DEVELOPMENT AND EVALUATION OF A COMPUTER-BASED INSTRUCTIONAL MODULE FOR THE STUDY OF ANTIBACTERIAL DRUGS

By

CYRIL ROY CLARKE

Bachelor of Veterinary Science
University of Pretoria
Onderstepoort, South Africa
1981

Doctor of Philosophy
Louisiana State University
Baton Rouge, Louisiana
1987

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Thesis Approved:

Martin Bunting
Thesis Adviser

Dean of the Graduate College

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CHAPTER I

INTRODUCTION

In recent years, veterinary medical curricula have undergone substantial revision that has been characterized by the use of active as opposed to passive learning and the application of multimedia learning resources, such as computer-based instructional modules (Hooper, 1994). The use of active, student-centered instruction arose from the recognition that successful veterinary practice requires the ability to find and organize information, analyze data efficiently, think critically, and make reasonable decisions, and does not just depend on memorization of facts. Although computers are well suited to the independent study consistent with student-centered instruction, usually they have been used simply as electronic textbooks in a manner more consistent with instructor-centered learning.

Numerous authors, including Gibb (1960), Brundage and Mackeracher (1980), Brookfield (1986, pp. 31), and Galbraith (1998), have expressed a preference for student-centered instruction as opposed to instructor-centered instruction. Student-centered instruction, which is consistent with the androgogical model of learning first popularized by Knowles (1980, pp. 43-44), assumes that adults: (1) perceive themselves as self-directed learners; (2) learn more effectively through experiential techniques; (3) become aware of specific learning needs when these are generated by real life tasks or problems; and (4) prefer learning to be directly applicable to their immediate or anticipated circumstances.

Despite the persuasive arguments in favor of a learner-centered approach, much of the instruction occurring in the preclinical years of veterinary and medical curricula is didactic and content-driven. Studies by Levine and Forman (1973) have reported that students retain little knowledge learned in the medical preclinical sciences by the time they reach their clinical training if presentation of the information occurs primarily by lecture and assignment of readings. Furthermore, knowledge that is recalled can seldom be applied effectively in the solution of clinical problems. Barrows (1985, pp. 4-5) concluded that these deficiencies in traditional educational methods result from instructors concentrating too much on curricular content and too little on application of knowledge in the context of patient care. Thus, knowledge is organized in a manner that is not conducive to recall in a clinical setting.

Computers are ideally suited to student-centered instruction because they can be used to provide the images and sounds necessary for the creation of a context that promotes experiential learning. Furthermore, study can be self-paced, which allows students to identify and explore personal learning goals. Unfortunately, most currently available computer-based instruction modules for veterinary medical education do not promote learning via the androgogical model but simply serve as electronic databases that mirror those represented by textbooks and photographic slide collections. The availability of interactive educational software modeled on the principles of learner centered instruction would be of considerable value to teachers of the preclinical sciences, particularly in the discipline of clinical pharmacology.

Therefore, the goals of this thesis project were to: (1) develop a computer-based instructional module that provides both a context and a model for student-centered study of the clinical pharmacology of antibacterial drugs; and (2) evaluate the effectiveness of the module using both objective and subjective methods.

CHAPTER II

LITERATURE REVIEW

Advances in computer hardware technology and software development over the last fifteen years have facilitated the delivery of information to biomedical students and promoted the use of clinical case material in the education of preclinical students not yet exposed to real patients. Computer-assisted learning (CAL) is particularly well suited to the biomedical sciences because the knowledge domain necessary for competent clinical practice includes a variety of conceptual, visual, auditory, and other sensory skills that can, to a large degree, be accommodated by the multimedia and interactive capabilities of computers. The introduction of CAL into biomedical training programs has occurred in conjunction with substantial revisions in program curricula, which have been characterized by integration of subject areas and increasing reliance on active as opposed to passive learning. The use of active, student-centered learning arose from the recognition that successful veterinary practice requires the ability to find and organize information, analyze data efficiently, think critically, and make reasonable decisions, and does not just depend on memorization of facts.

However, the use of computers in the educational process does not necessarily advance a particular model of learning because they are simply tools that can be employed in support of a variety of underlying instructional philosophies. Indeed, their frequent use as electronic textbooks is more consistent with instructor-centered learning than the student-centered learning to which they appear to be so well suited. Thus, an assessment of the potential benefit of incorporating computers into biomedical training programs is dependent on the goals of the educational endeavor and relies on an understanding of the underlying philosophies of adult education and the capabilities of computers that should best be employed to serve the selected model of learning. Therefore, the goals of this review are to: (1) identify and discuss the types of computer-assisted learning employed in biomedical education; (2) provide a brief review of the cognitive frameworks believed to promote learning of adults; (3) identify attributes and capabilities of computers that can be employed in support of adult learning; and (4) propose methods whereby the success of CAL can be evaluated.

Types of Computer-Assisted Learning in Biomedical Education

The history of computer use in biomedical education has been determined primarily by the developing state-of-the-art of computer technology and has involved three types of applications (Jonassen, 1996): (1) learning about computers (computer literacy); (2) learning from computers (computer is programmed to teach the student); and (3) learning with computers (using computers as cognitive tools).

Learning About Computers

Initially, learning about computers involved study of the basic components of computer hardware and introductory programming languages, such as BASIC. However, with the advent of user-friendly operating systems and software applications, educators realized that productive use of computers was not dependent on an understanding of programming. Objectives relating to learning about computers then evolved into more meaningful definitions that were framed in terms of the need for computer literacy, which Hunter (1983) broadly described as "the skills and knowledge needed by all citizens to survive and thrive in a society that is dependent on technology for handling information and solving complex problems." Recently, several of the medical schools in the University of California system established more specific recommendations for computer literacy and employed these as objectives to be achieved by completion of medical school (Masys, 1998). Objectives included abilities to: use word processing applications to create and edit documents and to incorporate elements such as figures and tables into these documents; retrieve relevant and timely information from printed sources and on-line databases; and communicate electronically by e-mail, newsgroups, file transfer, and the World Wide Web. Based on survey data compiled by the California Consortium for Informatics in Medical Education and Development (IMED), these objectives will be easily accomplished because many of the computer literacy competencies identified by the medical schools already exist in a large proportion of incoming first-year medical students (Masys, 1998). For example, as many as 98% of students reported that they had used a computer and a significant proportion of these were competent in word processing, on-line library database searching, and use of e-mail. Clearly, educational goals pertaining to learning about computers are likely to be de-emphasized in the future as students are increasingly exposed to computers from a young age.

Learning From Computers

Different methods whereby students learn from computers can be differentiated by the degree of interactivity that exists between the computer and the student user. The most common type of CAL employed in biomedical education involves the use of electronic textbooks. Initially, these were little different from the hard copy text versions, but more recently they have incorporated a wide range of multimedia, such as sound, digital video, animation, pictures, and text to display information. Electronic textbooks designed to support instruction in the morphological sciences often take the form of image libraries with explanatory notes. These are a parallel to the color atlas and can be very sophisticated, illustrating three-dimensional body structures using computerized reconstruction of two-dimensional images derived from computed tomography, magnetic resonance imaging, and other diagnostic methods that generate images in the form of multiple slices through anatomical structures. However, even the most modern of these electronic textbooks and image libraries are interactive only in the sense that they can be navigated by electronic page turning, hypertext-based indices, or clicking buttons to show relevant selected information such as pictures or video clips. This represents the lowest form of interactivity and could be described more accurately as reactivity than interactivity (Mooney and Bligh, 1996).

Higher forms of interactivity are evident in drill and practice programs, tutorials, or intelligent tutors, which are sometimes referred to as virtual intelligence programs. Drill and practice programs represented the most prominent form of interactive computer-assisted instruction during the 1970s and 1980s. These programs usually presented students with questions or problems and then provided feedback about the accuracy of responses. Responses to correct answers often involved graphic rewards, such as smiley faces, that were intended to provide positive reinforcement, thus encouraging particular responses when students were presented with a specific stimulus.

Tutorials go a step further by attempting to remediate incorrect answers. For example, incorrect answers selected from a multiple choice format may result in explanations of why the answer is incorrect and the student is then referred to a linked database, application, or electronic textbook that provides further information relevant to the question. Thereafter, the student may be given another opportunity to select the correct answer. Tutorials used in biomedical science education are often structured in the form of clinical cases. Presentation of a clinical case, aided by incorporation of photographic images, is usually followed by a series of questions related to diagnosis and case management, with detailed feedback relating to students' answers. An example of such a program is MEDICI, which was developed by the University of Adelaide medical faculty (Devitt and Palmer, 1998). This text-based program is supplemented by images, including photographs, video, graphs, and laboratory data and encourages students to progress logically through management of clinical cases by providing answers and further feedback to decisions. At the completion of each case, the student is given a score that serves as an assessment of the success with which the case was managed.

Interactivity can be further enhanced by using a new technology known as virtual reality. Virtual reality is defined as "a computer-generated three dimensional simulation in which the user both views and manipulates the contents of an environment" (Kaufman and Bell, 1997) and is characterized by three major attributes: (1) a three-dimensional representation of an environment; (2) real-time interaction with the environment; and (3) a user interface that allows communication using natural means, such as language and gestures. Based on the original technology developed to train aircraft pilots, virtual reality programs allow simulation of and "immersion" in a situation using three-dimensional vision, tactile pressure, multidirectional sound, and smell. For example, virtual reality simulators have been developed for a variety of medical procedures including; intravenous needle insertion, central venous line placement, bronchoscopy, flexible ureteroscopy insertion, neuroendoscopy, and cholecystectomy. As these examples of procedural simulators suggest, the educational goals of most of these virtual reality programs have been behavioral in nature and have involved psychomotor skills. Learning and teaching of psychomotor skills, which are mental and motor activities necessary to accomplish a manual task, are believed to involve seven sequential steps: conceptualization; visualization; verbalization; physical practice; correction and reinforcement; achievement of skill mastery, and autonomy (Kaufman and Bell, 1997). Use of virtual reality is particularly valuable for the physical practice, correction and reinforcement, and achievement of skill mastery steps that build upon the initial steps, which can be accomplished using less interactive means. Justifications for using virtual reality rather than real exposure to patients in teaching hospitals usually relate to cost-effectiveness, patient safety, and animal welfare considerations that have compelled biomedical colleges to reduce the use of animals in student laboratory exercises.

Intelligent tutoring is a further development of computer-assisted instruction made possible by advances in the 1990s by artificial intelligence research. These tutorials compare an array of student responses with a preprogrammed expert model that is considered to be the ideal response for a given situation. When the student response differs from the expert model, the discrepancy is identified and remedial instruction is provided. Several of these elements have been incorporated into a program, titled Integrated Case Studies and Medical Decision Making (ICS), developed by the University of Pittsburgh School of Medicine (Schor et al, 1995). Based on the problem-based learning (PBL) model of instruction, ICS presents students with clinical case material and then gives them the opportunity to select and interpret diagnostic tests that they think are appropriate for the patient. After students provide their interpretations or make their selections, the program provides the student with an expert's opinion. By working cooperatively and with the assistance of faculty facilitators, students were encouraged to think about the process of case management as much as the content of biomedical disciplines and to integrate basic and clinical sciences in a self-directed manner.

Learning With Computers

The premise underlying the argument in favor of learning with computers rather than from computers is that students learn best by thinking in meaningful ways and that this can be accomplished by engaging them in activities that can be embedded in the tasks and functional requirements of readily available and generally applicable computer applications. Referred to by Jonassen (1996) as "mindtools", programs such as spreadsheets and databases can be "adapted or developed to function as intellectual partners with the learner in order to engage and facilitate thinking and higher-order learning." Thus, computer applications are used as cognitive tools that allow the learners to create their own knowledge structures and engage in constructive learning, which has been defined by Simons (1993) as learning that is active, cumulative, integrative, reflective, and goal directed. For example, when students employ a database application, they are constructing their own understandings of the relationships and organization of the knowledge domain and they become the creators of knowledge rather than simply the receivers of a presentation. Thus, instead of having the instructor define the learner expectations and outcomes, responsibility and control rests with the learner, who has the opportunity to manipulate, reflect on, and learn from an experience. The partnership between the learner and the computer encourages development of methodologies for thinking about a problem or interpreting an issue that remains with the learner after the computer is switched off. Referred to as cognitive residues (Salmon et al, 1991), these methodologies serve as cognitive templates that can then be applied to many different situations not represented by the original computer-assisted exercise. However, providing cognitive tools to students does not necessarily result in meaningful learning because students may have difficulty formulating appropriate questions or strategies when using these tools (Ribbons, 1998). Therefore, it is usually necessary to give students the opportunity to acquire the necessary mental models or learning strategies by providing a framework of carefully constructed activities that encourage students to ask the right questions or apply robust analytical models, such as the hypothetico-deductive approach to hypothesis testing.

An example of a structured approach to the use of computers as cognitive tools is a wound assessment and management database developed for trainee nurses at Monash University in Victoria, Australia (Ribbons, 1998). The database consisted of demographic, physical, psychological, social and laboratory data as well as clinical diagnostic information derived from the records of patients with wounds. Using data field clusters that included physical assessment, clinical diagnoses together with initial and concurrent pathologies, laboratory data, risk assessment, wound assessment, and treatment modality, students were asked to test a number of suggested hypotheses, such as whether the presence of certain concurrent disease processes impeded wound healing. After sorting the data according to parameters such as wound stage and duration of healing, students searched for similarities or differences in patient profiles and used these findings to support or reject the hypotheses. They were also asked to develop conclusions or inferences from their analyses.

Aside from actively engaging learners in interpreting information and reflecting on their interpretations, this approach to computer-assisted learning also has the advantage of being cost-effective. Since the programs used are usually readily available in the public domain and can be applied to many different knowledge domains, there is no need for development of individual programs that are intended to focus on development of a limited set of specific skills. Furthermore, unlike specialized programs which may have a wide variety of user interfaces and operation requirements, mindtools require the acquisition of a limited number of user skills that can be applied to a wide range of subject contents.

Cognitive Frameworks for Education of Veterinary Medical Students

Over the past fifteen years, considerable attention has been focused on the goals and methods of veterinary medical education, leading to widespread revision of curricula and adoption of alternative methods of instruction. An important milestone in the history of educational reform was the creation in 1987 of the Pew National Veterinary Education Program, which supported development of national strategies to meet the needs of consumers of veterinary services. A principal recommendation arising from the strategic planning conducted by program participants was that the veterinary medical educational process should focus on the ability to find and use information rather than the accumulation of facts (Pritchard, 1989). This recommendation is consistent with an underlying philosophy of learning that differentiates lower-order learning, which is reproductive and analogous to a sponge in that students are required to remember information presented to them until an examination, at which time the information is wrung out of them (Papert, 1990; Schank and Jona, 1991, Paul, 1992), and higher-order learning, which involves students constructing knowledge that has personal meaning and is applicable and memorable.

Embedded in the higher-order, constructionist model of learning is the concept of critical thinking. Critical thinking has been defined as generalizable, higher order thinking, such as logic analyzing, planning, and inferring (Jonassen, 1996) and has been described by Ennis (1989) to occur in three dimensions: "logical (judging relationships between meanings of words and statement); critical (knowing the criteria for judging statements covered by the logical dimension); and pragmatic (considering the background and purpose of the judgment and the decision as to whether the statement is good enough for the purpose)." These definitions of critical thinking, like most traditional conceptions, are very logic orientated and do not acknowledge the important role of less rational dimensions of thinking that involve intuition, imagination, conceptual creativity, and insight.

In an attempt to recognize the multi-faceted nature of meaningful knowledge construction, the Integrated Thinking Model (Iowa Department of Education, 1989) was constructed to define complex thinking skills as an interactive system rather than as a collection of separate skills. This model serves as a very useful framework for the design and evaluation of computer-assisted learning programs employed in the education of veterinary medical students. The model (simplified in Figure 1) includes three interacting components involved in complex thinking: content/basic thinking; critical thinking; and creative thinking. Content/basic thinking involves "the skills, attitudes, and dispositions required to learn accepted information - basic academic content, general knowledge, 'common sense,' - and to recall this information after it has been learned" (Iowa Department of Education, 1989). Thus, content/basic thinking describes traditional memorization and recall of information that serves as the knowledge base necessary for the interacting critical and creative thinking components to operate. The inclusion of this component in the model suggests that the error of many veterinary programs that rely principally on didactic methods of instruction lies not in the attention given to acquisition and recall of knowledge but in the omission of the higher-order components of critical and creative thinking. Critical thinking involves evaluating the value of information using criteria and standards that are appropriate for a given situation, analyzing information by classifying it into meaningful entities and recognizing the relationships between the entities, and connecting the entities by describing their interactions in terms of similarity, cause and effect, and predicted outcomes. Creative thinking involves going beyond accepted knowledge to generate new knowledge in a subjective and personal manner through synthesis of metaphors, analogies, and interpretations that make information more understandable, imagining processes, outcomes, and possibilities suggested by the information, and elaborating on the information by relating it to personal experience. The three basic elements of the model, content/basic thinking, critical thinking, and creative thinking, do not operate sequentially but are used in combination to produce complex thinking skills that are employed to solve problems, design new creations, and make wise choices between alternatives in a rational and systematic way.

The Integrated Thinking Model can be placed within a broader and more generalized conceptual framework that distinguishes between teacher-centered and student-centered learning, often considered analogous to passive and active learning, respectively. Student-centered learning, which is consistent with the androgogical model of learning first popularized by Knowles (1980), assumes that adults: (1) perceive themselves as self-directed learners; (2) learn more effectively through experiential techniques; (3) become aware of specific learning needs when these are generated by real life tasks or problems; and (4) prefer learning to be directly applicable to their immediate or anticipated circumstances. These characteristics, together with the assumed developmental objectives of the student-centered learning process, give students the primary responsibility for their own learning and are consistent with the critical and creative thinking components of the Integrated Thinking Model. The content/basic thinking component in the Integrated Thinking Model is more consistent with teacher-centered-learning in that it deals with the domain of accepted knowledge that usually is presented by the teacher. However, the content/basic thinking component is distinguished from teacher-centered learning in that it is not insulated but exists in constant interaction with the critical and creative thinking components of the entire model to produce a complex thinking process.

The relative values of student-centered and teacher-centered learning in biomedical education have been the subject of vigorous debate in recent years. Despite persuasive arguments in favor of a learner-centered approach, much of the instruction occurring in the preclinical years of veterinary and medical curricula is didactic, content-driven, and teacher-centered. Studies by Levine and Forman (1973) have reported that students retain little knowledge learned in the medical preclinical sciences by the time they reach their clinical training if presentation of the information occurs primarily by lecture and assignment of readings. Furthermore, knowledge that is recalled can seldom be applied effectively in the solution of clinical problems. Barrows (1985) concludes that these deficiencies in traditional educational methods result from instructors concentrating too much on curricular content and too little on application of knowledge in the context of patient care. Thus, knowledge is organized in a manner that is not conducive to recall in a clinical setting. Clearly, computer-assisted learning that can be used in support of a more student-centered approach to biomedical education could greatly enhance an educational process that is intended to result in the acquisition of problem solving skills.

Use of Computers to Promote Acquisition of Problem Solving Skills

Despite the multimedia capabilities of computers that can be used to provide the images and sounds necessary for the creation of a context that promotes experiential learning and the flexibility that they provide that allows students to identify and explore personal learning goals, computer-assisted instruction does not necessarily promote student-centered learning. Most currently available computer-based instructional modules used in veterinary medical education simply serve as electronic databases that mirror those represented by textbooks and photographic slide collections. They seldom include elements that promote two of the three interacting components of complex thinking described in the Integrated Thinking Model; critical thinking and creative thinking. By focusing on the multimedia capabilities of computers, teachers often neglect to identify and address appropriate educational goals that the computer is supposed to serve. As lamented by Grigg and Stephens (1998), the "facilities available on modern computers can all too often encourage programmers to concentrate on producing intricate pieces of software in which the purpose of the package appears to be to demonstrate the ability of the software development team as opposed to providing a facility which can enrich a student's learning experience."

Using the Integrated Thinking Model as a representation of the thinking skills needed by veterinary practitioners, the following recommendations are proposed as requirements for CAL programs intended to promote student-centered learning:

- To ensure that students are prompted to employ critical and creative thinking skills in a relevant manner, a cognitive scaffolding should be provided. For example, a problem could be framed in terms of an individual clinical case, a disease outbreak, or a physiological mechanism. Ideally, the cognitive scaffolding should be structured in a manner that allows exploration of issues that go beyond the immediate context of the problem to promote development of critical and creative thinking skills that may be applied to other problems. Although students will learn a great deal of content information as they work through a particular case, it is not necessary that they learn all content information relevant to a particular discipline in this manner; research comparing problem-based learning with traditional didactic methods has indicted that the latter are better suited to the memorization of factual information (Albanese and

Mitchell, 1993; Vernon and Blake, 1993) and can be employed in conjunction with CAL for this purpose.

- Full use should be made of the multimedia capabilities of computers to provide a context in support of the experiential nature of student-centered learning. This may include the use of photographic images of patient lesions as well as diagnostic test results, such as radiographs and ultrasound images. When appropriate, use of auditory information should be employed, such as in the case of sounds resulting from auscultation of cardiopulmonary function. The clinical context created by use of multimedia promotes framing of questions and identification of learning issues that are relevant to the anticipated real life tasks, which is a hallmark of student-centered learning.

- Links within the CAL program and between the program and other computers to access resources, such as on-line literature search programs, internet web sites, electronic textbooks, and local area networks, can be use to provide a wide range of information that learners can employ to explore learning issues that they identify. Use of such links that extend beyond the knowledge domain provided by the instructor release the student from the learning objectives created by the teacher and promote self-directed learning, while still maintaining sufficient focus necessary for solution of the clinical problem.

- Sufficient interactivity between the program and the learner should be present to promote development of the decision-making and problem solving skills most commonly employed by experienced veterinary clinicians. Although veterinarians do on occasion employ pattern recognition skills, they most often follow a hypothetico-deductive reasoning process involving generation of a hypothesis based on available data, testing of the hypothesis by acquisition and evaluation of further data, followed by creation of a new hypothesis as they progress from diagnosis through treatment modalities. This approach determined by the hypothetico-deductive decision making process is analogous to ever increasing ramifications dividing and spreading out from the problem stem and can easily be built into the cognitive scaffolding of the program. using the method of hyperlinking. However, until sophisticated artificial intelligence computer technology is developed and applied in veterinary medicine, it is doubtful whether a CAL program can satisfactorily model the professional behavior of an experienced veterinarian. Therefore, the program should be structured to allow participation by the teacher in the student's learning. This can be accomplished while the student is using the CAL program or by saving student interpretations, responses, and questions for later instructor consideration.

- Caution should be exercised to avoid constraining students within the limits of the program developer's imagination and the tutorial elements of the program. Students should have the opportunity to organize information and concepts in a manner that has personal meaning and to explore issues and possibilities not previously anticipated or imagined by the programmer and incorporated into the program. This can be accomplished through the use of mindtools, such as spreadsheets and databases, which can be integrated into the program using hyperlinks. This essential component of the CAL program is necessary to extend the student's use of the computer beyond that of simply learning from computers to that of learning with computers, as discussed above.

Evaluation of Computer-Assisted Learning Programs

Evaluation of CAL programs should include assessment of the program itself as well as the effect of the program on the student and, when possible, comparison between the effectiveness of the program and alternative instructional methodologies available to the student. Hardin and Reis (1997) have proposed a comprehensive and structured approach to evaluation that includes the steps of alpha testing, beta testing, formative evaluation, and summative evaluation. Alpha testing refers to early developmental technological evaluation to determine whether all features of the program function as planned and advertised. For example, if clicking a certain button is intended to open a new data window, then this function should work as intended. Further testing of these functional features of the program by knowledgeable users not involved in program development is known as beta testing.

Assessment of program content and whether it meets its educational objectives occurs by formative evaluation. Initially, the program should be evaluated one-on-one by an expert in the lesson content who sits next to the student using the program to confirm that the student is performing as anticipated. This is followed by small-group testing, which usually involves assessing the impact of the program using pre- and post-testing. Finally, the last element of formative evaluation is the field trial that is conducted to determine whether the results of the small-group testing are applicable to a wider population and to determine the feasibility of employing the program on a large scale. After the program has been in use for some time, the instructional impact of the program can be assessed by a summative evaluation.

Often, evaluations of CAL seldom extend beyond soliciting opinions from peers and students about the functionality and suitability of programs. Considering the context of veterinary medical education, in which CAL programs are usually offered as alternatives to more traditional didactic teaching, it is important that comparisons be made between the different instructional methodologies. However, this is not easily accomplished because it involves separating students in the same class into different treatment groups and concerns about unequal treatment of the different groups of students. Furthermore, the developmental objectives, such as problem-solving skills, that that student-centered CAL is intended to promote are not as easily tested as the more behavioral objectives, such as memorization of content information, that are easily evaluated and easily achieved by teacher-centered instruction.

Nevertheless, several studies have been published that have attempted to evaluate the impact of CAL on biomedical students. One of these (Devitt and Palmer, 1998) evaluated student attitudes as well as the knowledge gained as a result of using a problem-based learning package. Formative evaluation was accomplished by administering pre- and post-tests to students who either used the CAL program or attended a tutorial on equivalent material. The pre-and post-tests were designed to measure recall of information, data analysis, and problem-solving skills. Although the students provided positive comments in support of the program and the formative evaluation revealed significant gains in knowledge, these gains were not significantly different from those achieved by the tutorial method. Considering that the tutorial method was structured to promote definition of learning objectives, exchange of ideas, and fostering of problem-based learning, evidence that the CAL program performed at least as well was encouraging.

Other evaluations of the effectiveness of CAL have been even more encouraging. Jelovsek and Adebonojo (1993) at the Tennessee State University College of Medicine examined 49 trials comparing CAL with conventional methods and reported that CAL was as good and usually better than the conventional approaches with regard to cognitive outcome, behavior, and learning theory. Similar conclusions were reported by Gathy et al (1991), who evaluated a histopathology CAL tutorial. These and other evaluations (Brown and Carlson, 1990) confirm that CAL can be used as a valuable tool in support of the education of students in the biomedical sciences. However, as recommended earlier in this review, use of the technology to promote student-centered learning and its subsumed critical and creative thinking elements is unlikely to be successful unless careful attention is paid to the educational objectives and the learning characteristics of students.

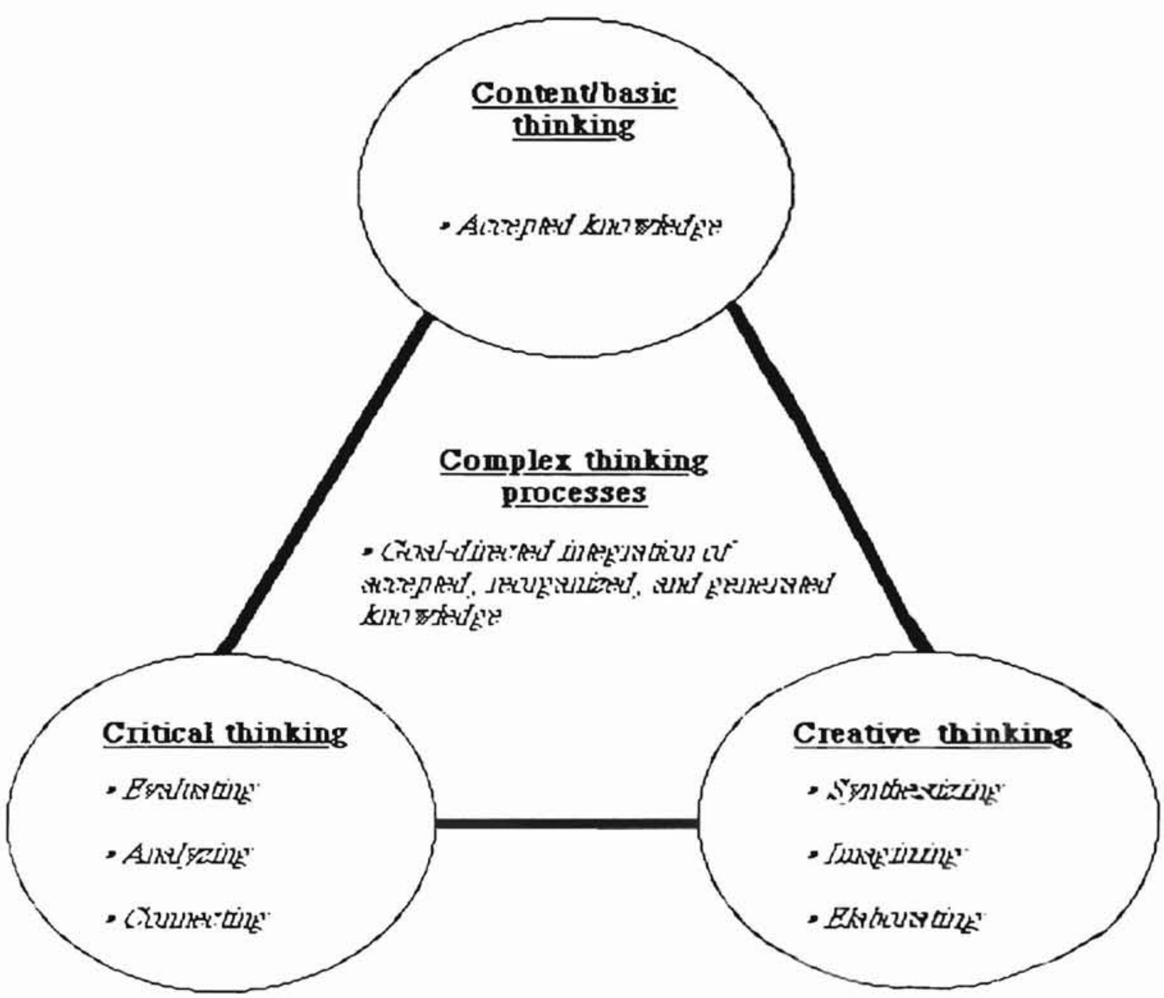

Figure 1. Simplified representation of the Integrated Thinking Model (Iowa Department of Education, 1989)

CHAPTER III

HYPOTHESIS AND THESIS OBJECTIVES

The hypothesis upon which this study was based is that use of a computer-based instructional module consisting of a clinical case, multimedia features, links to information resources, and interactive decision pathways, promotes learning by providing a relevant and engaging context for student-centered instruction and by encouraging the discovery and cognitive organization of new knowledge.

Specific objectives of the study were:

1. to develop, using commercially available software programming tools, a clinical case-based instructional module designed to instruct veterinary medical students in the clinical pharmacology of antibacterial agents and to provide access to the module via the world-wide web;

2. to refine the module based on review by experts in the field of interest;

3. to subject the module to evaluation by veterinary professional students; and

4. to test whether use of the module promoted further learning by veterinary medical students who had already been exposed to didactic presentation of the subject material.

CHAPTER IV

STUDY METHODOLOGY

Development of an Interactive, Case-Based, Computer-Aided Instructional Module

Instructional Module Requirements

Based on the review of the literature relating to models of adult learning and the use of computers to promote such learning in biomedical educational environments, the following features were identified as essential requirements of the instructional module:

- A clinical case, supported by images, descriptions of clinical signs, and diagnostic information, must provide a context relevant to and representative of the practice of veterinary medicine and therapeutic management of patients using antibacterial agents.

- Real-life tasks appropriate to veterinary practice should be simulated by constructing interative decision pathways that accurately represent diagnostic and therapeutic choices pertinent to management of the case as well as the consequences of correct and incorrect clinical decisions. These interactive decision pathways must be structured in such a manner as to promote use of a hypothetico-deductive clinical reasoning process, which is considered to be principal decision-making strategy employed by physicians to solve previously unencountered problems.

- The computational capabilities of the server computer should be employed to facilitate understanding of the complex mathematical relationships involved in pharmacological dosage estimation and adjustment.

- Easy access to a variety of information resources, including those developed specifically for inclusion in the module as well as those currently existing on other independent internet web sites, should promote acquisition of new knowledge as students identify learning issues while working through the clinical case.

- While publication of the instructional module should allow self-paced and independent study, students must be given the opportunity to provide feedback to the instructor, confirming their understanding of learning issues and identifying problems in understanding or new learning issues worthy of further discussion during scheduled class times.

Development of the Module

The instructional module was developed using Microsoft FrontPage (Microsoft Corporation), a commercially available program for creation of HTML-encoded web pages that can easily be published on the world-wide web. Important features of this web-authoring tool include: the capability of employing a variety of fonts, colors, and other text and paragraph formats to enhance the aesthetic qualities of the web pages; compatibility with a variety of digitized image formats necessary for creating a realistic clinical context; use of links between web pages and within web pages to create an hierarchical association between pages representative of a clinical decision-making process and to facilitate organization of and immediate access to a large amount of relevant information; and the ability to record and save student comments, responses to questions, and questions for later analysis and use by the instructor.

The instructional module consisted of several linked elements organized around a simulated clinical case that served as the core component of the program (Figure 2). The linked elements included a description of the instructional philosophy, an electronic textbook, pharmacology databases on the world-wide web, diagnostic test results, pharmacokinetic simulations of concentration-time plots, and a save-results feature that provided feedback to the instructor. The clinical case used to provide an appropriate context for study of the clinical pharmacology of the antibacterial agents was synthesized from several published case studies of cattle suffering from infectious glomerulonephritis (Hayashi et al. 1994; Hinchcliff et al, 1988; Markusfeld et al, 1989; Rebhun et al, 1989; Sugimoto et al, 1991; Wallace et al. 1990) and was further expanded in a manner consistent with well recognized clinical presentation of the disease. This particular disease was chosen because it provided an excellent context for addressing specific learning objectives relating to the selection and rational use of aminoglycoside antibacterial agents, principles of therapeutic drug monitoring, utility of *in vitro* antibacterial sensitivity data, and public health considerations concerning drug residues in food producing animals. Aside from these issues, which are particularly relevant to the specific treatment of renal infections in cattle, the case served as a useful representation of a wide variety of soft tissue infections and provided a context for study of general principles of antibacterial therapy.

The introductory home page (Figure 3) of the module included links to an explanation of student-centered learning and the hypothetico-deductive reasoning model (Figure 4) assumed in the clinical reasoning pathway, and instructions for using the module. There was no requirement that students examine the former; this information was available to students if they were interested in exploring the underlying conceptual basis for organization of the module. The latter were not extensive and assumed that students would be familiar with the navigational tools used by common web browsers.

Initial presentation of the clinical case (Figure 5), consisting of the clinical signalment and an image depicting the animal, was followed by a page containing a frameset of three separate frames describing the results of the physical examination of the patient and a series of diagnostic options that displayed further diagnostic information and images when selected (Figure 6). Guided by the results of diagnostic tests, students were asked to come to a conclusion concerning the diagnosis and to justify the diagnosis selected. The organization of this diagnostic phase was consistent with the hypothetico-deductive reasoning process, which involves development of a prioritized list of putative diagnostic hypotheses, which are based on available data (initial case presentation and results of the physical examination) and then tested by conducting further diagnostic steps. This model is repeated throughout the module to simulate the decision-making process involved in the diagnosis and therapy of infectious disease.

Once the diagnosis had been made, the student was presented with a series of therapeutic options, including the use of antibacterial agents, which was the focus of the instructional module. Students were encouraged to develop rational strategies for selection of antibacterial agents by asking them to identify criteria necessary for the selection of an ideal antibacterial agent for treating the infection and then providing pertinent feedback when individual agents were selected. Further management of the case was simulated by demonstrating the consequences of selecting specific dosage regimens for the antibacterial agents selected (Figure 7). Although many treatment options were available to the student, the module was structured to provide, ultimately, only one effective selection of antibacterial agent and dosage regimen and only when this decision pathway was followed, were the students able to return to the home page (Figure 8).

Incorporation of complicated algorithms for computation of plasma concentration-time relationships resulting from administration of all conceivable dosages regimens for individual antibacterial agents, usually involving the use of JAVA-based programs, was avoided by providing a more limited selection of dosage/dosage interval alternatives with links to illustrative plasma concentration-time plots saved as separate web page framesets (Figure 9). Although this approach precluded students exploring all possible consequences of adjusting dosage regimens, it nevertheless provided them with the opportunity to study the consequences of reasonable dosage alternatives. The same approach was used to simulate the process of therapeutic drug monitoring, which involves adjustment of dosage regimens to avoid toxicity and optimize efficacy, based on the plasma concentration of drug (Figure 10).

Throughout the module, students were provided access to informational resources, using links to other web pages and sites. The most important of these was an electronic textbook that included: (1) an explanation of the disposition of drugs, including absorption, distribution, and elimination as well as the mathematical description of these processes, which is termed pharmacokinetics; (2) a description of mechanisms of action, spectra of activity, adverse reactions, disposition, and individual generic names of the groups of antibacterial agents used in veterinary medicine; and (3) guidance concerning their clinical indications and use. In addition, several links were provided to other useful resources available on the world wide web, including to the Food Animal Residue Avoidance Databank, the Food and Drug Administration, and the web site of the American College of Veterinary Clinical Pharmacology. Aside from providing information relevant to the solution of the particular clinical problem presented in the module, these sites constitute important resources for practicing veterinarians and familiarity with these resources was considered important.

Further Development, Testing, and Evaluation of the Module

Developmental Testing

Initial testing of the program was conducted by the author (a specialist in veterinary clinical pharmacology), a colleague (also a veterinarian but specialized in another field of veterinary medicine), and a computer support specialist (experienced in computer-assisted instruction in biomedical sciences). This initial evaluation focused on: (1) aesthetic aspects of the module, including the use of fonts, colors, formats, and images; (2) the technological functioning of the program, particularly whether links, buttons, and save-results features worked as planned and advertised; and (3) the organization and flow of information that was presented as the student accessed linked pages.

Aside from minor problems related to the linking of web pages, the only major problem identified was an inability to save student comments, questions, and answers for later review by the instructor (save-results feature). To simplify this feature and to avoid introducing a level of complexity in the programming that would have detracted from the presentation of the clinical case, results from form frames (text windows) were saved without identifying the authors of individual submissions and compiled in a single word precessing document. Once problematic issues identified by the developmental testing and evaluation had been addressed or corrected, the module was subjected to further evaluation by students.

Use of Pre- and Post-testing to Assess the Effect of the Module on Student Learning

The instructional module was tested by measuring the increase in knowledge of students using the program and by subjecting the module to comprehensive evaluation by students. Students involved in the testing and evaluation of the module were enrolled in an elective course in clinical pharmacology, which was taught during the second year of the Doctor of Veterinary Medicine professional degree program. The 18 students enrolled in the course had already completed approximately 4 credit hours of pharmacology coursework, primarily via didactic instruction. Participation in the module testing and evaluation was voluntary and was not necessary for passing the course. At no time were participating students individually identified on tests or evaluations.

The increase in knowledge resulting from students using the program was measured by use of pre- and post-testing before and 1 week after students were allowed access to the web site (http://www.cvm.okstate.edu/instruction/mm_curr/xqea2/index.htm) at which the module had been published. The post-test was administered before any discussion of the module/clinical case occurred in class. The same test (Appendix I) was used for both pre- and post-testing and consisted of two parts: The first part had six multiple-choice questions that tested student's factual knowledge as well as their knowledge of principles necessary for estimation of appropriate dosage regimens. The second part was more developmental in nature and asked students to identify criteria that should be employed in the rational selection of effective antibacterial agents. Pre- and post tests completed by individual students were matched by use of unique 4-digit numbers generated by the students; the study author was not able to identify students using the numbers. Tests were scored and the grades achieved on the pre- and post-tests were compared using paired t tests.

Evaluation of the Module by Students

Students who participated in the pre- and post-testing to assess the effect of the module on student learning were also asked to evaluate the module. This occurred after students had been allowed independent access to the web-based module for a week and after a single class period of 1 hour, during which time the instructor discussed the clinical case and responded to student questions. These discussions were guided by the feedback provided to the instructor via the save-results feature of the module. The instrument (Appendix 2) developed to assess student opinions concerning the module addressed: (1) the programming/technology features of the module; (2) the ability of the program to provide a meaningful context for study of the clinical pharmacology of antibacterial agents; (3) the learning that occurred solely as a result of working through the module; (4) the value of integrating independent use of the module with class discussions of the clinical case involving the instructor; and (5) the degree to which students used the various elements of the module. Student responses were scored on a numerical scale that provided a quantitative assessment of how strongly they agreed or disagreed with specific statements. Furthermore, they were given the opportunity to comment on several features of the module and to indicate how much time they had committed to use of the module. Finally, they were asked to list what they perceived to be the primary objectives of the computer-based learning exercise.

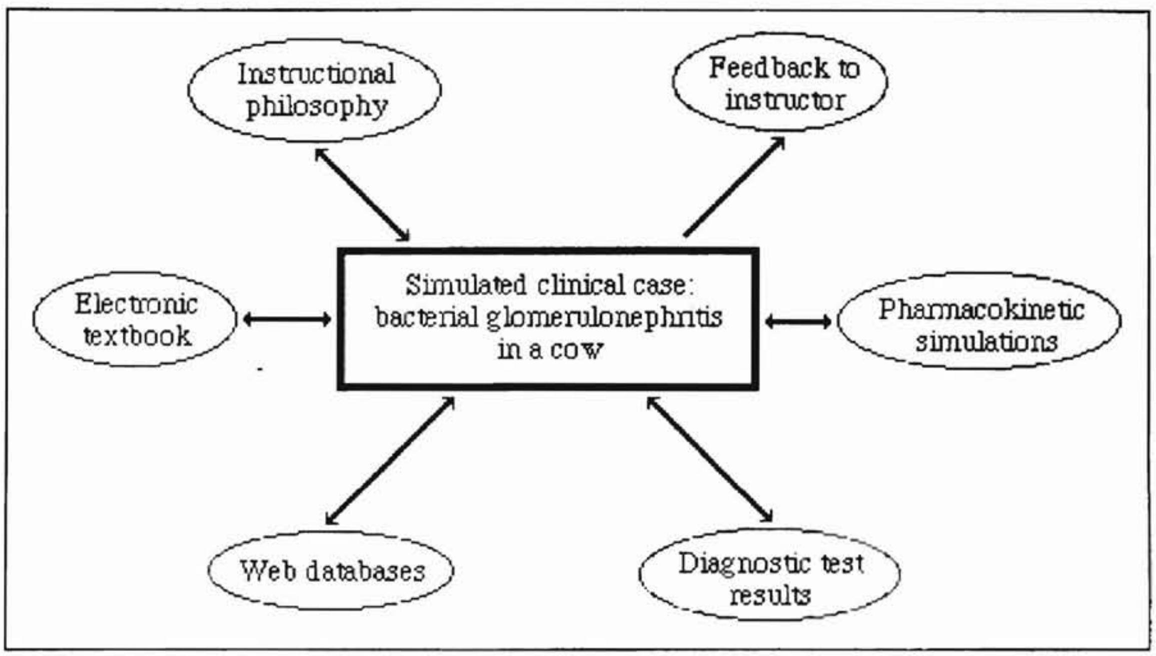

Figure 2. Linked elements of the instructional module organized around the core simulated clinical case, which served as an appropriate context for the study of the clinical pharmacology of antibacterial agents.

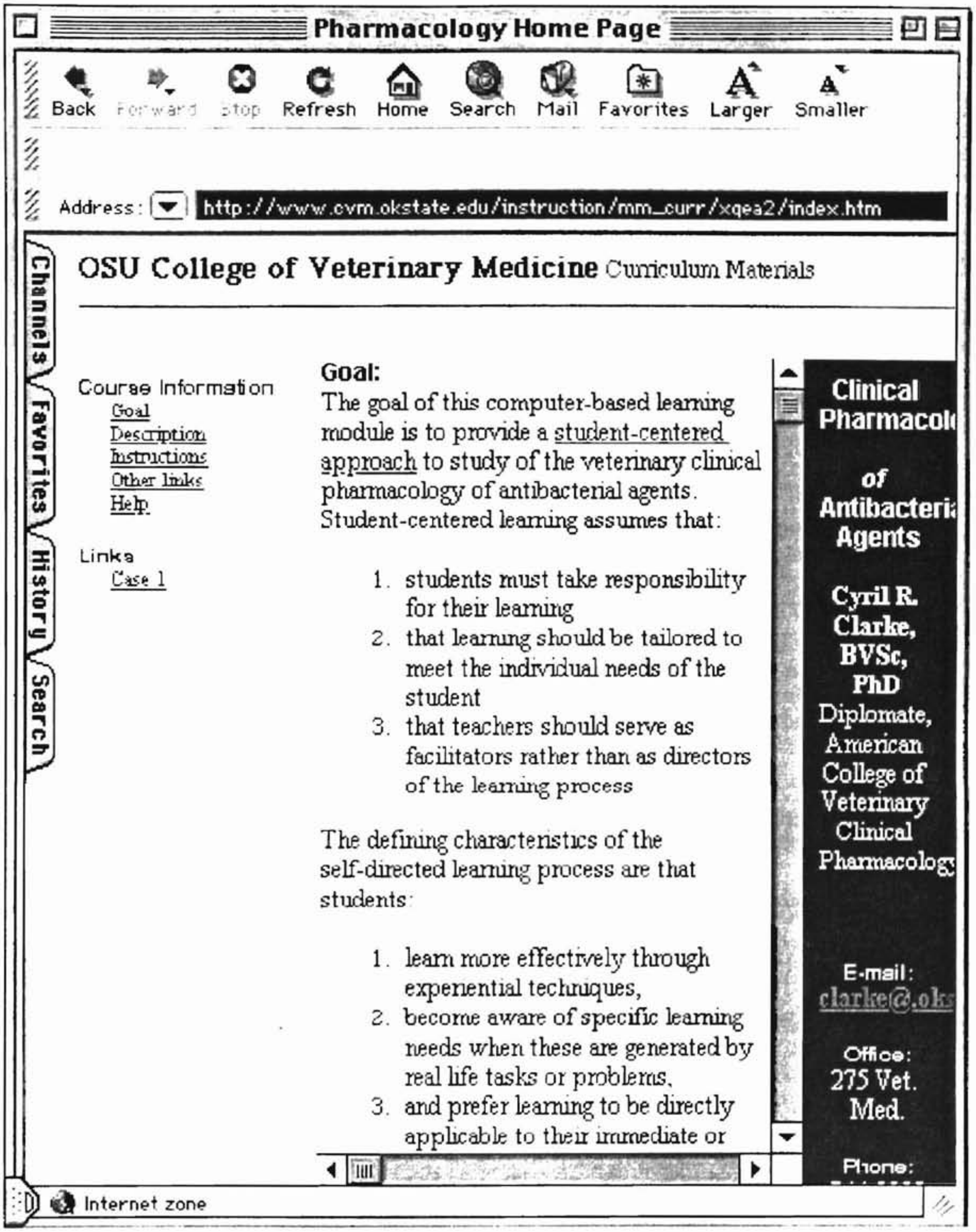

Figure 3. Introductory web page listing instructions for using the module and links to other web sites and pages.

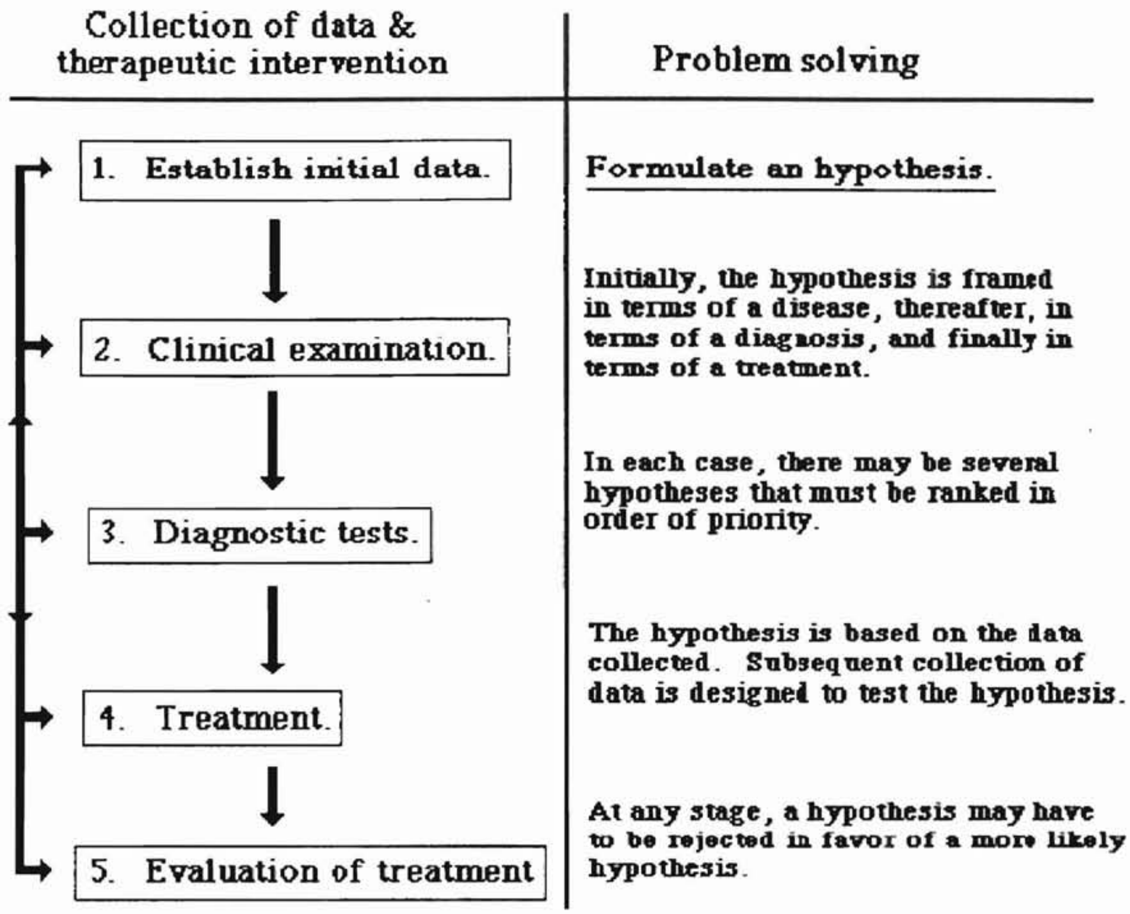

Figure 4. Clinical reasoning process based on the hypothetico-deductive model of problem solving.

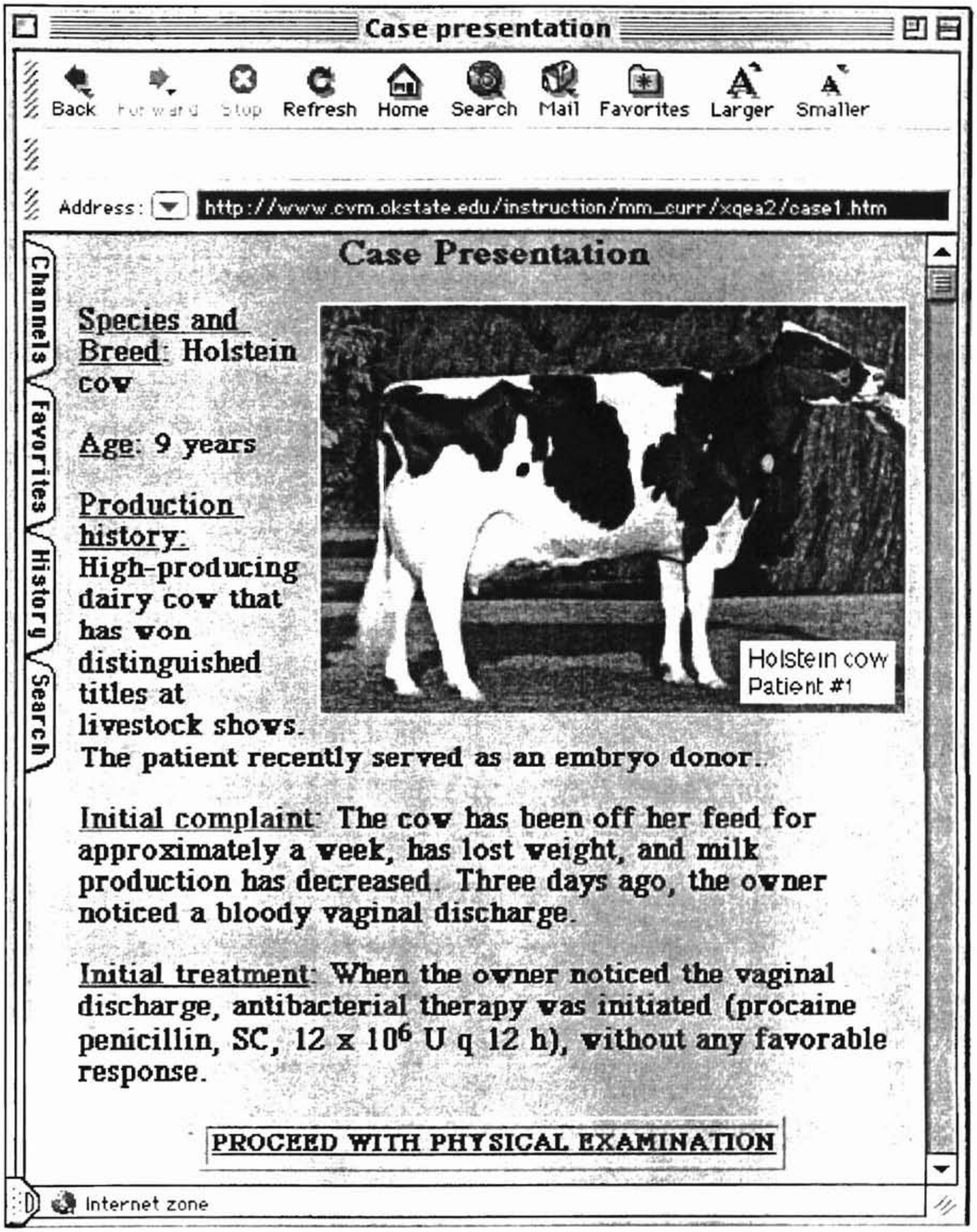

Figure 5. Web page describing presentation of the case, including clinical signalment.

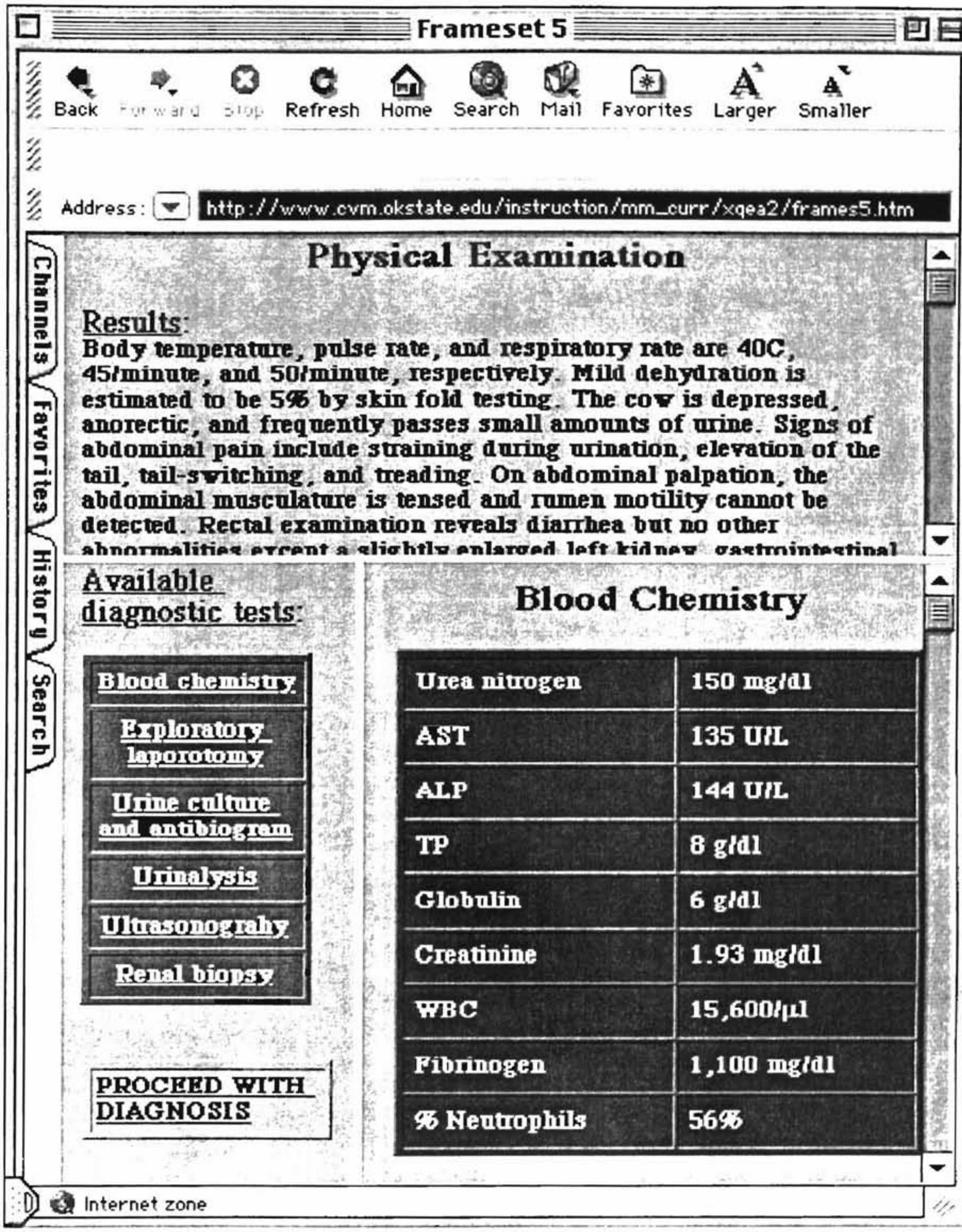

Figure 6. Web page frameset providing requested data in support of making a diagnosis.

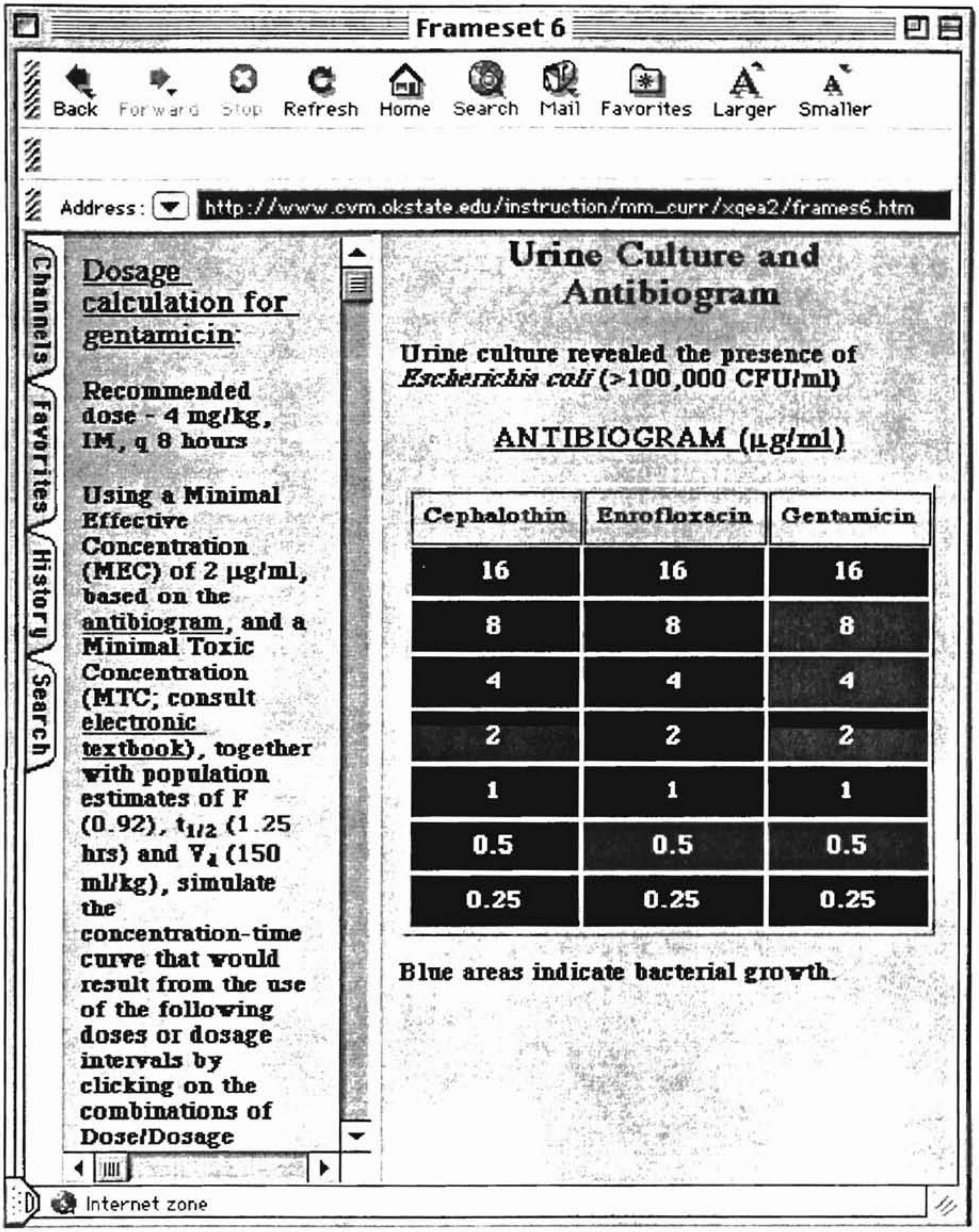

Figure 7. Web page prompting students to develop a recommendation in support of selecting an appropriate dosage based on pharmacokinetic and pharmacodynamic criteria.

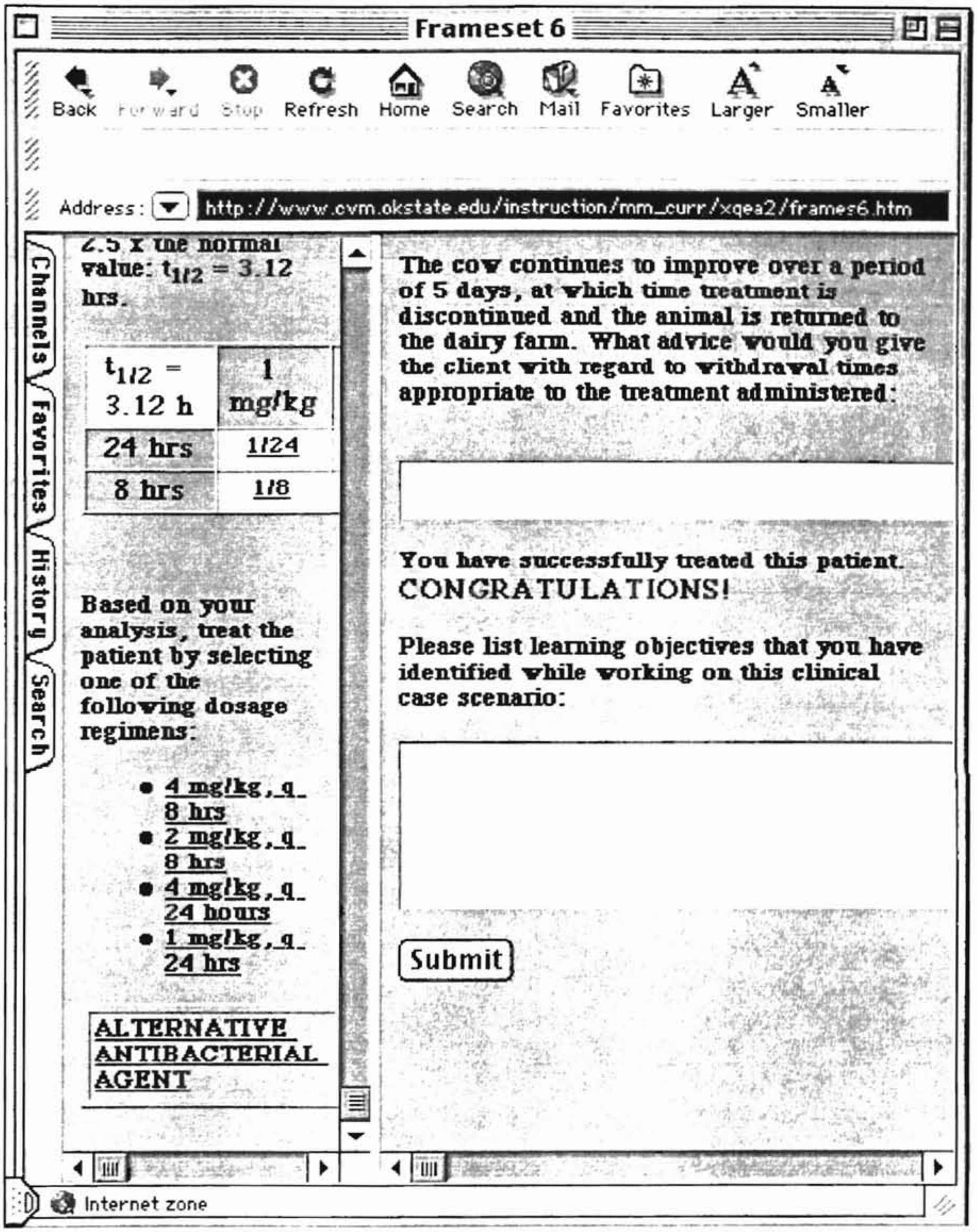

Figure 8. Web page announcing that the student had finally selected an appropriate course of therapeutic management.

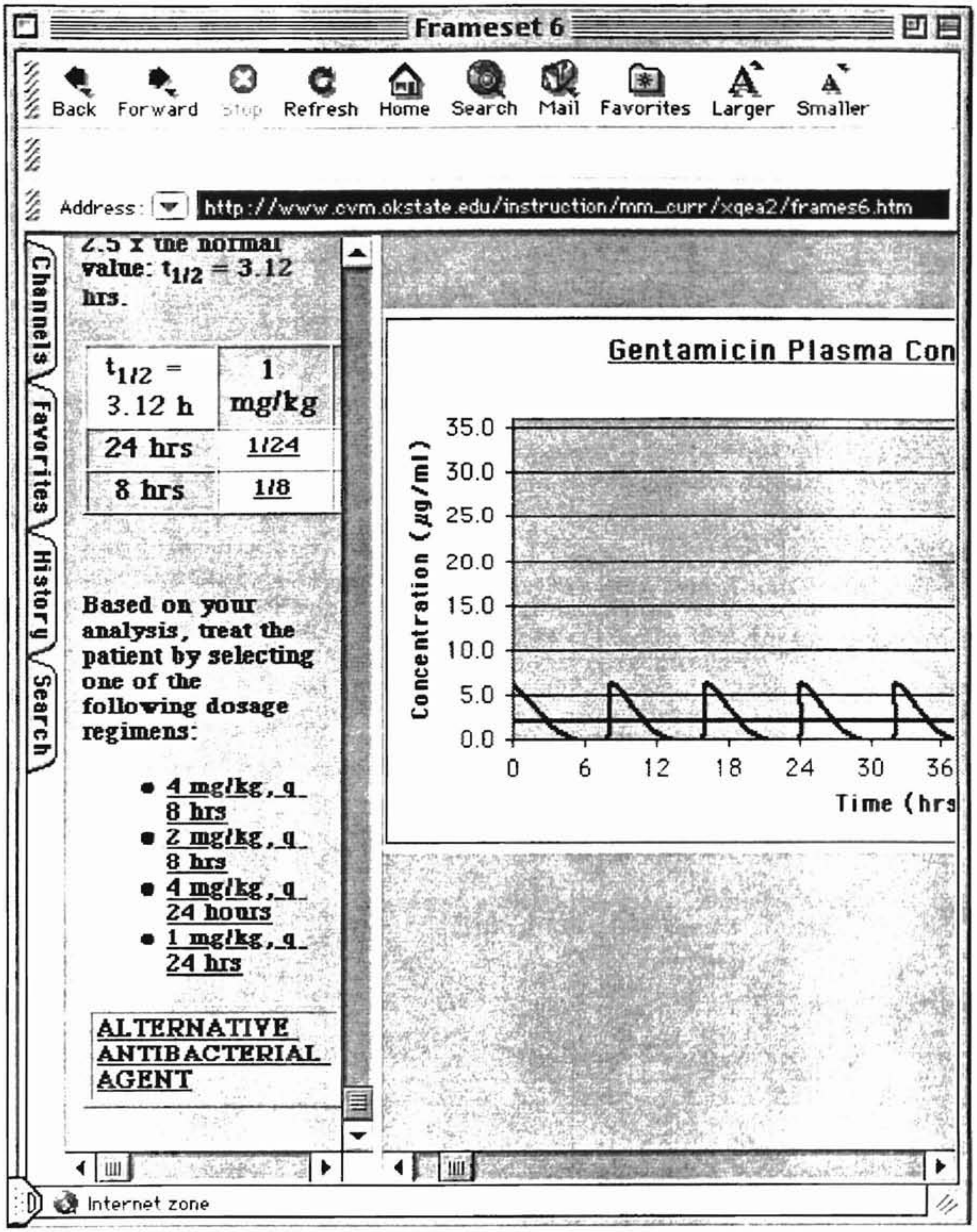

Figure 9. Web page illustrating the effect of dosage and dosage interval on the plasma concentration-time relationship.

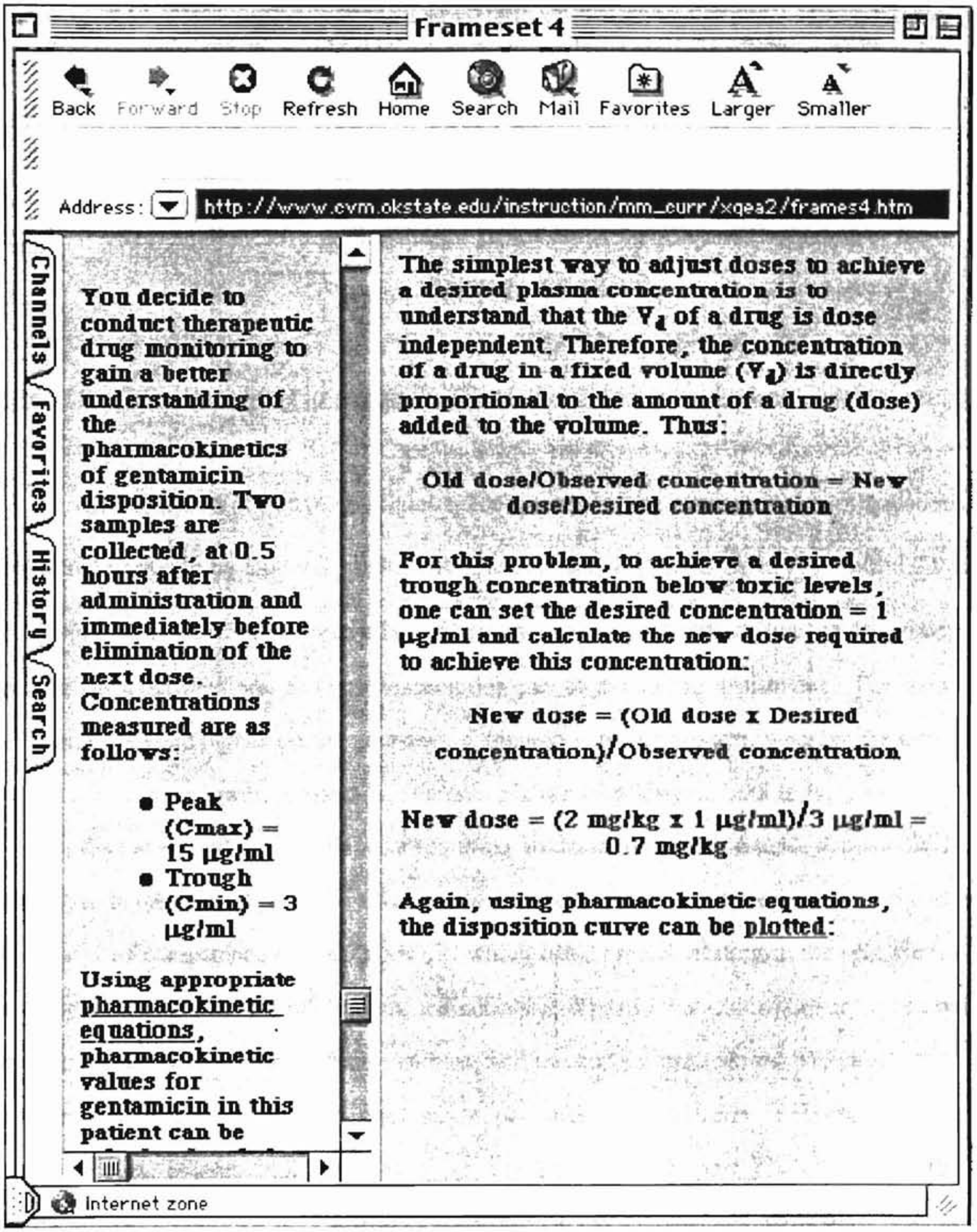

Figure 10. Web page guiding students through the principles and practice of therapeutic drug monitoring.

CHAPTER V

RESULTS

Testing of the effectiveness of the Instructional Module and Evaluation of the Module by Students

Use of Pre- and Post-testing to Assess the Effect of the Module on Student Learning

Of a total of 6 objective, multiple-choice questions, the mean numbers of questions answered correctly by students taking both the pre- and post-tests (n = 17) were 3.24 ± 1.35 and 3.35 ± 1.66, respectively. There was no significant difference in student performance between pre- and post-tests on this part of the testing instrument. The scores of 7 students were higher on the post-test, compared with the pre-test, whereas the scores of 5 students were lower. Generally, students performed poorly on both tests.

On the second part of the tests requiring students to identify criteria that should be employed in the rational selection of effective antibacterial agents, students demonstrated a high level of competence in their answers, which listed criteria relating to the spectrum of activity of antibacterial agents, pharmacokinetic and dispositional characteristics, potential for causing adverse effects or drug residues, and the cost of medication. However, these answers were consistent with the focus of didactic instruction received in prior pharmacology classes and there was no evidence on the post-test of any further development in understanding resulting from use of the module. In particular, students failed to address dosing considerations relating to the effect of dosage and dosage interval on plasma pharmacokinetics and efficacy or the relationship between antibacterial efficacy and either the peak plasma concentration or the duration that plasma concentrations are maintained above minimum inhibitory concentrations, which were themes emphasized in the module.

Evaluation of the Module by Students

Evaluations by students of the module were very supportive. Most students either strongly agreed or agreed that the module was aesthetically pleasing, well organized in a logical manner, and functioned as advertised (Figure 11). Furthermore, most students strongly agreed or agreed that the program was able to provide a meaningful context for the study of the clinical pharmacology of antibacterial agents (Figure 12). Although most students agreed that use of the module promoted learning and development of clinical problem solving abilities (Figure 13), they clearly indicated that their learning was best facilitated when self-study using the computer-based module was combined with personal interaction with the instructor during class discussions (Figure 14). Despite their strong support in favor of the educational potential of the module, it was apparent that they committed relatively little time to its use (an average of 0.98 ± 0.33 hours was committed to working with the program) and made little use of the module elements that provided access to additional information, such as the electronic textbook and other pharmacology web sites (Figure 15). In contradiction to the results of the pre- and post-testing, the majority of students indicated that they had learned a lot or a moderate amount from the computer module alone (Figure 16). As suggested by the evaluations relating to the benefits of class discussions, students felt that their learning resulting from a combination of using the module and participating in instructor-lead discussions exceeded that from using the module alone (Figure 16).

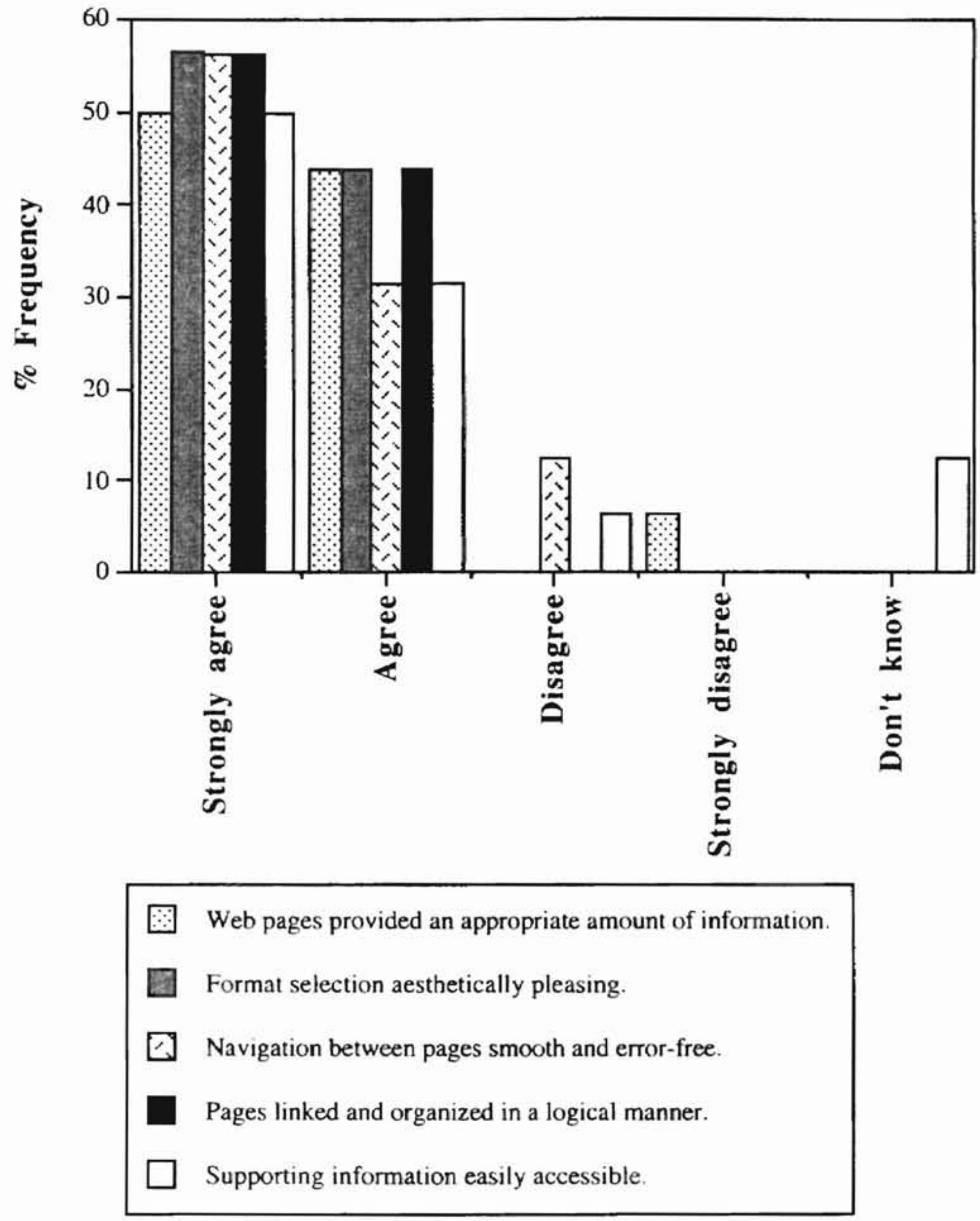

Figure 11. Student ratings of the programming/technology features of the computer-based instructional module, indicating levels of agreement with statements listed in the evaluation instrument (Appendix 2, 1.a, 1.b, 1.c, 1.d, and 1.e).

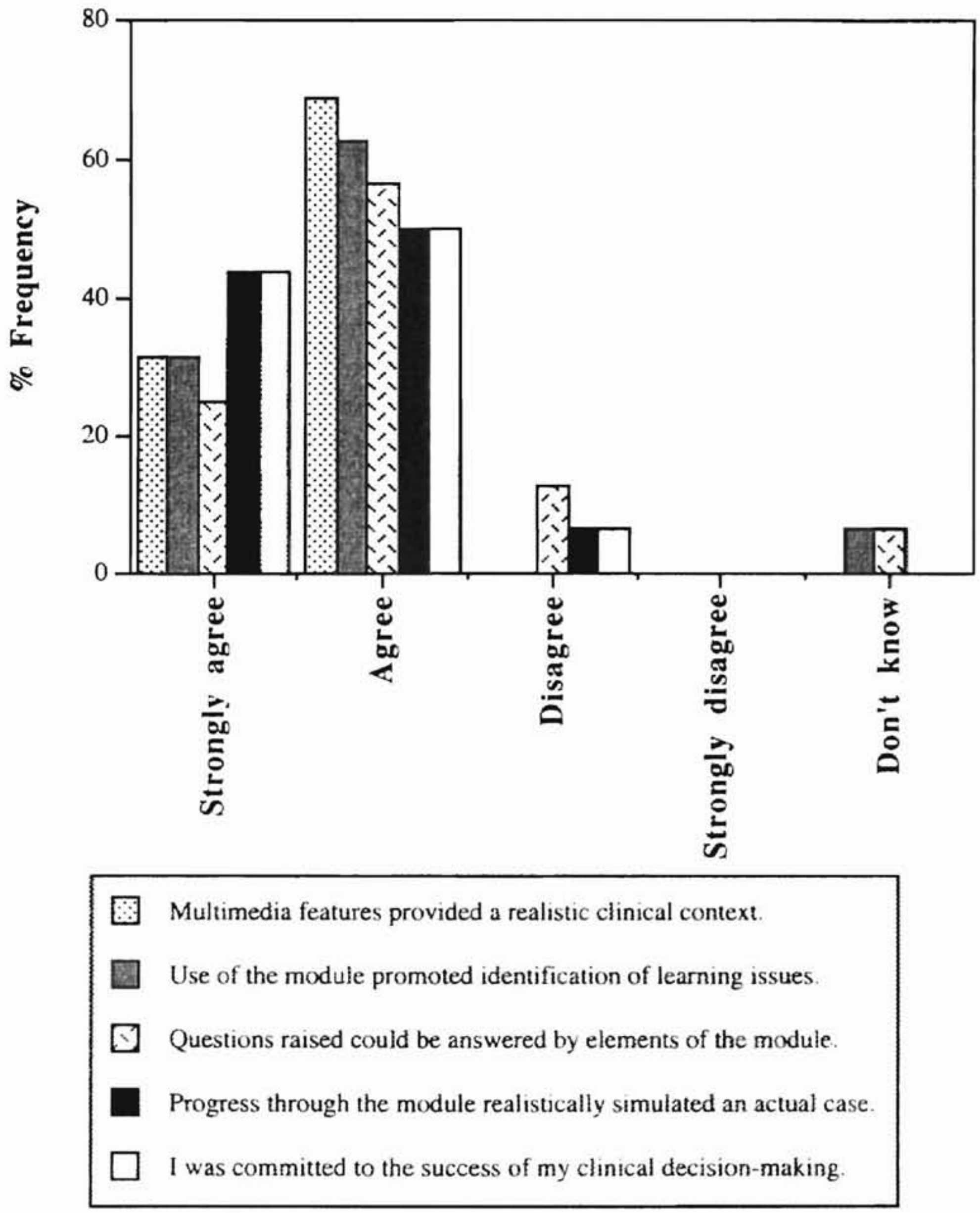

Figure 12. Student ratings regarding the ability of the program to provide a <u>meaningful context</u> for the study of the clinical pharmacology of antibacterial agents, indicating levels of agreement with statements listed in the evaluation instrument (Appendix 2, 2.a, 2.b, 2.c, 2.d, and 2.e).

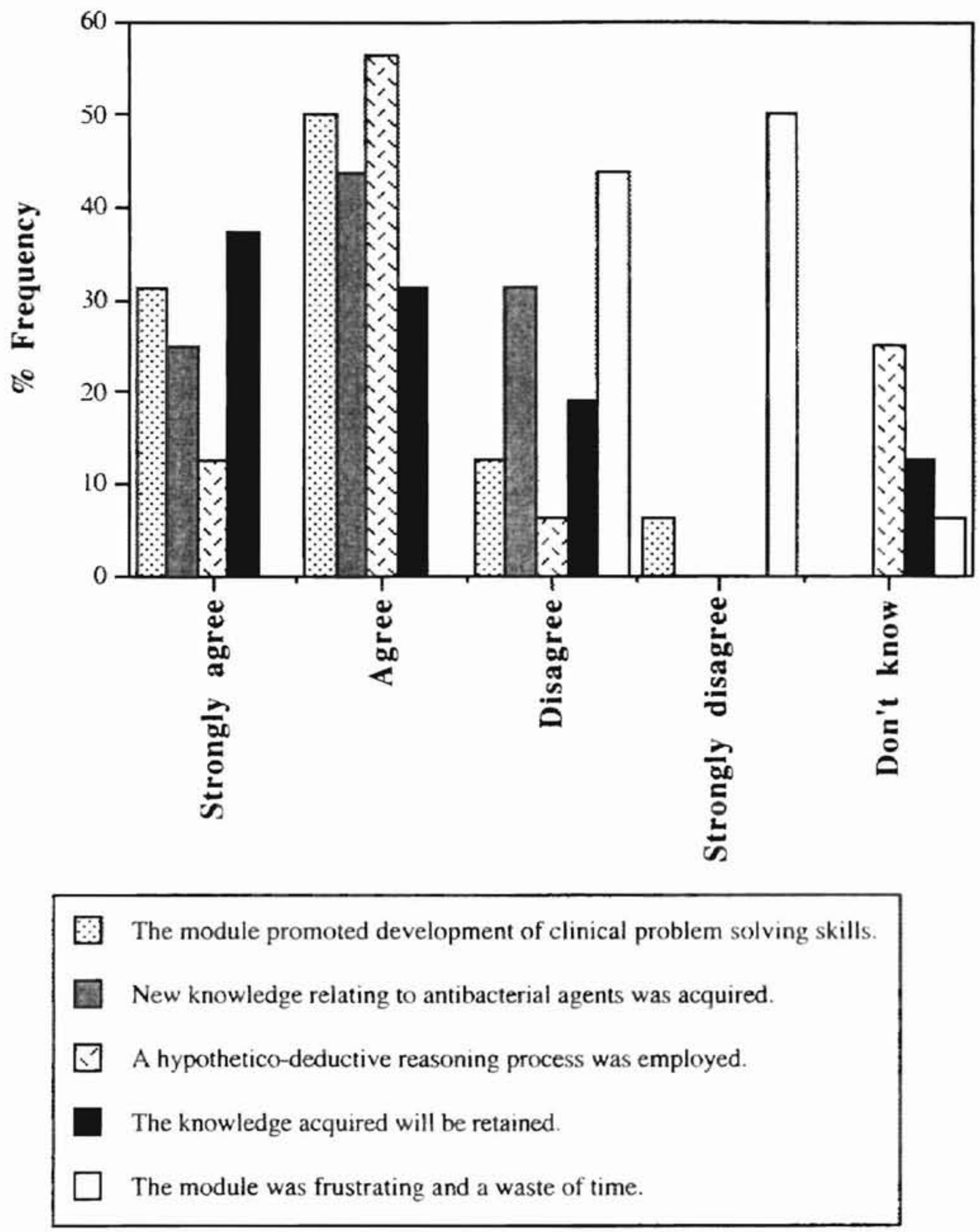

Figure 13. Student ratings assessing the learning that occurred solely as a result of working through the computer-based module, indicating levels of agreement with statements listed in the evaluation instrument (Appendix 2, 3.a, 3.b, 3.c, 3.d, and 3.e).

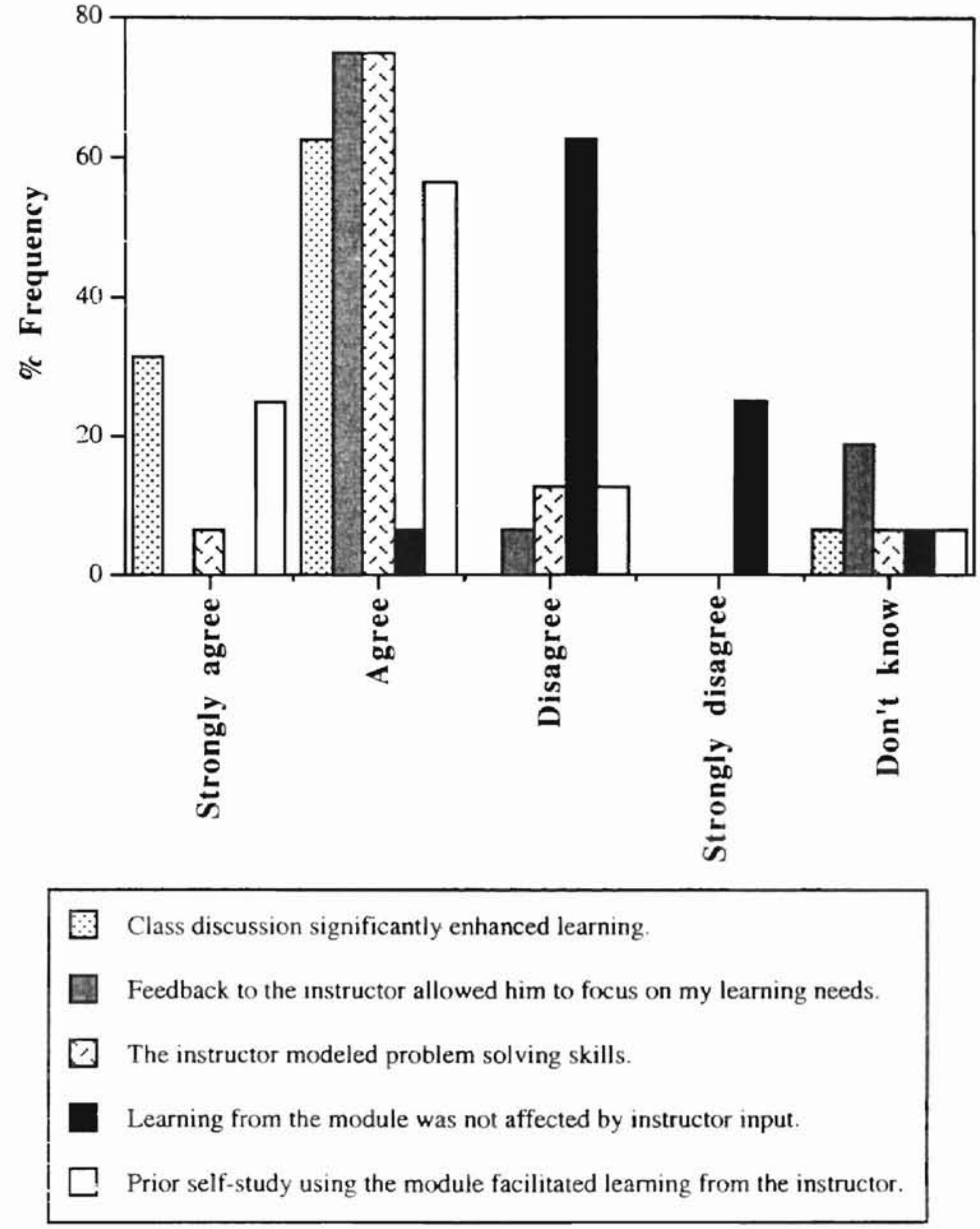

Figure 14. Student ratings regarding the role of the instructor and discussion of the clinical case in class, indicating levels of agreement with statements listed in the evaluation instrument (Appendix 2, 5.a, 5.b, 5.c, 5.d, and 5.e).

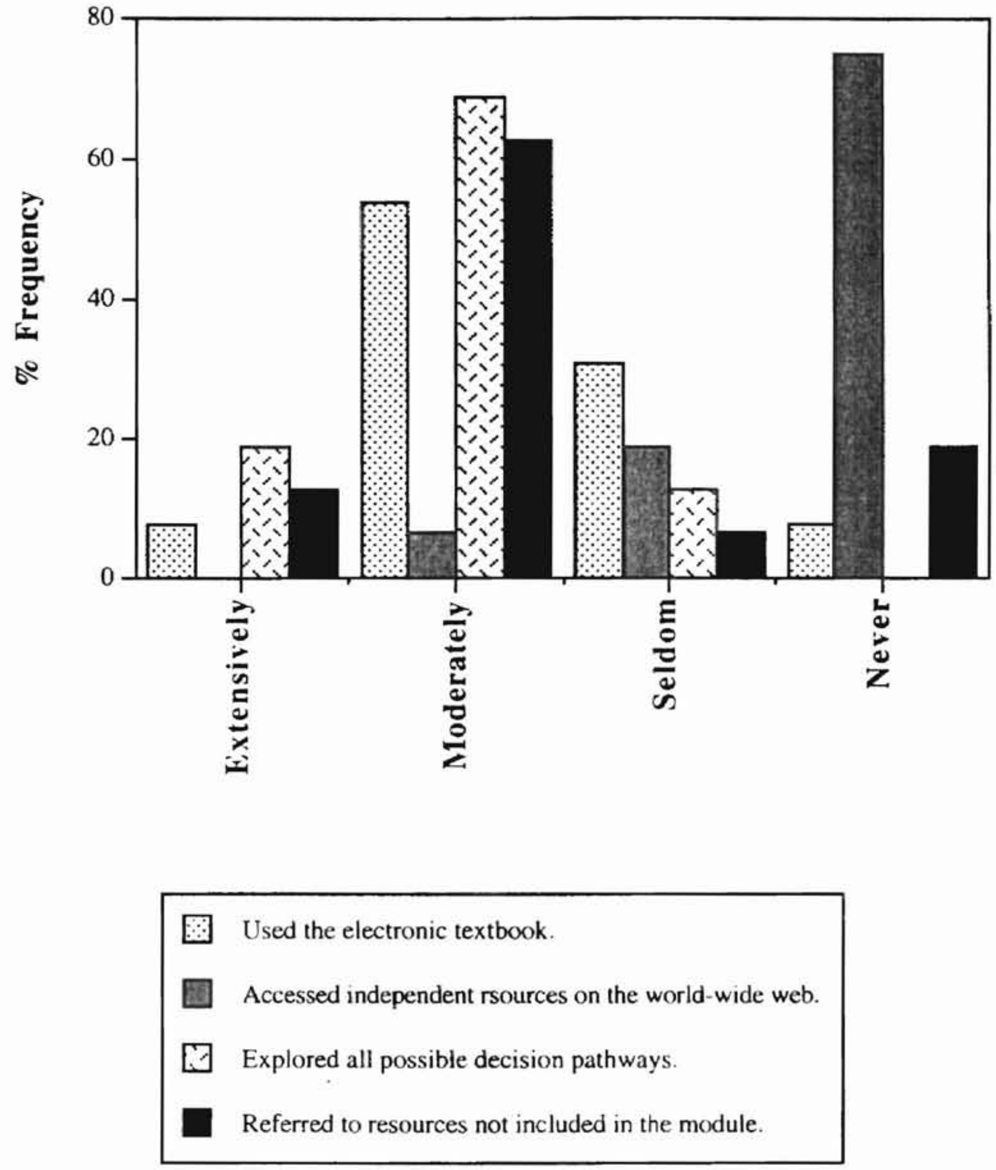

Figure 15. The degree to which students utilized the various elements of the computer-based module, as explored in the evaluation instrument (Appendix 2, 4.a, 4.b, 4.c, and 4.d).

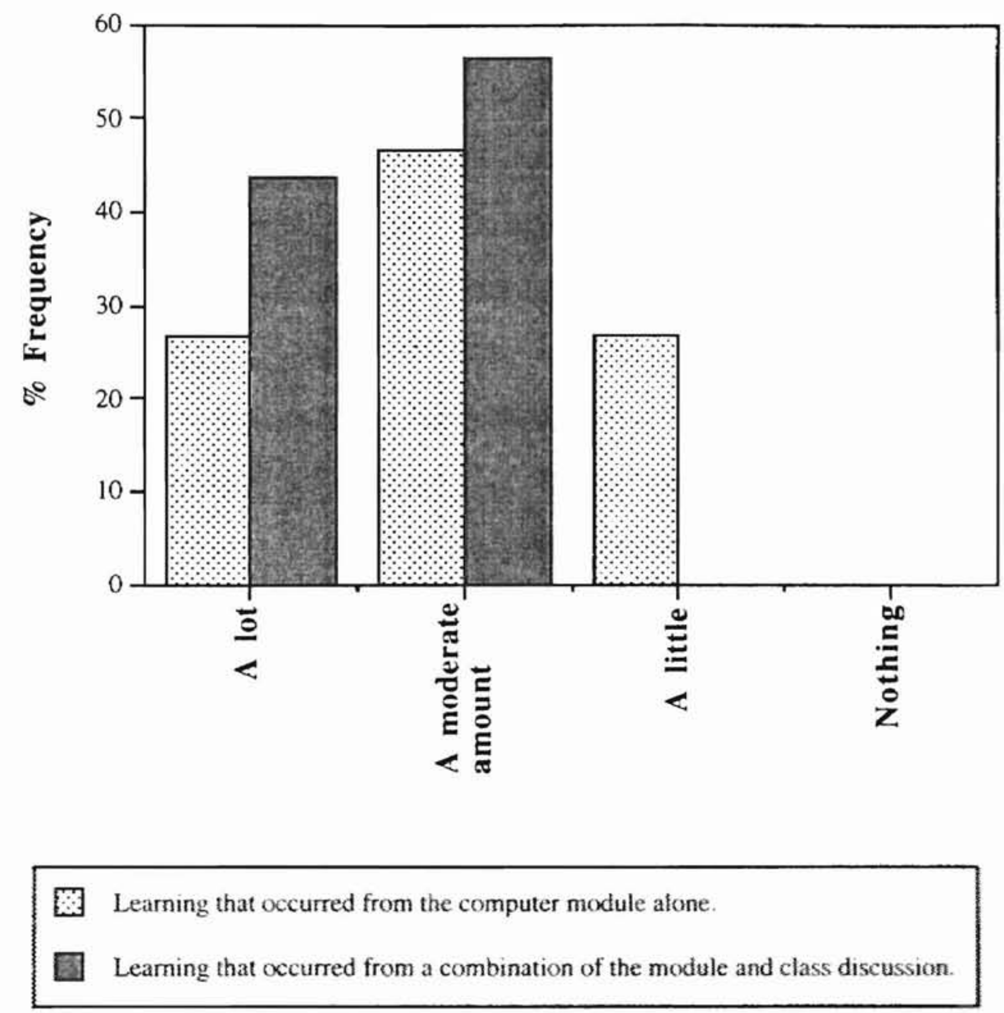

Figure 16. Overall student rating of computer based instruction, as explored in the evaluation instrument (Appendix 2, 6.a and 6.b).

CHAPTER VI

DISCUSSION

Based on the androgogical model of learning developed by Knowles (1980), adult students are best served by an educational process that promotes self-directed study, provides an experiential context for learning, stimulates the identification of learning needs through involvement with real life tasks or problems, and is clearly relevant to anticipated career goals. Considering the context of veterinary medical education, these requirements are usually met during the senior year of most training programs, when students rotate through clinical service units and participate in primary patient care. However, for the first few years of most programs, students usually enroll in basic science courses, including pharmacology, and have less exposure to clinical case material. During this period of training, the multimedia features and interactive capabilities of computers can be used to create appropriate clinical contexts in support of learning.

Student evaluation of the computer-based instructional module indicated that this instructional approach succeeded in creating a meaningful context for the study of the clinical pharmacology of antibacterial agents. Furthermore, students believed that working with the module alone promoted development of their clinical problem solving skills and that the new knowledge acquired was more likely to be retained than if it had been gained by means of didactic lectures. However, while lauding the benefits of self-study using the module, they clearly emphasized their preference for instructional methods that also included direct interactions with the instructor; for example, class discussions. Apparently, instructors bring to the classroom attributes and qualities than cannot be duplicated entirely by computer-based instruction and, even when computer-based instruction is organized to promote development of efficient and effective problem solving skills, there is considerable value in being able to observe an experienced instructor model these skills. The save-results feature of the module was well suited to an instructional approach that employed both self-study, using the computer-based module, and classroom discussion because it enabled the instructor to monitor progress of students, identify problems in understanding, and focus on specific learning issues during the class discussions.

Student perceptions regarding the learning achieved using the module were inconsistent with the results of the pre- and post testing, which failed to demonstrate any significant effect on knowledge acquisition. Although the tests were intended to assess both factual knowledge as well as knowledge of a more developmental nature, it is possible that they were not appropriately designed to evaluate the type of learning promoted by experiential instructional techniques. Generally, pedagogical models of instruction and learning assume that teachers have the responsibility of identifying learning needs and that learning effectiveness can be assessed by measuring quantifiable competencies, such as acquisition of factual knowledge. There is no doubt that the tests focused on measuring the success with which implicit competencies were achieved, such as knowledge relating to the pharmacological properties of antibacterial agents, whereas an important intended goal of the module was to promote development of clinical problem solving skills. This developmental goal was more consistent with the goals of androgogical models of instruction and is more difficult to measure than acquisition of factual knowledge. Previous studies evaluating the effectiveness of problem-based learning (PBL), which is based on the androgogical model of student-centered instruction, have encountered similar assessment challenges and have confirmed the relevance of educational goals to outcomes assessment: Two meta-analyses of studies evaluating the effectiveness of PBL (Vernon and Blake, 1993; Albanese and Mitchell, 1993) concluded that traditional didactic instructional methods were more effective in promoting acquisition of factual knowledge, as measured by performance on the Board of Medical Examiners examination, whereas PBL was significantly superior with respect to program evaluation by students, clinical performance, study behaviors, and student attitudes.

Nevertheless, the poor performances of students on both the pre- and post-tests were disappointing and could simply be related to the relatively short time that students spent working through the module (approximately 1 hour). Based on their commitment of time and as well as their responses to questions investigating their use of the various elements of the module (Figure 15), students generally did not make use of the links to information resources or explore learning issues beyond the immediate requirements of the clinical case. Therefore, it is questionable whether they committed enough time to developing a cognitive scaffolding that would allow them to address problems not encountered explicitly in the module. Indeed, their answers to the second part of the tests suggested that using the module failed to accomplish any refinement in their understanding of general principles of antibacterial therapy. Considering that students indicated that the module provided a realistic clinical context, this lack of enthusiasm for further study contradicts the assumption that self-directed learning is promoted by exposure to real life tasks or problems that are directly applicable to their anticipated careers. The module could possibly have been employed more beneficially if its use had constituted a graded requirement of the course, thus competing more effectively with other courses for available time limited by the busy professional curriculum.

The range of results obtained from use of the testing and evaluation instruments underscores the importance of using a combination of assessment methods, including both quantitative and qualitative, to fully evaluate the success of the many complex and interrelated activities involved in biomedical education. This observation is consistent with that of Schwartz et al (1994), who correlated knowledge gain, measured using pre- and post tests, with a combination of quantitative clinical performance measures and determined that single deletion of most performance measures lowered the reliability of the overall assessment. Reliance on the pre-and post-test results alone would have discouraged further development of computer-based modules whereas student evaluations indicate that, when used in conjunction with other instructional approaches, they represent a valuable instructional tool.

In conclusion, development and use of a computer-based instructional module, consisting of a clinical case, multimedia features, links to information resources, and interactive decision pathways, provided a relevant and engaging context for student-centered instruction, as demonstrated by student evaluations. While it is uncertain whether use of the module alone promoted development of clinical reasoning and problem solving skills, there was no evidence of a significant positive effect on acquisition of factual information or discovery and cognitive organization of new knowledge beyond that already accomplished by prior didactic lectures. Clearly, this type of computer-aided instruction is best employed in combination with other instructional approaches, such as instructor-lead class discussions.

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APPENDICES

Appendix 1

Evaluation of a Computer-Based Instructional Module - Pre-test/Post-test

1. In comparison with a dosage regimen of 5 mg/kg administered every 12 hours, how would the multiple-dose plasma concentration-time curve resulting from a dose of 5 mg/kg administered every 8 hours be different?

   a. Steady state would be achieved more rapidly after initiation of therapy.
   b. Trough concentrations at steady state would be higher
   c. At steady state, the relationship, ([peak]-[trough])/[peak], would be lower.
   d. b and c
   e. a and b

2. Gentamicin efficacy is maximized and toxicity is minimized when dosage regimens with relatively:

   a. low dose and short dosage interval are employed.
   b. high dose and short dosage interval are employed.
   c. high dose and long dosage interval are employed.
   d. low dose and long dosage interval are employed.

3. In comparison with the multiple-dose plasma concentration-time curve resulting from administration of ceftiofur to a healthy animal, the curve in an animal with reduced creatinine clearance (at steady state):

   a. has a higher value for the ratio, ([peak]-[trough])/[peak].
   b. has the same peak concentrations but higher trough concentrations.
   c. is the same as that in a healthy animal
   d. has higher peak and trough concentrations.
   e. has lower peak and trough concentrations.

4. If a dosage regimen of 10 mg/kg administered every 12 hours results in a trough concentration of 4 µg/ml, which one of the following adjusted dosage regimens could be employed to decrease the trough concentration to the safe level of 1 µg/ml?

   a. 2.5 mg/kg administered every 24 hours
   b 10 mg/kg administered every 24 hours
   c 5 mg/kg administered every 12 hours
   d. 2.5 mg/kg administered every 12 hours
   e. 5 mg/kg administered every 24 hours

5. Which of the following statements is true for ceftiofur antimicrobial action?

   a. Efficacy is related to the time that the plasma concentration exceeds the MIC.
   b. Efficacy is related to the magnitude of the peak concentration
   c. Efficacy depends on the postantibiotic effect.
   d. Efficacy is optimized when relatively high doses and long dosage intervals are employed.
   e. b and c

continued

Appendix 1 (continued)

6. Which of the following antimicrobial agents will achieve the highest concentrations of active drug in the urinary bladder?

   a. Tilmicosin
   b. Enrofloxacin
   c. Chloramphenicol
   d. Florfenicol
   e. Erythromycin

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7. In the space below, list 5 important criteria that should be considered when selecting an antimicrobial agent for use against a soft-tissue infection in a dairy cow.

   a.

   b.

   c.

   d.

   e.

Appendix 2

Evaluation of a Computer-Based Instructional Exercise

1. With reference to the programming/technology features of the computer-based instructional module, please indicate your level of agreement with each of the following statements by circling the appropriate number:

	Statement	Strongly agree	Agree	Disagree	Strongly disagree	Don't know
a.	Individual web pages provided an appropriate amount of information, without being cluttered with excessive content.	1	2	3	4	5
b.	The selection of fonts, font sizes, and colors was aesthetically pleasing.	1	2	3	4	5
c.	Navigation between pages and submission of textual answers to questions occurred smoothly and without error.	1	2	3	4	5
d.	The pages were linked and organized in a logical manner.	1	2	3	4	5
e.	Supporting information resources, such as the electronic textbook and www sites, could be easily accessed, without disrupting progress through the clinical case.	1	2	3	4	5

Please use the space below to comment on any aspect of the programming/technology features of the module:

continued

Appendix 2 (continued)

2. Regarding the ability of the program to provide a meaningful context for study of the clinical pharmacology of antibacterial agents, please indicate your level of agreement with each of the following statements by circling the appropriate number:

	Statement	Strongly agree	Agree	Disagree	Strongly disagree	Don't know
a.	The multimedia features of the module helped me to imagine what it would be like to treat an actual clinical case.	1	2	3	4	5
b	As I progressed through management of the case, I identified issues about which I wanted to learn more.	1	2	3	4	5
c.	Questions raised while working on the case could be answered by accessing parts of the module.	1	2	3	4	5
d.	Progress through the module realistically represented the steps I might take in my management of an actual case.	1	2	3	4	5
e.	I cared about whether my selections of treatments were appropriate or not.	1	2	3	4	5

Please use the space below to comment on the ability of the program to provide a meaningful context for study of the clinical pharmacology of antibacterial agents:

continued

Appendix 2 (continued)

3. Please assess the learning that occurred solely as a result of working through the computer-based module by indicating your level of agreement with each of the following statements (circle the appropriate number):

	Statement	Strongly agree	Agree	Disagree	Strongly disagree	Don't know
a.	The module helped me to develop a way to solve clinical problems and to treat clinical cases.	1	2	3	4	5
b.	I learned information about antibacterial agents and their clinical use that I did not know previously.	1	2	3	4	5
c.	The way I thought about the clinical case was similar to that described in the "student-centered learning" page.	1	2	3	4	5
d.	I believe that I am more likely to remember what I have learned than if the information had been presented in a didactic lecture.	1	2	3	4	5
e.	Working through the module was frustrating and a waste of time.	1	2	3	4	5

Please use the space below to comment on the learning that occurred solely as a result of working through the computer-based module:

continued

Appendix 2 (continued)

4. To what degree did you do the following while working through the case:

	Statement	Extensively	Moderately	Seldom	Never
a.	Make use of the electronic textbook.	1	2	3	4
b.	Access the www sites listed at the bottom of the home page.	1	2	3	4
c.	Explore all possible decision pathways, irrespective of whether they turned out to be appropriate or not.	1	2	3	4
d.	Refer to resources not included in the module, such as class notes or the advice of other students.	1	2	3	4

5. With regard to the role of the instructor and discussion of the clinical case in class, please indicate your level of agreement with each of the following statements by circling the appropriate number:

	Statement	Strongly agree	Agree	Disagree	Strongly disagree	Don't know
a.	Discussion of the case in class significantly enhanced my learning about the clinical pharmacology of antibacterial agents	1	2	3	4	5
b	Submission of answers while working through the case allowed the instructor to focus on my learning needs.	1	2	3	4	5
c.	The instructor helped me to develop my problem solving skills by modeling those skills in class.	1	2	3	4	5
d.	Learning from the computer module would have been just as effective without input from the instructor	1	2	3	4	5
e.	Prior self-study using the computer-based module facilitated any learning that occurred as a result of discussion of the case in class.	1	2	3	4	5

continued

Appendix 2 (continued)

6. Please provide an overall rating of the computer-based instruction by selecting the number corresponding to the appropriate answer to each of the following questions

Question	A lot	A moderate amount	A little	Nothing
a. How much did you learn from the computer module alone?	1	2	3	4
b. How much did you learn from the combination of computer module and class discussion?	1	2	3	4

7. How much time did you spend working on the computer-based module? ________________

8. Please list below what you think were the primary learning objectives of this computer-based learning exercise?

Appendix 3

Oklahoma State University
Institutional Review Board

Protocol Expires: 7/9/01

Date : Monday, July 10, 2000 **IRB Application No: ED00290**

Proposal Title: DEVELOPMENT AND EVALUATION OF A COMPUTER BASED INSTRUCTIONAL MODULE FOR THE STUDY OF ANTIBACTERIAL DRUGS

Principal Investigator(s) :

Cyril Clarke
264 Vet Med
Stillwater, OK 74078

Michael Mills
306 Willard
Stillwater, OK 74078

Reviewed and Processed as: Exempt

Approval Status Recommended by Reviewer(s) : Approved

Signature :

Carol Olson, Director of University Research Compliance

Monday, July 10, 2000
Date

Approvals are valid for one calendar year, after which time a request for continuation must be submitted. Any modifications to the research project approved by the IRB must be submitted for approval with the advisor's signature. The IRB office MUST be notified in writing when a project is complete. Approved projects are subject to monitoring by the IRB. Expedited and exempt projects may be reviewed by the full Institutional Review Board.

VITA

Cyril Roy Clarke

Candidate for the Degree of

Master of Science

Title: DEVELOPMENT AND EVALUATION OF A COMPUTER-BASED INSTRUCTIONAL MODULE FOR THE STUDY OF ANTIBACTERIAL DRUGS

Major Field: Higher Education

Biographical:

Personal Data: Born in Johannesburg, South Africa on October 13, 1958, the son of David and Petronella Clarke.

Education: Completed high school at St. Stithians College in December, 1975; received the Bachelor of Veterinary Science degree from the University of Pretoria in June of 1981 and the Doctor of Philosophy degree from the School of Veterinary Medicine, Louisiana State University in December of 1987; completed requirements for the Master of Science degree in Higher Education and Educational Administration in July of 2000.

Professional Experience: Practicing veterinarian form July 1981 to June 1983; faculty member of the College of Veterinary Medicine, Oklahoma State University from 1987 to present.