Development and Evaluation of an Interactive Internet-Based Pharmacokinetic Teaching Module

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An internet-based pharmacokinetic teaching module has been developed. This module is interactive, learner-centered, asynchronous, and requires minimal computer knowledge to operate. The main components of the module are the concept presentation, pharmacokinetic simulation exercise and self-assessment questions. Assessment of the module's effectiveness as a teaching tool showed that the module was very effective in teaching the steady state concept to undergraduate pharmacy students. The majority of the students who used this module indicated that if they have the option to choose the format for delivering the course content of their pharmacokinetics class, they would prefer the computer-based format. This is because most of the students think that well-designed computer-based teaching materials can be more effective than printed materials. Such computer-based and internet-based pharmacokinetic instructional materials can be very valuable not only for conventional students teaching but also for continuing education, distance-learning, and in-job training programs.

INTRODUCTION

The use of computers to deliver educational materials has been increasing over the past decade, because of the significant increase in the availability and the capability of a wide variety of computer hardware and software. The widespread availability of the internet access makes it easier to distribute such computer-based educational materials. Computers in general and the internet in particular have been used frequently to deliver instructional materials for health professions(1-6). A meta-analysis of twenty-nine studies that compared computer-based instruction and conventional teaching in nursing education showed that the use of computers resulted in improvement in the teaching effectiveness in the majority of the studies(6). Studies have shown that the world wide web can be very useful environment for interactive medical instruction by integrating images and text, and sharing information among multiple institutions(1,5). In pharmacy education, computer-based instructional programs have been shown to be very useful in increasing the student's understanding of theoretical concepts(2-4).

Pharmacokinetics classes are ideal for computer-based instruction. This is because the different pharmacokinetic parameters that govern the drug concentration-time profile in the body can be related together by mathematical expressions. This makes graphical presentation of the drug concentration-time profile very useful for presenting the interplay between the different pharmacokinetic parameters, and for understanding how the change in any of these parameters affects the overall disposition of the drug in the body. For this reason, computer simulations have been used effectively as a tool for teaching pharmacokinetics(7-12). Pharmacokinetic computer simulations allow visualization of the drug concentration-time profile during the simulated situation. This visual appreciation is very important in understanding the basic pharmacokinetic principles.

The primary purpose of this paper is to describe a prototype interactive, internet-based, learner-centered, and asynchronous module for teaching the basic principles of pharmacokinetics. The effectiveness of this module as a teaching tool for the basic principles of pharmacokinetics was evaluated. The representative topic chosen for this prototype module is the steady state concept during multiple drug administration.

MATERIALS AND METHODS

Planning

Advance planning is considered a crucial step for the development of effective internet-based instructional materials(13). The primary objective of the module was to teach the steady state concept during multiple drug administration. This module was designed primarily for undergraduate pharmacy students and anyone who will be interested in learning about basic pharmacokinetic concepts. The plan was to design a module that can be operated entirely with a computer mouse rather than a keyboard, in order to accommodate the wide range of computer skills of the expected users. Because of the nature of the world wide web and the fact that most of the users will be in an open unattended setting, help was provided whenever it was possible and the module was designed to respond to all possible actions by the user. The expected time to run the entire module was one to one and half hours.

Module Description

This module is a stand-alone application developed utilizing the commercially available Authorware® software (Macromedia, Inc., San Francisco, CA). The developed module is installed on the internet (http://barbital.phar.wsu.edu/hedaya/module01/) and can run on the Windows and the Macintosh platforms. However all

[1]To run this module you have to download and install the plug-in "Shockwave for Authorware" on your internet browser. The appropriate "Shockwave for Authorware" for your internet browser and for your operating system can be obtained from: www.macromedia.com. A link to this site is provided in an introductory page for the module (http://barbitol.phar.wsu.edu/hedaya/module01/).

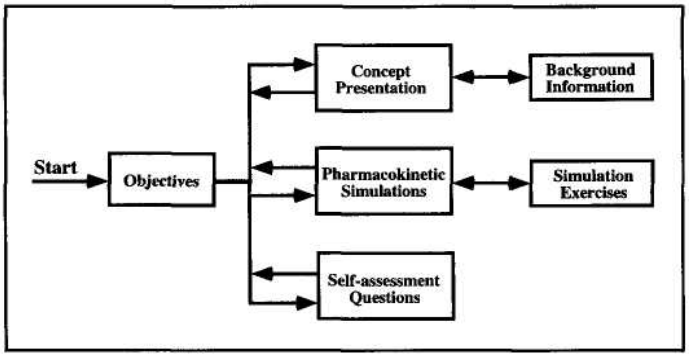

Fig. 1. Schematic presentation of the module structure showing its major components. The arrows represent the possible navigation directions

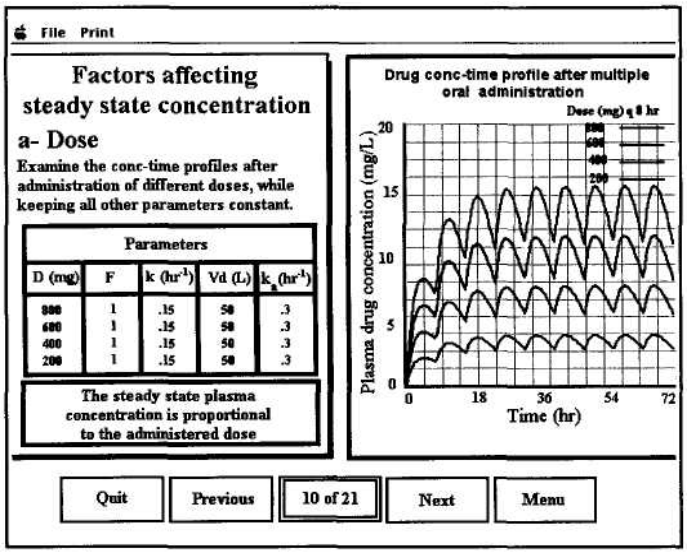

Fig. 2. A representative example of the information presented in the concept presentation. The figure shows how the change in the dose affects the steady state plasma concentrations.

internet browsers require the installation of a special plug-in program to run this module[1].

The module starts with a clear statement of the objectives followed by the main components which are divided into three parts: concept presentation, pharmacokinetic simulation, and self-assessment questions (Figure 1). The module is designed to let the user control the pace and the sequence of the presentation. The design also allows the user to navigate easily from one part of the presentation to the other.

Objectives. The module starts with a statement about the specific objectives of the presented information. These objectives not only include knowledge and comprehension of the presented information but also include application, analysis, utilization and evaluation of this information, to ensure maximum benefits for the user. Specifically, after completing the entire module the user should be able to: (*i*) know and comprehend the steady state concept during multiple drug administration; (*ii*) identify the factors that affect the steady state plasma concentration during multiple drug administration; (*iii*) calculate the steady state drug concentrations and patient's pharmacokinetic parameters during multiple drug administration; (*iv*) analyze the effect of changing one or more of the pharmacokinetic parameters

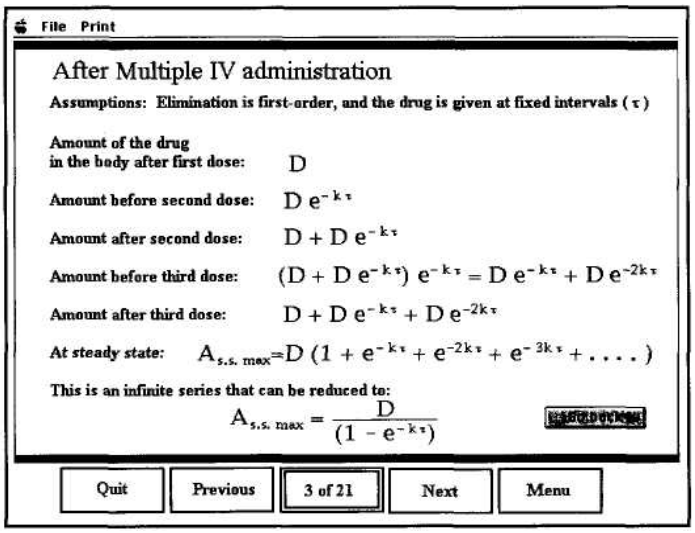

Fig. 3. A representative example of the background information that the user can access. The figure shows the mathematical derivation of the equation that describes the maximum amount of the drug in the body during multiple iv administration.

on the steady state plasma concentration during multiple drug administration; (*v*) recommend dosing regimens to achieve specific plasma concentrations in particular patients; (*vi*) evaluate the appropriateness of certain dosing regimens in specific patients.

Concept Presentation. The main body of the module starts with an introduction of the pharmacokinetic concept. The concept presentation utilizes text and graphics to clearly illustrate the presented information (Figure 2). This presentation is concise and is kept to the minimum amount of information required to introduce the concept. Although this component is designed as a longitudinal presentation to ensure that the user goes through all the necessary information, the presentation is vertically hyper-linked to additional background information. These links include simple definition of terms, derivations, and short presentations (Figure 3). Also, the presentation can be linked to other modules when additional topics become available. Again this background information is presented in the form of text and graphics. This format of the concept presentation places the user in control of the pace of the presentation. Users with good background about the concept, will go through the presentation faster than users who will require frequent access to the background information. This part of the module helps the user know and comprehend the general concept (objective 1, knowledge and comprehension).

The concept presentation also includes simple examples that the user can solve to reinforce specific important points in the presentation. The answers of these examples are given step-by-step to direct the user to the right solution. These examples are included to make sure that the user not only know the presented information, but also can apply this information in other simulated situations, (objective 2, application).

Pharmacokinetic Simulations. The second part of the module is a pharmacokinetic simulation exercise. This component is very important to make sure that the user can analyze, utilize, and evaluate similar or related information in other situations. This pharmacokinetic simulation is designed in a for

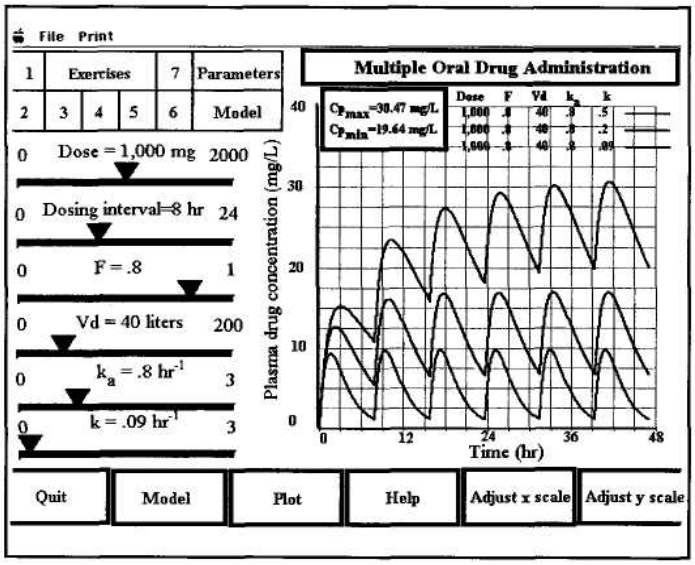

Fig. 4. A representative example of the computer simulations. The figure shown the effect of changing the elimination rate constant on the steady state plasma concentrations, when all other parameters are kept constant.

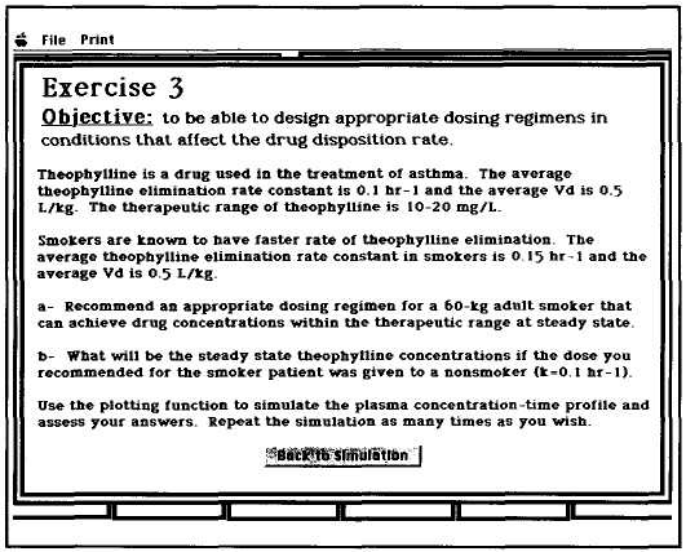

Fig. 5. A representative example of the exercises provided to guide the simulations. The figure shows an exercise to design a dosing regimen in a condition that affects the drug disposition.

mat that makes it interactive, user-friendly and requires minimal computer knowledge to operate. All the functions included in this simulation exercise such as changing the simulation scale, on-line help, selecting the value for each parameter, and starting the simulation can be done by using the computer mouse. The plasma concentrations are computed based on the selected parameter values utilizing a numerical method and the resulting drug concentration-time profiles can be plotted on a linear scale and on a semilog scale.

The pharmacokinetic simulation exercise starts with a screen that contain the pharmacokinetic model used in the simulation. In the presented module, a one compartment pharmacokinetic model with first-order absorption and first-order elimination was used. The main screen in the simulation exercise is where the values for the pharmacokinetic parameters are selected and the plasma concentration-time profiles are plotted. Each of the pharmacokinetic parameters that affect the plasma concentration-time profile (*i.e.*, dose, dosing interval, bioavailability, absorption rate constant, and elimination rate constant) is presented as a slider (Figure 4). The user can slide this slider on a scale to choose the desired value for the parameters. The selected value for each parameter is continuously displayed. The user can change the scales for the time and concentration axes and can get help regarding how to run the simulation. The user is provided with the appropriate message when the value of any of the parameters is missing or when steady state is not achieved during the simulation time.

The computer simulation is supplemented with several suggested exercises that the user can go through to ensure the maximum benefit of this activity. One of the exercises suggests that the user changes one or more of the pharmacokinetic parameters and examine the effect on the drug concentration-time profile. This is very important in understanding the interplay between the different pharmacokinetic parameters and analyzing how the change in these parameters affects the overall pharmacokinetic profile of the drug (Figure 4). This exercise should help the user understand the interrelations between the different pharmacokinetic parameters (objective 3, analysis).

Another exercise asks the user to utilize his/her knowledge to design dosing regimens (dose and dosing interval) to achieve therapeutic drug concentrations at steady state, given specific values for the pharmacokinetic parameters. Also, the user is asked to design appropriate dosing regimens during disease states or conditions that can affect the disposition of the drug (Figure 5). Simulation of the drug concentration-time profile resulting from the recommended dosing regimen gives the user immediate feedback to see if the recommended dosing regimen was appropriate, or changes should be made. The user can repeat these simulations until the desired goal of selecting an appropriate dosing regimen is achieved (objective 4, utilization).

The exercises also ask the user to evaluate the appropriateness of certain dosing regimens for patients during different disease states. The user can also evaluate the outcome of administration of the average drug doses during disease states. Simulation of the drug concentration-time profile allows the user to check if his/her evaluation was appropriate (objective 5, evaluation).

Self-assessment Questions. The final component of the module is the self-assessment questions. When the user feels that he/she has mastered the presented information, his/her performance can be evaluated with a group of multiple choice questions. The user is asked to answer a set of questions selected at random from larger number of questions. After each question the user is given an immediate feedback for his/her performance in answering the question (Figure 6). At the end of the self-assessment questions the user is given feedback about his/her overall performance in answering all the questions.

ASSESSMENT

The effectiveness of this module as a teaching tool was evaluated by comparing the performance of pharmacy students in solving a pretest and a posttest given before and after using the module. The second professional-year pharmacy students were utilized in this evaluation process. For this evaluation process the module was modified so that after the student input an identification number a set of 10 multiple-

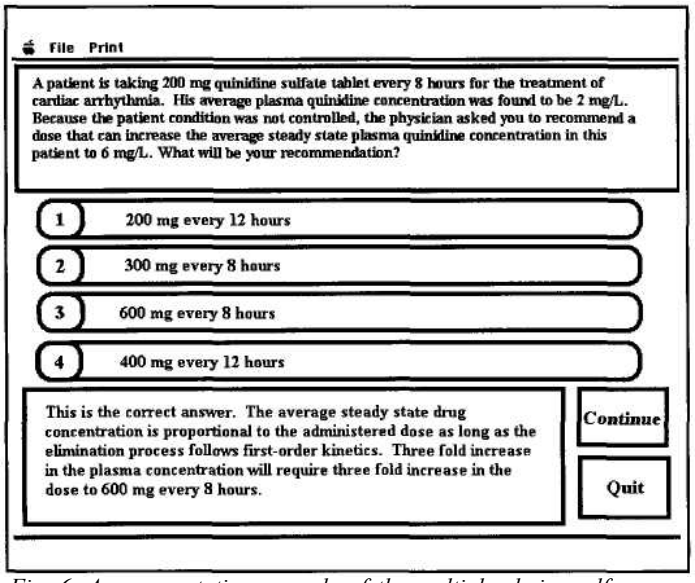

Fig. 6. A representative example of the multiple-choice self-assessment questions. The figure shows the question and the feedback that immediately appears after answering the question.

choice questions was presented. The students were encourage to try to answer these pretest questions to the best of their ability. The students did not get any feedback regarding their performance in answering the questions in the pretest. After the pretest the students were able to use the introduction and the simulation components of the module without any time restriction, until they felt comfortable with the presented information. The student were then directed to take a posttest consisted of a set of 10 multiple-choice questions. The students did not get any feedback after answering each question, however they were presented with the number of correct answers they made after the end of the entire posttest. After the posttest, the module was terminated so that the user cannot retake the posttest during the same session. The students were given the option of going through the module for a second time to improve their performance in the questions. A common gateway interface (CGI) script written in Java was used to record the student identification and performance in answering the pretest and the posttest on a text file saved on the home server.

The effectiveness of the module as a teaching tool was evaluated by comparing the performance of all the students in the pretest and the posttest. Also, the performance of the students who used the module for a second time in the pretest and the posttest was compared with the average performance of all the students when they used the module for the first time. Furthermore, the students were asked to fill out a survey in order to evaluate the module from the user's point of view.

RESULTS

The performance (the number of correct answers) of the students in answering the pretest and posttest questions is summarized in Figure 7. The students' performance (n=68 students) in answering the pretest was compared with their performance in answering the posttest using a nonparametric statistical analysis (Statistics Analysis System, SAS Institute Inc., Cary, NC). Kruskal-Wallis test showed that the average performance of the students improved significantly from 5.4±3.13 to 8.9±1.16 ($P = 0.0001$), after using the module. The analysis also showed that the performance of the students

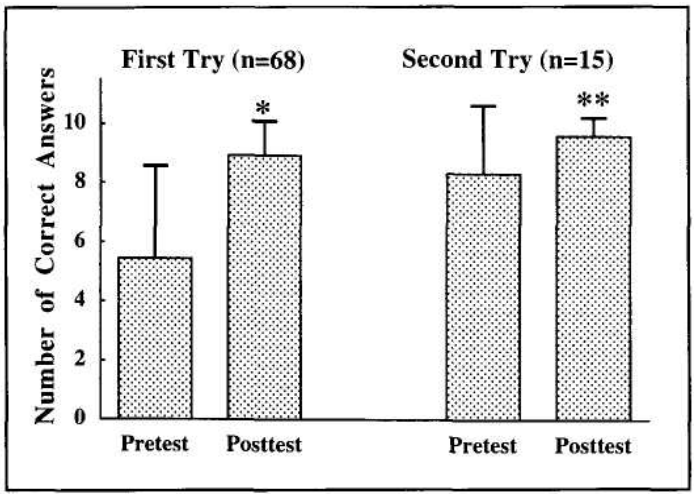

*Fig. 7. The students' performance presented as the number of correct answers in the pretest and posttest forallstudents (n=68 students) when they used the module for the first time, and for the students who used the module for a second time (n=15 students). The results are presented as mean±SD. *Significantly different from the pretest (Kruskal-Wallis test, P = 0.0001); **Significantly different from the posttest when the module was used for the first time (Kruskal-Wallis test, P = 0.013)*

who used the module for a second time (n=15 students) improved from 8.33±2.32 to 9.6±0.63 after using the module for the second time, a difference which was barely insignificant ($P = 0.059$). However, the performance of the students who used the module for a second time in the posttest questions was significantly better than the average performance of all the students in the posttest when they used the module for the first time. The performance of these students significantly improved from 8.9±1.16 to 9.6±0.63 ($P = 0.013$). The responses of the students who participated in the survey (n=44 students) indicated that this internet-based module was easy to use and the information was presented clearly. The majority of the students mentioned that the computer capabilities made understanding the pharmacokinetic concepts from the computer-based presentation easier than if the same information was presented in a printed format. The students indicated that the three main components of the module were important in learning the presented pharmacokinetic concepts. Overall, most of the students who participated in the survey found this internet-based module to be a useful tool for learning the basic pharmacokinetic principles. A summary of the responses for the entire survey is presented in the Appendix

DISCUSSION

The intent of this paper was to describe and to evaluate a prototype internet-based module which can be utilized for teaching pharmacokinetics for undergraduate pharmacy students. Because this module can be accessed via the internet, it can be very valuable for distance learning, continuing education, and in-job training programs. Assessment of the effectiveness of this module indicated that this internet-based instructional materials can increase the students' understanding of the basic pharmacokinetic principles.

The performance of the students in answering questions improved significantly after reviewing the module, which is an indication that the developed module is an effective tool for teaching the basic pharmacokinetic principles. It is important to point out that the average performance of the students in answering the pretest during their first try was 5.4.

Also, the performance of the students who used the module twice in the pretest during their second try was not different from the average performance in the posttest during the first try (P = 0.72). This information indicates that the students tried their best in answering the pretest questions, which supports the validity of our assessment procedures.

The students who used the module twice performed lower than average in the posttest during their first try (8.07±l .67 for this group of students and 8.9±1.16 for all students). So, one can argue that these are the students who did not perform well in the posttest during the first try and that is why their performance improved. For this reason, we compared the performance of these students in answering the posttest during their second try with the overall performance for all the students in the posttest during the first try. This analysis showed that using the module for a second time improved the ability of the students to answer the posttest questions, which suggests that repeated use of the module can increase the students' understanding of the presented materials.

The responses of the students to the survey clearly indicated that the module was easy to use and that the information was presented in a format that is easy to understand. The majority of the students found this module to be a good learning tool for the basic pharmacokinetic principles. The majority of the students also indicated that they would prefer the computer-based format as a medium for delivering the course content of their pharmacokinetic class. The most frequently mentioned reason for this preference was that well-designed computer-based instructional materials can be more effective learning tool compared to conventional printed materials.

CONCLUSION

An internet-based module for teaching pharmacokinetics was developed. This is an interactive, menu-driven, learner-centered, synchronous module which requires minimal computer knowledge to run. This module is a very effective teaching tool to improve the students' understanding of the basic pharmacokinetic concepts. Such computer modules can be used as a supplement for undergraduate pharmacokinetic teaching. Also, this module can be used for continuing education programs for pharmacists, or as lessons in distant learning programs and the virtual university.

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APPENDIX. SURVEY RESULTS

Please mark each of the following statements by circling the appropriate letter according to the following scale:

A = Strongly agree B = Agree
C = Neutral D = Disagree E = Strongly Disagree

1. The module was easy to use and the presented information was easy to understand.
   (A) 89 % (B) 6% (C) 5%
   (D) 0% (E) 0%
2. Because of the computer capabilities, the computer-based presentation of the pharmacokinetic concepts was easier to understand than if the same information was presented in a printed format.
   (A) 59% (B) 18% (C) 14%
   (D) 7% (E) 2%
3. The text in the presentation was very concise, and the graphics were clear and useful for understanding the presented information.
   (A) 70% (B) 23% (C) 2%
   (D) 5% (2) (E) 0%
4. The introduction component of the module was useful in understanding the basic pharmacokinetic concepts.
   (A) 57% (B) 34% (C) 9%
   (D) 0% (E) 0%
5. The examples and the problems included in the introduction section were helpful in reinforcing the presented information.
   (A) 61% (B) 32% (C) 5% (2)
   (D) 2% (E) 0%
6. The simulation component of the module was helpful to understand how the change in the pharmacokinetic parameter(s) affects the plasma concentration time profile of the drug.
   (A) 43% (B) 39% (C) 16%
   (D) 2% (E) 0%
7. The questions at the end of the module were good self-assessment tool to determine if I understood the major concepts in the presentation.
   (A) 59% (B) 32% (C) 9%
   (D) 0% (E) 0%
8. Overall, this internet-based pharmacokinetic module is a useful tool for learning the basic pharmacokinetic principles.
   (A) 73% (B) 18% (C) 9%
   (D) 0% (E) 0%
9. If I had the choice to choose one format for learning the course content for pharmacokinetics, I would have chosen:
   (A) Computer-based format: 80%
   (B) Conventional printed format: 20%