market as the external entities, and the manager/executive as the user of the system). A company simulation can be developed for teaching problem solving in business education.

6.2 Benefits

This research has demonstrated both the benefits and limiting features associated with the project development and application of IMMELDA.

The methodology for the development of IMMELDA can be applied to other medicine-related CAI systems such as nursing. First, the general task of a nurse needs to be defined through interviews with the domain experts (i.e., nurses and physicians). After the

knowledge is acquired, the knowledge presentation and case development can be performed. All these steps can be carried out as in the case development process previously explained. At the same time, user interface design can also proceed as previously presented in the interface development process.

Furthermore, the results allow for the adaptation of IMMELDA to business and management education. Business education is similar to medical education. One of the most important issues in business education is helping students develop problem solving skills. The accommodation of IMMELDA can be used for teaching analytical and decision making skills. The multimedia graphical interface can motivate students to use computer-based technology which is widely utilized in the industry.

This research can be also applied to other CAI development. However, as the technology keeps changing, the research has to be modified according to new scenarios. For example, there is a new environment for CAI -- the Internet. User can access the CAI (i.e., patient simulation) through the Internet, for example, the World Wide Web. Under that environment, interface design is different from that for regular standalone computer environment (PC or Macintosh). Guidelines for building CAI in the Internet environment should be consulted.

In addition, the new interface allowed for more comprehensive system testing and evaluation of IMMELDA. This led to changes in case developments. Now, a proper case development process has been developed. The case development process can be applied to develop more medical cases. Since the present medical cases are limited to the area of the gastrointestinal system, it is necessary to enhance the scope of the system or the depth of gastrointestinal cases for further development of IMMELDA.

6.3 Limitations

This research suffered from the system testing. The system was tested by the users - medical professionals, including the physicians and medical students. For instance, the medical students volunteered to participate in the testing, and were obviously interested in the CAI system. Those students who did not test the system were either not interested or did not have time to participate. Consequently, the results of system testing might not completely represent all perspectives of potential system users.

However, it is unreasonable to assume that all the system users will participate in the testing. All the students who participated in the testing were senior medical students in third or later years, and they represent the target population of IMMELDA's users. Therefore, those participants are representative test users and the observations can be generalized to the bulk of potential users.

Additionally, those students who participated in the experiment with prototype I could not be recruited to participate again after the prototype II had been made. During the prototype I experiment, all students signed the participation form (see Appendix H) and agreed to participate in future experiments. Unfortunately, when the prototype II was ready, none of those students were able to participate. If those students had participated in the experiment, the results of two experiments could have been directly compared and the users' perceptions of the system and its usability could have been further examined.

Physicians as experiment participants are critical. During the research, physicians' participation in the system development was limited to the provision of their expertise for the case development. Physicians are the decision makers in the project. Their opinions affect the content and working of IMMELDA. Physicians' involvement might have been

enhanced if the prototype could also be evaluated by physicians other than those involved in the project. More subjective feedback could be elicited. The ideal physicians are those who teach courses regularly and have more daily contact with students. This can ensure that the prototype fulfills teaching requirements.

6.4 Future Research

Based on the researcher's experiences, feedback from the students and physicians, and from the observation of other medical educational software, potential research agendas are presented.

IMMELDA's impact on medical students' learning must be established by conducting a comparison experiment involving two student groups. The students will be divided into two experiment groups for a quiz. Students in the control group will only use their references and textbook to prepare for their test. The test group will use both textbooks and IMMELDA. The results of the test between these two groups can be compared to determine whether IMMELDA has an impact on the results of the quiz.

In addition, to obtain more complete and accurate information regarding users and their preferences towards simulation, a survey can be conducted in the computer laboratory at the Medical Education Center, Ottawa Civic Hospital. In the laboratory, there is advanced computer equipment with many medical education software packages which are available in the market. Students are encouraged to use these software packages to enhance their knowledge.

A questionnaire can be given to each of the students to rate their opinion on the software used. Information can be obtained on what they liked or disliked and the reasons for their preferences. A variation of the above suggestion is to provide the questionnaire on the

computer. When a student has worked with a software package, she completes the questionnaire.

As technology continues to advance, the keyboard and mouse are not the only input devices of systems. Voice can also be applied as an input for the systems. For future research, IMMELDA can incorporate voice recognition; it allows users to verbalize their input commands instead of using the mouse. The impact of voice input on IMMELDA's interface can be examined.

Last but not least, IMMELDA can be developed into a virtual reality. IMMELDA is a patient simulation system for diagnostic and treatment skills training of medical students. By applying the virtual reality concept, the realism of IMMELDA simulated patient-physician interaction may be increased.

6.5 Concluding Remarks

A user-centered development approach has been applied to interface development for the design and evaluation of IMMELDA. It has been found that the approach has enhanced IMMELDA's interface. It has also found that the level of users' involvement should be greater. Based on user feedback, this approach can be further improved through more research as just discussed.

In summary, the main findings of this research are:

1. There are two types of users for IMMELDA - - medical students and physicians;
2. The user-centered approach can be problematic when more than one type of user is involved in interface development process.

3. Without proper criteria for a satisfactory interface for users, user-centered approach can be an endless process in trying to fulfill user satisfaction.

The approach to interface development can be improved through the following suggestions:

- All possible needs of users should be determined.
- The tasks and responsibilities of all parties involved in the project should be clearly defined.
- Developers should make decisions on the technical aspects of the interface.
- Domain experts should make decisions for the content of the interface (e.g., in the IMMELDA scenario, physicians should decide the content of the medical cases.)
- The responsibility of test users should be increased. Selected test users should not only participate in the user testing but should also be involved in the user design phase regarding input of opinions.
- Reduce the continuous attempts to fulfill users' needs by making a trade-off among the following variables: time frame of the project, cost of production, user satisfaction, and appropriate learning for the user.
- The interface development process requires good project management from a project leader.

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Appendices

Appendix A. Research Outline for Carleton University Ethics Committee

User Interface Design for Medical Student Training System

Research Outline for Carleton University Ethics Committee

Purpose of the Research

The purpose of this research is to test a patient simulation system; a computer aided instruction system for medical training. This research is a part of a larger project sponsored by the Natural Sciences and Engineering Research Council and the Max Bell Foundation to develop, test and deploy a patient simulator. The initial field testing and deployment will take place at the University of Ottawa Faculty of Medicine and the Children Hospital of Eastern Ontario.

This patient simulation system is currently at the prototype stage and it needs to be thoroughly tested by its prospective users -- the medical students. An important part of the testing involves user interface. The development of an easy to use and user friendly interface requires active involvement of the future users. Their suggestions and comments need to be elicited. This is the aim of the testing and it will provide the basis for further development of the prototype. In addition, the information from the participants may be used in the development of other similar computer aided instruction for education and training in other areas than medicine.

The aim of the testing exercise is to find the strengths and weaknesses of the system and especially its interface. The objective of this research is to test the system and not the users.

Process for Obtaining Informed Consent

The prospective participants for the testing of the patient simulation will be third year or higher medical students who are enrolled in the School of Medicine, University of Ottawa. A brief description of the research (see Appendix 1) will be given to University of Ottawa medical school professors to read at their classes. Persons who are interested in participating will be required provide complete information on a sign-up sheet. Sign-up sheets will be available from professors as well as they will be posted at the Roger

Guindon Hall (University of Ottawa). Each sign-up sheet will be approved by Dr. J. Turnbull, Assistant Dean (Education) of the Faculty of Medicine (see Appendix 1). The deadline for putting name on a sign-up sheet is January 6, 1995. Each person will receive an honorarium of \$10 for full participation. The funds for this project are obtained from a grant awarded to Drs. Rubin, Kersten, Szpakowicz and Turnbull by the Max Bell Foundation.

In order to ensure voluntary participation, each prospective participant will be given a Participant Information Sheet and Consent Form (see Appendix 2). These will be given prior to the start of the testing exercise. The consent form has to be signed to enable participation. Any questions regarding the research in general, and the testing in particular will be answered at this time.

Research Instruments

Each participant will be given a case of a sick child in the emergency room setting and will be required to interact with the patient simulation system to make diagnostic and treatment decisions. One participant at a time will perform the testing. An estimated twenty five testing sessions will be held in three or four groups. After each group the interface of the patient simulation system will be re-evaluated and modifications made. During the testing, participants will be encouraged to verbalize their thoughts about the system. An observer will take notes on participants' verbal protocol.

After completing the testing, participants will be asked to fill out a questionnaire (see Appendix 3). This will be used to ascertain information on participants' opinion of the system as well as general demographic information.

The entire exercise (testing and answering of questionnaire) is estimated to take between 45 and 60 minutes.

Means of Ensuring Confidentiality

Participants will be identified only by a subject number. The subject number will also be used on the questionnaire. The master list of participants and associated subject number will be kept in a locked cabinet. Only the principal researcher will have access to this

cabinet. No member of the thesis committee will have access to this information. In addition, subject numbers will not be used in reporting the findings of this research.

Risks and Benefits

There are no known risks to participants.

A direct benefit to participants will be the experience of using one of the most current medical educational tool, a computer-based patient simulator. A long term benefit will be the participants' contribution to further develop the prototype into a more effective and easy to use system. Thus, they will be contributing to the advancement of medical education.

Dissemination of Results

A summary of the research results will be compiled and be made available to participants upon request. Given that this research is part of a master thesis in the School of Business, a copy of the thesis will be placed in the School of Business and the MacOdrum Library at Carleton University. A copy of the thesis will also be given to the Library of the Faculty of Medicine of the University of Ottawa. Those interested in the research may access a copy of the thesis from either of the three locations previously named or from the principal researcher.

Appendix B1. Sign-up Form I**Patient Simulation**

EXPERIMENT TITLE:	Medical Training System - Prototype Testing
EXPERIMENTERS' NAME & RM #:	Stephen Chow & Dr. J. Tolmie, Rm 2137, Roger Guidon Hall
EXPERIMENTER'S PHONE NO.:	788-2600 ext. 1816
LOCATION OF EXPERIMENT :	Room 2137, Roger Guidon Hall
FACULTY ADVISOR:	Drs. G.E. Kersten, S. Rubin & J. Turnbull

Brief Description

The purpose of this research is to develop and test a patient simulation system, which is a computer aided instruction being used as a medical education tool. It will be used to train and test medical students in diagnostic and treatment skills.

The patient simulation system is still a prototype. The prototype falls in the "Sick Child In The Emergency Room" domain. Testing of the prototype will require participants to perform a medical case analysis. That is, they will be given a list of the patient's current symptoms and diagnostic options to choose from. At the end of the testing session, participants will be asked to fill out a questionnaire. The entire exercise (testing and questionnaire) is estimated to take between 45 and 60 minutes.

A Patient Simulation is a computer aided instruction (CAI) which is being used in the training of medical students. It was developed in collaboration with Carleton University, University of Ottawa, and the Children Hospital of Eastern Ontario. This training tool will provide medical students with various symptoms and a list of diagnostic options. The advantage of this system over other traditional training methods is that it enables them to

develop their problem solving skills by learning from their mistakes without any detrimental effects since they will not be using human subjects.

The aim of the testing exercise is to find the strengths and weaknesses of the system. We are testing the system **NOT** the user. At the end of the testing, participants will be asked to fill out a questionnaire. The whole exercise (testing and answering of questionnaire) is estimated to take between 45 and 60 minutes.

We are looking for third year or higher medical students. Each person will receive an honorarium of \$10 for full participation.

If you are interested in participating please complete the sign-up sheet either from your professor or at the Roger Guidon Hall. The deadline for putting your name on a sign-up sheet is January 6, 1995. You will be contacted by telephone to set a convenient time for your participation.

Thank you for your help!

Appendix B2. Sign-up Form II

Patient Simulation

THE EXPERIMENT: The medical training system IMMELDA: testing the prototype

EXPERIMENTERS: Stephen Chow (Carleton University),
Tel. 788-2600 ext. 2373 or ext. 1816

FACULTY ADVISORS: Dr. S. Rubin (CHEO), Dr. J. Turnbull (Faculty of Medicine),
Dr. G. Kersten (Carleton University),
Dr. S. Szpakowicz (Department of Computer Science)

The purpose of our research is to develop and test the patient simulation system IMMELDA. IMMELDA has been developed jointly by Carleton University, University of Ottawa, and the Children's Hospital of Eastern Ontario. It is a computer-aided instruction system that will be used in medical education to help train and evaluate the diagnostic and treatment skills of medical students. It will provide a student with various symptoms and a list of diagnostic options, and the student will manage a simulated case. The advantage of IMMELDA over traditional training methods is that it helps develop problem solving skills by allowing the students to learn from their mistakes without detrimental effects to real patients.

The IMMELDA system is now at an advance prototype stage. It has to be used in a controlled classroom-like situation to help assess the quality of the medical knowledge and the presentation facilities, and to uncover possible weaknesses of the system. Note that it is the system that is being tested, *not* the user. The participants will analyze a medical case and relate their impressions to the experimenters. At the end of a testing session, they will be asked to fill out a questionnaire. The entire exercise (testing and completing the questionnaire) should take between 45 and 60 minutes.

We are looking for medical students in their third year or higher. Participation will be gratefully recognized, duly acknowledged and rewarded by a token amount of \$10. The experiment will take place between August 7 and August 9, in Roger Guindon Hall (Health Science Building), room 2137.

If you are interested in participating in the experiment, or you simply have questions, please call Stephen Chow at 788-2600 ext. 2373 or 1816 (daytime) or 594-8273 (night) and leave your name and phone number. A convenient time will be arranged for your participation.

Thank you very much for your time! The experiment is part of Stephen's research for a Master's degree, and he will greatly appreciate any help.

Appendix C. Letter of Room Request for Experiment

TO: Dr. G.A. Kinson

cc: Dr. J. Turnbull, Dr. S. Rubin, Dr. G.E. Kersten, Dr. S. Szpakowicz,
Dr. J. Tolmie

FROM: S. Chow

RE: Room Request For Software Testing

The study falls into 'Sick Child in the Emergency Room' area. The purpose of this study is to develop and test a computer system to be used as a medical education tool for the training and the testing of medical students in diagnostic and treatment skills.

The system is still a prototype. We are eliciting user comments and suggestions to improve and enhance the system and make it effective and easy to use. The aim of the testing session is to find the strengths and weaknesses of the system.

Dr. J. Turnbull (University of Ottawa), Dr. S. Rubin (CHEO), Dr. G.E. Kersten (Carleton University), Dr. S. Szpakowicz (University of Ottawa), Dr. J. Tolmie (Carleton University), S. Chow (Carleton University), and others are working on this project. Dr. Tolmie and I are responsible to carry out testing sessions which will be held at the designated room. Occasionally, Dr. Turnbull, Dr. Rubin, Dr. Kersten, and Dr. Szpakowicz will participate the testing sessions.

The participants for the testing session will be recruited on voluntary basis. Sign-up sheets will be posted around the campus including outside the experiment room. Each testing session will be expected finishing between thirty minutes to sixty minutes. At the end of a session, each participant will receive a small monetary award.

To avoid any disturbance during the testing session, an empty room is required. Only the participant and the testing examiners will be at the room. The schedule for testing will be given to Pierre Drouin in advance. An 'Experiment In Progress' note will be also posted

outside the door before each session starts. There will be no more than five testing sessions per day. The whole process is expected finishing by the end of April 95.

Appendix D. Consent Form for Experiment Participation**Medical Training System - Prototype Testing****Consent Form**

I have read the Participant Information sheet, and agree to participate in the Medical Training System - Prototype Testing. I understand that any information I provide is completely confidential and will be used for research purpose only. If there is any scores for the testing session, such information will not be publicly identifiable in any way, nor will they play any part in the evaluation by the Faculty. I further understand that I am free to withdraw from the testing at any time.

Signature

Name (Please print)

Date

Appendix E. Experiment Introduction

Medical Training System - Prototype Testing

Participant Information

Sick Child in the Emergency Room

The purpose of this research is to develop and test a patient simulation system, which is a computer aided instruction being used as a medical education tool. It will be used to train and test medical students in diagnostic and treatment skills.

This patient simulation system is still a prototype. The prototype falls in the "Sick Child In The Emergency Room" domain. Testing of the prototype will require participants to perform a medical case analysis. That is, you will be given a list of the patient's current symptoms and diagnostic options to choose from. At the end of the testing session, you will be asked to fill out a questionnaire. The entire exercise (testing and questionnaire) is estimated to take between 45 and 60 minutes.

The aim of the testing exercise is to find the strengths and weaknesses of the system. We are testing the system NOT the user. Hence, you will be asked to verbalize your opinions about the system throughout the testing. In addition, you are encouraged to comment freely about the questionnaire. All information provided will be confidential and will only be used for research purposes. You are free to withdraw from the testing exercise at any time. Each person will receive an honorarium of \$10 for full participation.

Your feedback is very important as the information you provide will be used to further develop the prototype. Further, you will be contributing to the advancement of medical education.

If you have any questions or comments about the research and testing, please contact Stephen Chow at the School of Business, Carleton University, 788-2600 ext. 1816 or Dr. Gregory Kersten (Thesis Supervisor) at 788-2388. A summary of the research results will be compiled and be available to participants upon request.

Thank you for your help!

Appendix F. Questionnaire I

Prototype Testing Questionnaire

Please check ✓ one box for each question:

User-Computer Interaction

1. How would you rate the complexity of the system?

Very
Simple
☐

Simple
☐

Neither Simple
nor Complex
☐

Complex
☐

Very
Complex
☐

2. Did you like using mouse as an input device?

Like
Extremely
☐

Like
☐

Neutral
☐

Dislike
☐

Dislike
Extremely
☐

3. How would you rate the options provided in the menus?

Very
Appropriate
☐

Mostly
Appropriate
☐

Undecided
☐

Not Very
Appropriate
☐

Not At All
Appropriate
☐

4. How easy was it to understand the clinical information?

Very
Difficult
☐

Difficult
☐

Neither Easy
nor Difficult
☐

Easy
☐

Very
Easy
☐

5. How would you rate the amount of information you were given?

Very
Inadequate
☐

Mostly
Inadequate
☐

Undecided
☐

Mostly
Adequate
☐

Very
Adequate
☐

Comments:

Graphics

6. How would you rate the layout of the screen?

Very Poor
☐

Poor
☐

Average
☐

Good
☐

Excellent
☐

7. How useful were the pictures and video clips you were shown?

Very Useful
☐

Somewhat Useful
☐

Occasionally Useful
☐

Somewhat Useless
☐

Totally Useless
☐

8. How would you rate the control of the pictures and video clips?

Very Flexible
☐

Somewhat Flexible
☐

Undecided
☐

Somewhat Rigid
☐

Very Rigid
☐

Comments:

Case Management

9. Did you like the way you brought up a new case?

Like Extremely
☐

Like
☐

Neutral
☐

Dislike
☐

Dislike Extremely
☐

10. How accurate was the medical information provided by the system?

Accurate Less Than
20% of the Time
☐

20% to
40%
☐

40% to
60%
☐

60% to
80%
☐

Accurate Over
80% of the Time
☐

Undecided
☐

11. How realistic was the exercise in terms of case management?

Very Unrealistic
☐

Somewhat Unrealistic
☐

Undecided
☐

Somewhat Realistic
☐

Very Realistic
☐

Comments:

Further Development

12. Do you think an aid (e.g., references to textbooks and other educational materials) should be added to this system?

Definitely Yes	Yes	No Opinion	No	Definitely No
☐	☐	☐	☐	☐

13. Do you think the system should evaluate your performance? (e.g., a score will be given based on the way you manage the case)

Definitely Yes	Yes	No Opinion	No	Definitely No
☐	☐	☐	☐	☐

Comments:

Educational Aspect

14. Is this system appropriate for teaching diagnostic skills to medical students?

Not At All Appropriate	Not Very Appropriate	Undecided	Mostly Appropriate	Very Appropriate
☐	☐	☐	☐	☐

15. Is this system appropriate for teaching treatment skills to medical students?

Not At All Appropriate	Not Very Appropriate	Undecided	Mostly Appropriate	Very Appropriate
☐	☐	☐	☐	☐

16. Do you think the use of the system would be appropriate for performance evaluation instead of the multiple choice test now used?

Very Appropriate	Mostly Appropriate	Undecided	Not Very Appropriate	Not At All Appropriate
☐	☐	☐	☐	☐

17. Would you use this system as a self-evaluation tool for diagnostic skills?

Definitely Yes	Yes	No Opinion	No	Definitely No
☐	☐	☐	☐	☐

18. Do you think this system is appropriate for group study?

Not At All
Appropriate ☐

Not Very
Appropriate ☐

Undecided ☐

Mostly
Appropriate ☐

Very
Appropriate ☐

19. Where would you prefer to use this system? (Please check all that apply)

Home ☐
Hospital ☐
Medical Library ☐

University ☐
Other, please specify _____

Prefer Not To Use ☐

Comments: _____

Demographic Information

20. At what faculty are you currently enrolled?

Arts ☐
Medicine ☐
Science ☐

Social Science ☐
Other, please specify _____

21. What year are you in?

Third ☐
Fourth ☐
Other, please specify _____

Graduate ☐
Post graduate ☐

22. What is your area of specialization?

23. What is your gender?

Male ☐

Female ☐

24. How do you rate yourself as a computer user?

a novice ☐
an intermediate ☐

an expert ☐

25. Have you ever used computer assisted instruction?
 No ☐ Yes ☐

26. What is your age?

under 22	☐	33 - 37	☐
23 - 27	☐	38+	☐
28 - 32	☐		

27. In general, did you like using the system?

Like Extremely	Like	Neutral	Dislike	Dislike Extremely
☐	☐	☐	☐	☐

What did you like or dislike about the system?

Comments:

Are there additional comments you would like to make about the system?

Thank you for your cooperation and assistance

Appendix G. Questionnaire II

Prototype Testing Questionnaire

Please circle one number for each question unless specify:

User-Computer Interaction

1. How would you rate the use of the system?	Complex
1	2	3	4	Simple
5
2. How would you rate the options provided in the menus?	Inappropriate
1	2	3	4	Appropriate
5
3. How easy was it to understand the clinical information?	Difficult
1	2	3	4	Easy
5
4. How would you rate the amount of information you were given?	Inadequate
1	2	3	4	Adequate
5
5. How would you rate the help function & Help menu provided?	Dislike
1	2	3	4	Like
5

Comments:

Graphics

6. How would you rate the layout of the screen?	Poor
1	2	3	4	Excellent
5
7. How useful were the pictures you were shown?	Useless
1	2	3	4	Useful
5
8. How would you rate the control of the pictures?	Rigid
1	2	3	4	Flexible
5

Comments:

Case Management

9. Did you like the way you brought up a new case? Dislike 1 2 3 4 Like 5
10. How realistic was the exercise in terms of case management? Unrealistic 1 2 3 4 Realistic 5
11. Is this system appropriate for teaching diagnostic skills to medical students? Inappropriate 1 2 3 4 Appropriate 5
12. Is this system appropriate for teaching treatment skills to medical students? Inappropriate 1 2 3 4 Appropriate 5
13. How accurate was the medical information provided by the system? (Please check one)
Accurate Less Than
20% of the Time	20% to
40%	40% to
60%	60% to
80%	Accurate Over
80% of the Time	Undecided
☐	☐	☐	☐	☐	☐

Comments: _____

Others Aspect

14. Do you think this system is appropriate for? (Please check all that apply)

Group Study ☐ Self-evaluation Tool ☐

Performance Evaluation (instead of multiple choice tests) ☐

Other, please specify _____

None of above ☐

15. Where would you prefer to use this system? (Please check all that apply)

Home ☐ Hospital ☐ University ☐

Medical Library ☐ Other, please specify _____

Prefer Not To Use ☐

16. How do you rate yourself as a computer user?

a novice ☐ an intermediate ☐ an expert ☐

17. Have you ever used computer assisted instruction / patient simulation system?
(Please check one)

No ☐ Yes ☐

18. In general, did you like
using the system?

Dislike Like
1 2 3 4 5

What did you like or dislike about the system?

Comments:

Are there additional comments you would like to make about the system?

Thank you for your cooperation and assistance

Appendix H. Future Participation Form**Medical Training System - Prototype Testing****Participation Form**

Thank you for your participation. Would you be willing to participate in another testing in the future?

Yes ☐

No ☐

If yes, please complete the following:

Name: _____

The best time to contact you _____

Tel: (Day) _____

(Evening) _____

Thank you for your cooperation and assistance !

Appendix I. Summary of Testing I Results

User-Computer Interaction

1. How would you rate the complexity of the system?

Response	Very Simple	Simple 1	Neither Simple nor Complex 5	Complex	Very Complex
----------	-------------	-------------	------------------------------------	---------	--------------

2. Did you like using mouse as an input device?

Response	Like Extremely 3	Like 2	Neutral 1	Dislike	Dislike Extremely
----------	------------------------	-----------	--------------	---------	----------------------

3. How would you rate the options provided in the menus?

Response	Very Appropriate	Mostly Appropriate 4	Undecided 2	Not Very Appropriate	Not At All Appropriate
----------	---------------------	----------------------------	----------------	-------------------------	---------------------------

4. How easy was it to understand the clinical information?

Response	Very Difficult	Difficult 1	Neither Easy nor Difficult 3	Easy 2	Very Easy
----------	-------------------	----------------	------------------------------------	-----------	--------------

5. How would you rate the amount of information you were given?

Response	Very Inadequate	Mostly Inadequate 2	Undecided 1	Mostly Adequate 3	Very Adequate
----------	--------------------	---------------------------	----------------	-------------------------	------------------

Section Commented by: all six subjects

Graphics

6. How would you rate the layout of the screen?

Response	Very Poor	Poor	Average 4	Good 2	Excellent
----------	-----------	------	--------------	-----------	-----------

7. How useful were the pictures and video clips you were shown?

	Very Useful	Somewhat Useful	Occasionally Useful	Somewhat Useless	Totally Useless
Response (two blank)	3	1			

8. How would you rate the control of the pictures and video clips?

	Very Flexible	Somewhat Flexible	Undecided	Somewhat Rigid	Very Rigid
Response (one blank)	2	1	2		

Section Commented by: four subjects

Case Management

9. Did you like the way you brought up a new case?

	Like Extremely	Like	Neutral	Dislike	Dislike Extremely
Response	1	1	4		

10. How accurate was the medical information provided by the system?

	Accurate Less Than 20% of the Time	20% to 40%	40% to 60%	60% to 80%	Accurate Over 80% of the Time	Undecided
Response				2	1	3

11. How realistic was the exercise in terms of case management?

	Very Unrealistic	Somewhat Unrealistic	Undecided	Somewhat Realistic	Very Realistic
Response		1	1	4	

Section Commented by: all six subjects

Further Development

12. Do you think an aid (e.g., references to textbooks and other educational materials) should be added to this system?

	Definitely Yes	Yes	No Opinion	No	Definitely No
Response	1	5			

13. Do you think the system should evaluate your performance? (e.g., a score will be given based on the way you manage the case)

	Definitely Yes	Yes	No Opinion	No	Definitely No
Response	3	2	1		

Section Commented by: four subjects

Educational Aspect

14. Is this system appropriate for teaching diagnostic skills to medical students?

	Not At All Appropriate	Not Very Appropriate	Undecided	Mostly Appropriate	Very Appropriate
Response			1	3	2

15. Is this system appropriate for teaching treatment skills to medical students?

	Not At All Appropriate	Not Very Appropriate	Undecided	Mostly Appropriate	Very Appropriate
Response			1	4	1

16. Do you think the use of the system would be appropriate for performance evaluation instead of the multiple choice test now used?

	Very Appropriate	Mostly Appropriate	Undecided	Not Very Appropriate	Not At All Appropriate
Response	2	2	1		1

17. Would you use this system as a self-evaluation tool for diagnostic skills?

	Definitely Yes	Yes	No Opinion	No	Definitely No
Response	3	3			

18. Do you think this system is appropriate for group study?

	Not At All Appropriate	Not Very Appropriate	Undecided	Mostly Appropriate	Very Appropriate
Response		3	1		2

19. Where would you prefer to use this system? (Please check all that apply)

	Home	Hospital	Medical Library	University	Other	Prefer Not To Use
Response	5	2	4	5		

Section Commented by: four subjects

Demographic Information

20. At what faculty are you currently enrolled?

All subjects are enrolled in Medicine.

21. What year are you in?

All subjects are in third year study.

22. What is your area of specialization?

All subjects are not in any area of specialization

23. What is your gender?

	Male	Female
Response	4	2

24. As a computer user, do you consider yourself as

	a novice	an intermediate	an expert
Response	3	2	1

25. Have you ever used computer assisted instruction?

	No	Yes
Response	1	5

26. What age range are you in?

All subjects are in the age range between 23 to 27

27. In general, did you like using the system?

	Like Extremely	Like	Neutral	Dislike	Dislike Extremely
Response	1	4	1		

This 'What did you like or dislike?' commented by: all six subjects

This 'Are there additional comments you would like to make about such a system?' commented by: four subjects

Appendix J. Summary of Testing II Results

User-Computer Interaction

1. How would you rate the use of the system?	Complex 1	2	3	4	Simple 5
Response: (3.8)			1	4	
2. How would you rate the options provided in the menus?	Inappropriate 1	2	3	4	Appropriate 5
Response: (3.2)		1	2	2	
3. How easy was it to understand the clinical information?	Difficult 1	2	3	4	Easy 5
Response: (4.2)		1		1	3
4. How would you rate the amount of information you were given?	Inadequate 1	2	3	4	Adequate 5
Response: (4)		1	1		3
5. How would you rate the help function & Help menu provided?	Dislike 1	2	3	4	Like 5
Response: (3.25)		1	2		1
1 N/A					

Comments: Three participants

Graphics

6. How would you rate the layout of the screen?	Poor 1	2	3	4	Excellent 5
Response: (4.2)			1	2	2
7. How useful were the pictures you were shown?	Useless 1	2	3	4	Useful 5
Response: (4.6)				2	3
8. How would you rate the control of the pictures?	Rigid 1	2	3	4	Flexible 5
Response: (3.75)		1		2	1
1 N/A					

Comments: Three participants

Case Management

9. Did you like the way you brought up a new case?

Dislike

1

2

3

4

Like
5

Response: (3.25)

1 N/A

1

1

2

10. How realistic was the exercise in terms of case management?

Unrealistic

1

2

3

4

Realistic
5

Response: (3.4)

2

2

1

11. Is this system appropriate for teaching diagnostic skills to medical students?

Inappropriate

1

2

3

4

Appropriate
5

Response: (3.4)

1

1

3

12. Is this system appropriate for teaching treatment skills to medical students?

Inappropriate

1

2

3

4

Appropriate
5

Response: (3.8)

2

2

1

13. How accurate was the medical information provided by the system? (Please check one)

Accurate Less Than
20% of the Time20% to
40%40% to
60%60% to
80%Accurate Over
80% of the Time

Undecided

Response:

1 N/A

1

2

1

Comments: One participant

Others Aspect

14. Do you think this system is appropriate for? (Please check all that apply)

Group

Self-evaluation

Performance Evaluation

Study

Tool

(instead of multiple choice tests)

Other

None of above

Response:

4

4

1

teaching

15. Where would you prefer to use this system? (Please check all that apply)

Home

Hospital

Medical Library

University

Other

Prefer Not To Use

Response:

3

3

4

2

16. How do you rate yourself as a computer user?

	a novice	an intermediate	an expert
Response:	3	2	0

17. Have you ever used computer assisted instruction / patient simulation system?
(Please check one)

	No	Yes
Response:	2	3

18. In general, did you like using the system?	Dislike					Like
	1	2	3	4	5	
Response:			2	1	1	
1 not sure						

What did you like or dislike about the system?

Comments: Two participants

Are there additional comments you would like to make about the system?

Two participants

Appendix K. Summary of Testing III Results

User-Computer Interaction

1. How would you rate the use of the system?	Complex 1	2	3	4	Simple 5
Response: (3.50)			2	2	
1 Between 2 & 3					
2. How would you rate the options provided in the menus?	Inappropriate 1	2	3	4	Appropriate 5
Response: (3.75)			1	3	
1 Between 2 & 3					
3. How easy was it to understand the clinical information?	Difficult 1	2	3	4	Easy 5
Response: (3.80)		1	1	1	2
4. How would you rate the amount of information you were given?	Inadequate 1	2	3	4	Adequate 5
Response: (4.00)			1	2	1
1 Excessive					
5. How would you rate the help function & Help menu provided?	Dislike 1	2	3	4	Like 5
Response: (3.50)		1		3	
1 Between 2 & 3					

Comments: Three subjects

Graphics

6. How would you rate the layout of the screen?	Poor 1	2	3	4	Excellent 5
Response: (3.00)		1	2	1	
1 Between 2 & 3					
7. How useful were the pictures you were shown?	Useless 1	2	3	4	Useful 5
Response: (4.00)			2	1	2
8. How would you rate the control of the pictures?	Rigid 1	2	3	4	Flexible 5
Response: (3.40)			3	2	

Comments: Four subjects

Case Management

9. Did you like the way you brought up a new case?

Dislike

Like
5

1 2 3 4

Response: (3.50)

2 2

1 N/A

10. How realistic was the exercise in terms of case management?

Unrealistic

Realistic
5

1 2 3 4

Response: (3.50)

2 2

1 Between 2 & 3

11. Is this system appropriate for teaching diagnostic skills to medical students?

Inappropriate

Appropriate
5

1 2 3 4

Response: (3.25)

1 1 2

1 Between 2 & 3

12. Is this system appropriate for teaching treatment skills to medical students?

Inappropriate

Appropriate
5

1 2 3 4

Response: (3.25)

3 1

1 Between 2 & 3

13. How accurate was the medical information provided by the system? (Please check one)

Accurate Less Than
20% of the Time20% to
40%40% to
60%60% to
80%Accurate Over
80% of the Time

Undecided

Response:

1 N/A

2 2 1

Comments: Five subjects

Others Aspect

14. Do you think this system is appropriate for? (Please check all that apply)

Group
StudySelf-evaluation
Tool

Performance Evaluation

(instead of multiple choice tests)

Other

None of above

Response:

3

4

2

teaching

15. Where would you prefer to use this system? (Please check all that apply)

Home

Hospital

Medical Library

University

Other

Prefer Not To Use

Response:

3

4

4

4

16. How do you rate yourself as a computer user?

	a novice	an intermediate	an expert
Response:	2	2	1

17. Have you ever used computer assisted instruction / patient simulation system?
(Please check one)

	No	Yes
Response:		5

18. In general, did you like using the system?	Dislike					Like
	1	2	3	4		5
Response:		(3 . 60)	2	3		

What did you like or dislike about the system?

Comments: Four subjects

Are there additional comments you would like to make about the system?
Two subjects

Appendix L. Glossary Terms

Acronyms

Test

CSF	Cerebro-spinal Fluid
ECG or EKG	Electrocardiogram
Echo	Echocardiogram
EEG	Electroencephalogram
ERCP	Endoscopic Retrograde Cholangiopancreatography
LP	Lumber Puncture
PFTs	Pulmonary Function Tests
SMA-7	Na ⁺ , K ⁺ , Cl ⁻ , HCO ₃ , BUN, Creatine, glucose

Illness

CHF	Congestive Heart Failure
MI	Myocardial Infarction
COPD	Chronic Obstructive Pulmonary Disease
GN	Glomerulo Nephritis
PND	Paraxysmal Nocturnal Dyspnea
SLE	Systemic Lupus Erythomatosus

Systems

CVS	Cardiovascular System
ENT	Ear, Nose, Throat
Chest	Respiratory System

Joints

IP	Interphalangeal
MCP	Metacarpophlangeal Joint
PIP	Proximal Interphalanged Joint

Miscellaneous

ABGs	Arterial Blood Gases
ALA	Antilymphocyte Antibodies
APA	Antiplatelete Antibodies
ASO	Antistreptolysin O Titres
AST	Asparate Amino-Transferase (or ALT)
BUN	Blood Urea Nitrogen
CABG	Coronary Artery Bypass Grafting
C ₃	Complement-3
CH ₅ O	Total Functional Hemolyte Complement
DLC	Differential Leukocyte Count
FEV ₁	Forced Expiratory Volume in one second
FVC	Forced Vital Capacity
FEV ₁ /FVC	Ratio of Forced Expiratory Volume in one second to Forced Vital

	Capacity
GB	Gall Bladder
GFR	Glomerulo Filtration Rate
Hb	Hemoglobin
HCO ₃	Bicarbonates
INR	International Rule Blood Coagulopathy
JVD	Juglovenous Distention
LDH	Lactic Dehydrogenase(Serum)
LVEF	Left Ventricular Ejection Fraction
MI	Myocardial Infarction
MCH	Mean Corpuscular Hemoglobin
MCHC	Mean Corpuscular Hemoglobin Concentration
MCV	Mean Corpuscular Volume
PTT	Partial Thromboplastin Time
PT	Prothrombin Time
RBC	Red Blood Cell
RV	Residual Volume
urobilirubinogen	Urine for Specific Bile Pigment
VC	Vital Capacity
WBC	White Blood Cell
TLC	Total Lung Capacity
BP	Blood Pressure
D/D	Differential Diagnoses List
HPI	History of Present Illness
H/O	History of
NAD	No Abnormal Detection
Pmx	Past Medical History
Pt	Patient
RR	Respiration Rate
SOB	Shortness of Breath
CK-MB	
CK-MM	Muscle
CK-BB	Brain (CNS)

blood pressure (140/90) 140 systolic, 90 diastolic

S₃ - Third Heart Sound (Rapid filling of blood)

- in children, soft, low pitched

- abnormal above age of 30 in presence of heart disease
occur .12 -.38 seconds after 2nd heart sound

LS₃ Left sided S₃ - due to Left ventricular disease of LVF
 Right sided S₃ - due to Right ventricular disease of RVF

LS₃ best heard at apex, on expiration

RS₃ best heard at lower left sternal border on inspiration, (Tricuspid area sometimes in right supra claviclar fossa)

S₄ - Fourth Heart Sound (Forceful contraction)

- preceded 1st heart sound (S₁)
- also called as atrial or presystolic gallop
- soft pitch (heard through bell)
- could be left or right (LS₄ or RS₄)

- LS₄**
- associated with presystolic apical impulse.
 - wax & wane with respiration (loud on expiration)
 - due to decrease compliance of left ventricle (AR, systemic hypertension, AS, cardiomyopathy Acute MI)
 - hyperkinetic circulatory effects (hyperthyroidism)

- RS₄**
- lower left sternal border
 - associated with lower left parasternal heave
 - decrease compliance of right ventricle
 - increase resistance to right ventricular filling (Pulmonary Hypertension, ASD, VSD, PDA, PE, Pulmonary Artery Stenosis, Cardiomyopathis)

Mean Corpuscular Hemoglobin:

Amount of Hemoglobin per RBC, n=26-34pg (pg=picogram)

Mean Corpuscular Hemoglobin Concentration:

Average volume of the RBC, n=80-100fL

Mean Corpuscular Volume:

How fully RBC (Erythrocyte) volume is filled with Hemoglobin :- $Hb / MCV \times RBC$
n=310-360gm/L

Appendix M. Detail Explanation for not hospitalization

COPD

The acidic state of patient (7.28 pH) with the degree of obstruction (FEV1 $\approx$ 18% and FEV1/FVC ratio only 33%) and history of previous admission indicate severity of disease and prompt examiner to be alert and admit the patient in hospital.

CHF

Patient needs hospitalization because looking at his general examination and history he has high Juglovenous Pressure/Distention (JVD) indicating failing state of his right heart along with the chest X-ray signs of severe congestion of lung fields causing oxygenation problem and breathlessness, collectively indicating a need for immediate attention.

Choledocolithiasis (Adult)

Patient needs hospitalization because her presenting signs and symptoms, history and general examination suggestive of some severe degree of physiological as well as anatomical problem in her hepatobiliary tract. We have seen that this patient has repeated attack of such pain in past but today presented not only with severe pain also with jaundice and dark colored urine indicating serious complication requiring specific detailed investigation. To visualize the tract we will have to perform some specific testing which require hospitalization, for example, ERCP.

Detail Explanation for incorrect specific tests:

Electrocardiograph (ECG or EKG)

This test is not sensible to perform in this case because EKG is a test to detect electrical activity of heart or cardiac muscle and used to diagnose abnormal heart or cardiac activity. In this given case, there is no any history or general or systemic examination finding suggestive of any abnormal heart activity.

Immunological Test

This test is not sensible to perform in this case because these tests are performed to detect circulating antibodies in blood to diagnose and to see activity of disease involving multiple systems in body as a result of deposition of pathogenic antibodies and their immune complexes. These antibodies are produced in body of patient and pathogenic immune complexes, coupled with feature to suppress.

Echocardiography

This test is not sensible to perform in this case because this tests is performed to record position and motion of the heart borders or walls and valves, to see flow of blood through these valves by reflected echoes of ultrasonic waves transmitted through the chest wall of patient. In this presented case there is not cardiovascular abnormality is presented on history as well as physical examination.

Liver Function Tests

This test is not sensible to perform in this case because this test is performed to detect any physiological abnormality in hepatobiliary system. In this presented case there are no clinical signs and symptoms on history and examination suggestive of any hepatobiliary or gastrointestinal system abnormality.

Renal Function Tests (Creatinine Clearance Test)

This test is not sensible to perform in this case because this test is performed to detect and see any abnormality in renal or kidney physiology. In this presented case there are no clinical symptomatology suggestive of any renal system abnormality.

Cerebro-spinal Fluid (CSF) / Lumber Puncture (LP)

This test is not sensible to perform in this case because lumber puncture is performed to collect cerebrospinal fluid to see any inflammatory process going on in central nervous system causing neurological state in patient. In the presented case there is no neurological sign and symptoms suggestive of abnormality in central nervous system.

Endoscopic Retrograde Cholangiopancreatography (ERCP)

This test is not sensible to perform in this case because this procedure is performed to visualize the abnormality in the biliary tract. In the presented case there is no any abnormal biliary or gastrointestinal abnormality or signs and symptoms suggestive of GI or biliary tract abnormality.

Pulmonary Function Tests (PFTs)

This test is not sensible to perform in this case because this test is specifically performed to detect obstructive or restrictive pattern of the disease of the lungs by interpreting graphics and values of different lung volumes and capacities. In this presented case there is no any pulmonary abnormal symptomatology seen.

Definition for the tests:

ALT: Alanine Aminotransferase (SGPT-GPT)

This is an intracellular enzyme involved in amino acid metabolism present in large concentration in liver kidney and a smaller amount in skeletal muscle and heart. These enzyme are released in extra cellular (Blood) compartment because of organ (tissue) damage.

For example, Hepatitis (Acute Viral) ALT > AST

Biliary Tract Obstruction (AST > ALT)

(Cholangitis, Choledocolithiasis)

AST: Aspartate Aminotransferase (SGOT/GOT)

This is an intracellular enzyme involved in amino acid metabolism. It is presented in liver, skeletal muscle, brain, red cells and heart. Release in blood in organ damage. This AST enzyme is increased during alcoholic liver cirrhosis (AST > ALT). Also during liver

abscesses metastasis, primary liver cancers and also in myocardial infarction, myopathis, muscular dystrophy, rhabdomyolysis, ischemic injuries, hypoxia.

LDH (Lactate dehydrogenase)

This enzyme is widely distributed in body cells and fluid. This enzyme catalyzes the interconversion of lactate and pyruvate in presence of NAD/NADH. The elevated serum level of enzyme are seen in tissue necrosis, acute cardiac muscle injury, skeletal muscle, various malignancies (carcinomas). Hemolytic anemia, polycythemia, obstructive jaundice, renal disease. False elevated levels are seen in hemolysed blood if collected inappropriately.

S. Alkaline Phosphatase

This enzyme is found in liver, bone, intestine and placenta and increased in obstructive hepatobiliary disease, hyperparathyroidism, bone-sarcoma and gastrointestinal disease like ulcers and bowel infarct.

Anti-nuclear Antibody (ANA)

These are heterogeneous antibodies against nuclear antigen, for example, DNA or RNA, histones and Non-Histonic Proteins

The high titres are found normally in old age (>65 years)

Increase in connective tissue disorder like SLE (98%), Rheumatoid Arthritis (approx. 50%), scleroderma (60%)

Mixed connective tissue disorder (100%), Sjoren's syndrome (80%)

presence of these antibodies support the SLE diagnosis to consider but negative ANA test does not completely rule out SLE

ASO - Antistreptolysin O Titres

These are the antibodies against antigen streptolysin O - produced by streptococci-A. These streptococcal antibodies appear in serum after 2 weeks of infection and titer rises till 4-6 weeks and remain elevated for 6 months to 1 year. It is measured quantitatively by

hemolytic activity of streptolysin-O toxin by ASO-Antibodies in serum. The levels are seen elevated in recent β -hemolytic streptococci streptococcal pharyngitis/tonsillitis (40-50%) and rheumatic fever (80-85%) and also in post streptococcal glomerulo nephritis.

α - Antitrypsin

This is an α -1 globulin glycoprotein serine protease inhibitor (Pi). Decrease level causes increase activity of trypsin and panacinar emphysema in adult and level diseases in children with ZZ and SZ phenotype (Pizz, Pisz). The levels are increased during inflammation, infection, rheumatic disease, malignancies and pregnancy. The low levels are seen in nephrotic syndrome and congenital α -Antitrypsin deficiency disorders. This is not a common cause of emphysema in adult where smoking is most common cause for COPD/emphysema.

Creatine Clearance Test

This is the test for glomerular filtration rate. Creatinine clearance is measured by collecting urine in 24 hours and calculated as follow:

$$\text{creatinine clearance (mL/mt)} = \text{Urine Creatine} \times \text{Volume/mt} / \text{Plasma creatine mg\%}$$

It is corrected according to body surface area (BSA) in meter square. The correct formula is as

$$\begin{aligned} \text{creatinine clearance} &= \text{creatinine clearance incorrect} \times 1.73/\text{BSA} \\ \text{normal value } CL_{Cr} &= 90 - 130 \text{ mL/m/1.73m}^2\text{BSA} \end{aligned}$$

It is decreased in acute and chronic renal failure and decreased renal blood flow condition like shock, hemorrhage, dehydration, CHF and use of nephrotic drugs.

Creatine Kinase

It is an intracellular enzyme used to split creatine phosphate in the presence of ADP to yield creatine and ATP. Skeletal muscle, heart muscle and brain cells are rich in this enzyme and release by such tissue damage. This has 3 isoenzyme - made up of 2 component M&B. According to their electrophoretic mobility, these are classified 3 groups:

BB - Brain Component - with greatest electrophoretic mobility

MM - skeletal muscle

MB - myocardin has 40% MB isoenzyme

MB - increase in myocardial infarction, cardinal appear approx. 4 hours after infarction.

MM - muscular dystrophy, polymyositis peak at 12-24 hours, by 48 hours

These MM, BB are not clinically useful.

Hematocrit

The hematocrit represents the percentage of whole blood volume composed of erythrocytes

Hematocrit = total red blood cell count x mean corpuscular volume

Hct = (RBCs x MCV)

Hematocrit increases due to hemoconcentration

Physiological - dehydration, burn, vomiting

Pathological - polycythemia, extreme physical exercise

decreased in macrocytic anemia

 hypothyroidism

 folate deficiency

 hemolytic anemia

 microcytic anemia (Iron deficiency Anemia, Thalassemia)

Appendix N. Procedures for Multimedia Incorporation

The procedures of adding pictures material into IMMELDA:

1. Some sample pictures and diagrams were found and gave to Audiovisual Department at CHEO for scanning.
2. The pictures were transferred into window bitmap format PC files.
3. Transformed the window bitmap pictures files to jpeg format files
4. Imported jpeg format files into Macintosh by JPEGView software and saved the files as PICT Mac format files.
5. Using ResEdit software, created ResEdit picture file with PICT resources fork.
6. The ResEdit files were added into the medical cases (IMMELDA).

The procedures of adding sound material into IMMELDA:

1. The sample sound were transferred into window wave format PC files.
2. Transformed the window wave pictures files to AIF format files
3. Imported AIF format files into Macintosh by Sound Machine software and saved the files as AIFF Mac format files.
4. Using ResEdit software, created ResEdit sound file with AIFF resources fork.
5. The ResEdit files were added into the medical cases (IMMELDA).

The procedures of recording sound material into IMMELDA:

1. Recorded a sample message directly into Macintosh through a microphone.
2. Saved the message as AIFF Mac format file.
3. Using ResEdit software, created ResEdit sound file with AIFF resources fork.
4. The ResEdit file was added into the medical cases (IMMELDA).

Appendix O. Screen Snapshots of IMMELDA

The screenshot displays the IMMELDA software interface. At the top, a menu bar includes 'Options', 'View', 'Control', 'Data', and 'Help'. The system clock shows '20:09:20'. Below the menu bar, a status bar reads 'Processing your responses ... have patience'. The main interface is divided into two primary panels: 'Patient' on the left and 'Case Management History' on the right. The 'Patient' panel contains the text: 'presenting complaint: 35 year old female presented in emergency department with severe right sided colicky abdominal pain dark colored urine and itching all over her body'. The 'Case Management History' panel is currently empty. A 'Select next action' dialog box is open over the 'Case Management History' panel, listing the following options: 'advance time', 'contact specialist', 'diagnosis', 'history and general exam', 'hospitalization', 'interim treatment', and 'tests'. The 'history and general exam' option is highlighted by the mouse cursor. At the bottom of the dialog box are 'Select' and 'Close' buttons. Below the dialog box, the 'Time and Score' panel shows 'day(1)'. A large black rectangular area is visible at the bottom left of the interface.

Options View Control Data Help 20:09:20

Processing your responses ... have patience

Patient

presenting complaint:
35 year old female presented in emergency department
with severe right sided colicky abdominal pain
dark colored urine and itching all over her body

Case Management History

Select next action

- advance time
- contact specialist
- diagnosis
- history and general exam
- hospitalization
- interim treatment
- tests

Select Close

Time and Score

day(1)

This screen snapshot show a typical case management for a choledocolithiasis. The student is presented with initial symptoms of the patient.

Options View Control Data Help 20:09:38

Processing your responses ... have patience

Patient	Case Management History
<p>sick pale looking young female blood pressure(130/70 mm of Hg) pulse(94/mt) temperature(37 C) respiratory rate(24/mt) head and neck: normal, no rigidity eye: no exothalms sclera - moderate jaundice fundoscopic examination, no abnormality detected chest: normal in shape bilaterally symmetrical movement except only mild expansion of 1.5 cm during each breath (shallow breathing) vocal fremitus: on auscultation chest clear breath sounds - no adventitious or added sounds were heard clear air entry CNS: on auscultation normal 1st and 2nd heart sound no S3 or S4 no murmur in any area abdomen: on observation approx normal shape diffused mild tenderness on touch specially severe in right upper and epigastric region murray's sign positive no tenderness in right lower quadrant or in umbilical region</p>	<p>history and general exam</p> <p>Select next action</p> <ul style="list-style-type: none"> advance time contact specialist diagnosis hospitalization interim treatment tests <p>Select Close</p>
	<p>Time and Score</p> <p>day(1)</p>

As shown above, the results of general examination and patient history are displayed after the student selected history and general exam.

Options View Control Data Help 20:11:32

Processing your responses ... have patience

Patient

blood negative (no RBCs seen under microscopy)
glucose (4.5 mmol/L, normal 3.5-6.5 mmol/L)
ketone bodies negative
microscopic not significant
specific gravity 1.1 increased (n = 1.008 - 1.03)

specific tests(radiological studies):
ultrasound of abdomen
enlarged inflamed gall bladder wall approx 5mm thick
full of multiple stones
multiple stones seen in a inflamed thick walled bileduct
ERCP showed multiple stones in common bileduct
radionuclide scanning
technetium scanning showed
- only liver visualization
- no visualization of the gall bladder and bileduct
- indicating malfunctioning of gall function

specific tests(liver function):
S.Lipase (80 mmol/L, normal 7-60 mmol/L)
S.Alkaline phosphatase (250 U/L, normal 25-110 U/L)
S.Bilirubin total increased (30 µmol/L, normal 5-20 µmol/L)
direct(3+) conjugated, 15 mmol/L, normal 0-4 mmol/L
indirect(1+) unconjugated, 20 mmol/L, normal 0-12 mmol/L
S.Albumin (30 g/L, normal 35-50 g/L)
Serum Trans aminase (80 IU/L, normal 0-35 IU/L)
Serum Lactic Dehydrogenase (300 U/L, normal 115-220 U/L)
Blood Clotting Profile:
Partial Thrombo Plastin Time (50 seconds, normal 24-34 seconds)
Prothrombin Time (20 second, normal 9-12 seconds)
INR increased (3.0)

Case Management History

history and general exam
routine tests
specific tests(liver function)
specific tests(radiological studies)

Please choose correct diagnosis

acute hepatitis
cholecystitis
✓ choledocholithiasis
cholelithiasis
cholangitis
postpone diagnosis

Select Close

Time and Score

day(1)

After the student selected routine tests, liver function test, and radiological studies, student decided to make diagnosis of the case.

Choledocolithiasis is the correct diagnosis and a prompt with detail explanation is shown to confirm student's correct diagnosis.

If missing an important test (i.e., X-ray test was missing before make diagnosis), no diagnosis can be made as shown on this screen.

After selecting the incorrect diagnosis for the case, the correct diagnosis in detailed explanation is prompted.

After selecting "advance time", patient condition can be changed as shown on the screen.

Under the Help menu, user can obtain explanation on terms found in the case. In the above, "Button" was selected.

“Heart Sound” was selected for explanation under the Help menu.

IMAGE EVALUATION TEST TARGET (QA-3)

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