

Development and Assessment of an Internet-Based Tutorial to Supplement the Teaching of Medicinal Chemistry within a Multidisciplinary, Disease-Based Course

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Pharmacy academicians are well in accord for the need to supplement lecture material with participatory activities that engage students to reach higher levels of problem-solving capability. Additionally, changing pharmacy student demographics and advances in information technology dictate that student-consumers desire surrogate methods to traditional study and memorization of notes. Hence, a set of highly interactive tutorials was developed for the medicinal chemistry component of a multidisciplinary disease-based course. Tutorial design with features such as hidden questions, 3-D molecular modeling, and extended summaries allow for varying levels of student involvement. A study was conducted to assess students' perceptions of the utility of the tutorials and determine whether students who utilized them fared better on an examination. Analysis of data obtained from student surveys indicates that students regarded the tutorials very highly as a study aid and adjunct to lecture course material. Principal components analysis revealed that students conceptualize the utility of the tutorials across two domains; one for its use in learning course concepts and a second for its application in developing higher order cognitive skills. Users of the program scored better than nonusers on the medicinal chemistry portion of a subsequent examination, although the difference was not statistically significant. Moreover, further analysis of examination scores through one-way ANOVA procedures suggested certain students would have especially benefited from use of the tutorials. Survey respondents indicated overwhelmingly that the tutorials should continue to be made available, and, in fact, should be expanded to include more questions at a higher level of sophistication in addition to questions from other disciplines involved in the disease-based course.

INTRODUCTION

Consistent with changes throughout U.S. schools of pharmacy, Duquesne University introduced in 1994 a new six-year entry level PharmD curriculum to replace the existing five-year BS program. Among the many changes that were made was the implementation of a series of six integrated, disease-based modules (referred to as pharmaceutical and biomedical science or "PHBMS" courses) in lieu of traditional stand-alone courses in medicinal chemistry, pathophysiology, pharmacology, and therapeutics (Table I). In the BS program, medicinal chemistry was offered as two, four-credit courses in both the fall and spring semesters of the students' fourth year. In preparation for the integrated, disease-based modules, the spring semester course was initially combined with pharmacology courses during the 1996 and 1997 spring semesters. In the new PharmD program, the fall semester course was renumbered but remained a stand-alone course with essentially the same subject material as it had in the BS program. It serves as the introductory medicinal chemistry course and contains basic concepts such as the acid/base nature of drugs, functional groups, solubility, stereochemistry, receptor binding, and metabolism. Adrenergic, cholinergic and CNS agents are also discussed in this course. In contrast, the topics previously discussed in the spring semester course were distributed into five of the six aforementioned modules. The medicinal chemistry of drugs used to treat neurological and psychiatric disorders is discussed in the fall semester course and is therefore not included in the first PHBMS course. Over the past two years, the average

enrollment for the PHBMS courses was 120 students.

Development and implementation of the integrated modules created numerous challenges for faculty from various disciplines involved in their teaching. Foremost within the discipline of medicinal chemistry was a desire to highlight the chemical aspects of drug action and emphasize the relevance of medicinal chemistry in the therapeutic decision-making process. Medicinal chemistry faculty at other universities have also encountered these same challenges and along with the authors have addressed them through a variety of instructional techniques. The incorporation of case study discussions into traditional and integrated courses is currently one of the most widely used methods to teach students how to apply discipline-specific information to actual patient scenarios. This is true, not only in the area of medicinal chemistry(1-4), but also in other basic science disciplines such as pharmaceuticals(5), pharmacology(6), and biochemistry(7). A similar strategy, termed Structurally Based Therapeutic Evaluation, has been developed at Creighton University(8) and requires students to address specific therapeutic criteria when evaluating chemical and structural information. Additionally, computer-based tutorials which highlight structure identification and classification, the acid/base nature of drugs, and functional group chemistry have been previously reported by Duquesne faculty(9).

All of the above strategies are consistent with recent trends in pharmaceutical education. They emphasize thinking

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Table I. Description of courses

Course number	Overview of major course topics
PHBMS 422	neurological disorders (seizures, pain management, Alzheimer's disease, Parkinson's disease) and psychiatric disorders (schizophrenia, psychoses, depression, mania, anxiety)
PHBMS 423	rheumatoid arthritis, inflammatory disorders, gout, peptic ulcer disease, and allergic disorders
PHBMS 424	edema, angina pectoris, congestive heart failure, hyperlipidemia, arrhythmic disorders, hypertension, stroke, and coagulation disorders
PHBMS 425	endocrine (pituitary disorders, thyroid disorders, diabetes mellitus, adrenal disorders, reproductive disorders, bone disease) and nutritional disorders
PHBMS 426	infectious disease (bacterial, viral, fungal, and protozoal infections)
PHBMS 427	pulmonary, neoplastic, hematological and immunological disorders

abilities and problem-based learning, skills which have been identified as essential for enabling entry-level practitioners to logically and analytically solve patient problems and recommend appropriate therapeutic action(10). They also require and promote active learning, a skill identified by the Focus Group on Liberalization of the Professional Curriculum as being an extremely important curricular component(11). Finally, the development and implementation of computer-based case studies(2,5) and tutorials(9) are consistent with the American Council on Pharmaceutical Education's statement that the enhancement of computer skills is an important issue in teaching and learning processes(12).

Coinciding with the above trends, advances in software technology and the proliferation of Internet use in higher education have facilitated the redesign of courses and the introduction of innovative teaching strategies. Within U.S. schools of pharmacy, Internet-based courses, modules and tutorials have been developed and reported for a variety of subjects, including pharmacokinetics(13,14), drug literature evaluation(15), pharmaceutical calculations(16), and pharmacotherapy(17). These reports indicate that Internet-based educational tools can improve learning, examination performance, educational outcomes, accessibility to course materials, and provide a positive learning experience. Additionally, student evaluations indicate an overall satisfaction with, and in some cases a preference for, Internet-based materials(14). To date, reports of similar, Internet-based, educational tools for the area of medicinal chemistry have been sparse.

Based upon all of these factors, an Internet-based, medicinal chemistry tutorial was developed for PHBMS 423, the first fully integrated, disease-based module taught in Duquesne's revised curriculum. For topics covered within the module, the educational goals for the tutorial were to enhance students' ability to classify and identify drug structures, to provide a chemical rationale supporting the appropriateness of a particular drug or drug class in the treatment of a particular disease or patient, to explain the chemical, biochemical and pharmacological mechanism of drug action, and to relate the chemical structure of drugs to their therapeutic actions.

TUTORIAL DEVELOPMENT

Initial Considerations

The software program ToolBook II Instructor, 5.0¹ was used to develop the computer tutorial. The major advantage of this version of ToolBook was that it enabled the development of Internet-based course material, a feature not available on previous versions of the software and one highly desired by the course instructor. Previously developed, non-internet-based, medicinal chemistry tutorials(9) were accessible either through the school's Pharmacy Computer and Resource Center (PCRC) or through the copying and distribution of an authorized, truncated

version of the program along with the tutorial files. Both of these methods were time consuming and provided several constraints. Initially, the tutorials had to be individually copied by the instructor to each computer in the PCRC. In subsequent years, the University's computer center assumed the responsibility of loading the software; however, this often required a wait of several weeks. As the initial tutorials became more popular, it was common for 50 to 60 students per semester to request individual copies. As a result, previous tutorials were only installed, copied and distributed once they were totally complete. In some instances, this provided only a small window of time for their use. Additionally, changes and additions presented logistical problems and were only done periodically. In contrast, Internet-based tutorials can easily be updated on a regular basis, thus ensuring that all students have access to the most recent version without having to constantly copy and reinstall files. Finally, there is no need for students to wait until the tutorial is completely finished in order to use it. Student use can begin as soon as the first pages are loaded onto a Web site. Internet accessibility for course material designed with ToolBook II Instructor (v. 5.0) can be accomplished in two ways. First, tutorials can be written and saved in HyperText Markup Language (HTML) and Java script and loaded directly onto the Internet. While this method initially appeared to be the best, numerous barriers quickly arose. Foremost among these were limitations in tutorial design and the manner in which structures and schematics could be imported. While ToolBook provides an extensive collection of over 200 pre-scripted "plug-and-play" question widgets, only a portion of these could be used for Internet-tutorial design. While standard multiple choice, true/false, and fill-in the blank questions could be used, more interactive and adaptable questions such as definable multiple choice questions, object and structure matching, drag-and-drop objects, text ordering for sequencing statements, and slider scales for numeric answers were unavailable. Since informal class survey results identified these interactive and varied question types to be one of the most attractive features of the author's previously reported tutorials, this limitation was the major factor in the decision not to use HTML and Java script for tutorial development. Another factor was the inability to use the "Object Link and Embed" option of ToolBook to directly add structures and schematics from ISIS/DRAW,² a powerful, multifunctional chemical drawing program. In order for these images to be used for HTML and Java, they must first be converted to "jpg" or other compatible file formats. While this doesn't necessarily change the appearance of the tutorial, it requires significantly more time and more importantly does not allow for rapid editing.

¹Available from Asymetrix Corporation, Bellevue WA 98004.

²Available from MDL Information Systems, San Leandro CA 94577.

The second way in which ToolBook tutorials can have Internet accessibility is through the use of Neuron, a plug-in which is available free of charge through the manufacturer's Web site (www.asymetrix.com/products/toolbook2/neuron/index.html). It allows users to run, but not edit, ToolBook tutorials. It also allows the developers to take advantage of all options and features of the software. Neuron works with both Microsoft Internet Explorer and Netscape Navigator. Based upon the restrictions described for HTML and Java script, this method of distribution was adopted.

Web Site Development

Prior to the development of any new tutorials, Netscape Communicator (version 4.01) was used to create a Web site [<http://www.home.cc.duq.edu/~harrold>]. All previously developed tutorials were upgraded to Internet-compatible versions and uploaded onto the site. In addition, the appropriate version of Neuron as well as instructions for downloading and installing the plug-in were added to the site. It was assumed that some students would prefer the option of downloading and installing the actual tutorial files, as opposed to just viewing them on the Internet. Therefore, all previously developed tutorials were packaged as zipped files and uploaded to the site as well. Directions for downloading and installing the files were also included. These efforts increased the accessibility of the author's previously developed materials, but more importantly provided a framework for the development and distribution of new tutorials.

Tutorial Development and Implementation

Development of the tutorial for PHBMS 423 began in the summer of 1997, approximately six months prior to the first offering of the course. Initial efforts focused on the overall presentation style and format. In general, the tutorial was envisioned as a supplemental educational tool which would reinforce major concepts discussed in course lectures and assigned readings. The overall design objective was to create a tutorial which would be easy to use, educationally beneficial, and in a format which was appealing, enjoyable and able to spark student interest. Thus, a format which was significantly different than a simple "computerization" of course lectures was desired. After investigating several options, a Socratic method, wherein the vast majority of the course content is revealed piece by piece through a sequence of questions, was adopted. The tutorial was subdivided into four chapters, each of which corresponded to a course lecture sequence. Chapter one contained questions regarding agents used to treat gout as well as the chemistry and biochemistry of uric acid; chapter two contained questions regarding eicosanoids and agents affecting the leukotriene pathway; chapter three contained questions regarding nonsteroidal anti-inflammatory drugs (NSAIDs) and acetaminophen; and chapter four contained questions regarding histamine, histamine antagonists, and other compounds used to treat allergic conditions and peptic ulcer disease.

An initial version of the tutorial was uploaded to the previously discussed Web site prior to the start of the 1997 fall semester. It contained chapter one as well as the basic framework and navigation for the other three chapters. As shown in Figure 1, each tutorial page contained a "Main Index" button which allowed the user to easily move among the four chapters. Additionally, each chapter page contained a "Go to question #" option to allow navigation to a specific question within that chapter. This latter feature was added so that students could review specific questions or quickly return to the point where they last used the tutorial. As an initial effort to increase

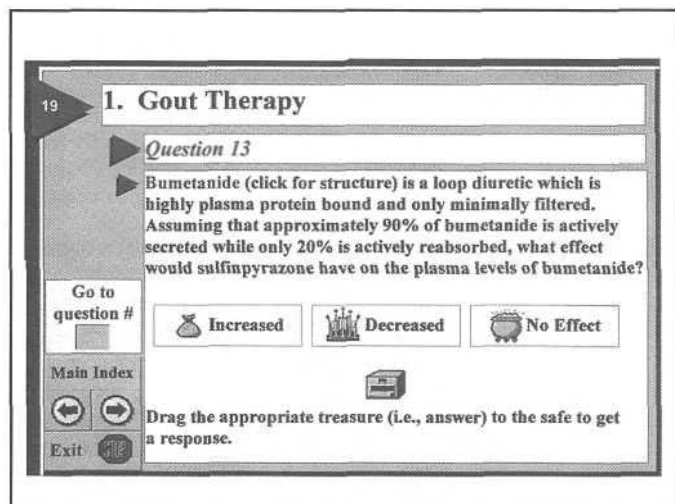


Fig. 1. Sample "Drag and Drop" question.

awareness of the Internet-based tutorials, students taking the fall semester medicinal chemistry course were provided with an informational flyer describing the author's Web site and previous work. Students were especially encouraged to use a previously developed tutorial on acid/base designation and functional group chemistry(9) since these topics would be first introduced during the fall semester. It was hoped that this early exposure would facilitate the acceptance and use of Internet-based materials for medicinal chemistry courses and topics.

Questions were sporadically added to the PHBMS 423 tutorial throughout the fall semester. By the beginning of the spring 1998 semester, chapters two and three were approximately two-thirds complete. On the first day of class, students were provided with an updated informational flyer and were given a short demonstration of the tutorial. New questions were added almost daily throughout the semester, especially when examinations were imminent. A notation on the title page allowed students to quickly determine if the tutorial had been revised since they last used it. In most instances, chapters pertinent to an upcoming examination were completed approximately one week ahead of schedule. As an additional strategy to encourage student use, small portions of the tutorial were periodically incorporated into the normal class lectures. When completed, the tutorial contained over 75 questions, each of which was designed to provide extensive feedback for both correct and incorrect responses. Thus, students who fully explored each question would eventually review all of the major concepts pertinent to the course.

As previously mentioned, the tutorial was designed to be not only educationally beneficial but also interesting and enjoyable. These latter objectives were met primarily through the use of multiple question types and assorted feedback techniques. The examples described below highlight some of the methods used and are indicative of the overall tutorial design. "Drag and Drop" animations require students to select an icon corresponding to their answer and move it to a particular target in order to get a response. An example is shown in Figure 1. Here students are required to deposit a treasure (i.e., a bag of money, a golden crown, or a pot of gold) in the safe. Animations for other questions include choosing the correct brush to paint a canvas, the proper vehicle to get to a house, the proper arrow to hit a target, and the correct disc to insert into a

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3. Nonsteroidal Anti-inflammatory Drugs

Question 10

Fenoprofen contains an unsubstituted aromatic ring. The position of substitution of the lower ring can increase either potency and/or duration of the compound. Indicate the appropriate positions for substitution by moving the pointers.

Go to question #

Main Index

Exit

Increase duration

para

meta

ortho

Increase potency

Fig. 2. Sample question hyperlinked to the additional feedback pages

Conformational Restriction By Ortho Groups

Substituents at the *ortho* position provide the most steric hindrance and force the two aromatic rings to assume the perpendicular conformation required for binding to the NSAID receptor. Substituents at both *ortho* positions obviously provides the optimal "locking" of the required conformation.

Carboxylic acid (red) is pointed toward the screen.

Chloro group (green) in *ortho* position is larger and provides more steric hindrance than the hydrogens (blue).

Return To Questions

Fig. 3. Feedback page containing ALCHEMY 3D screen shot.

computer. The example in Figure 1 also illustrates another common feature. Red colored "hot words" allow students to view structures and schematics, review definitions, or obtain hints. In this case, the structure of bumetanide can be viewed by clicking its name. A similar type of question, shown in Figure 2, requires students to move a pointer to select specific atoms, functional groups, or substitution sites. In all instances, selecting correct or incorrect answers will result in a "pop-up" text box explaining why the response was either correct or incorrect. When appropriate, hyperlinked pages containing further structural or mechanistic information will also appear. This is exemplified by the question shown in Figure 2. If the "increase potency" pointer is moved to the ortho position, the student will initially receive feedback that his/her answer is correct. Following this, the tutorial will display the page shown in Figure 3. This page provides an extended explanation and includes another feature of the tutorial, a screen shot from the molecular modeling software program, ALCHEMY.³ The screen shot here, as well as others used within the tutorial, were incorporated to better show the three-dimensional aspect of specific compounds. Animations using ALCHEMY generated

³Available from Tripos Associates, St. Louis MO 63144.

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4. Histamine, H₁ and H₂ Antagonists, Etc.

Question 2

Which of the following statements concerning histamine is/are correct?

Go to question #

Main Index

Exit

Histamine can be classified as an autocoid.

Histadine is formed from the decarboxylation of histamine.

Histamine has no real clinical use.

Histamine is a conformationally flexible molecule.

Fig. 4. Sample multiple choice question hyperlinked to animation pages

Conformational Flexibility of Histamine

This conformation is known as the "gauche" conformation and is required for the binding of histamine to H₂ receptors.

Continue Animation

Distance between nitrogen atoms: 2.91 Angstroms

Fig. 5. Feedback page containing 3D animation.

models were also used to view the rotation of bonds and to help explain conformational changes which affect drug action. This is illustrated in Figures 4 and 5. Selection of "Histamine is a conformationally flexible molecule" as the answer to the question shown in Figure 4 eventually leads to an animation showing the rotation of the side chain of histamine (Figure 5). In addition, an explanation of the importance of this rotation is provided. An additional feature used with all normal multiple choice questions, such as that shown in Figure 4, is an automatic scrambling of answers upon exiting the page. Thus students who review the questions more than once will always find something different.

A design feature not previously used by the author was the incorporation of hidden questions. These questions were only accessible by choosing specific correct or incorrect responses and either emphasized an important concept or allowed students a second chance to answer a similar question. They were designed to encourage students to fully examine all of the questions and answers, as opposed to the "I know this, I'll just go to the next question" or the "I got it right, I'm done" approaches. An example of the use of hidden questions is seen in Figures 6 and 7. In this example, students who fully explore both options to the case study question shown in Figure 6 will encounter three additional, related questions. Selecting

65 4. Histamine, H₁ and H₂ Antagonists, Etc.

Question 15

A patient enters your pharmacy complaining of cold and flu symptoms. In addition, she has had trouble sleeping and asks you to recommend a product which she could use at bedtime. Which would be best, a product containing Compound A or a product containing Compound B?

Compound A

Compound B

Go to question #

Main Index

Exit

Fig. 6. Sample case study question.

“Compound B”, the incorrect answer, will lead to the page shown in Figure 7. This page contains an explanation as to why this compound is not the best choice and further tests students’ knowledge of this drug class. The navigational arrow in the bottom right-hand corner leads to yet another question concerning “Compound B.” Although not shown, selecting the correct answer, “Compound A”, will lead to a similar page with an explanation and an additional classification question. For the purpose of preventing frustration, incorrect answers to fill-in-the-blank questions, such as that shown in Figure 7, always allow students to type in the word “answer” in order to view the correct response.

The tutorial for PHBMS 423 was completed by the end of the spring 1998 semester. Following some minor updates in the summer of 1998, the tutorial was packaged as a zipped file, similar to those previously described, for students who wished to download and install it. As expected, its development and distribution were much more efficient than previously reported efforts(9). Even though the tutorial was constantly under revision throughout the semester, student use began during the first week of class. Also as expected, the number of students requesting individual copies of the tutorial decreased from 50-60 to less than five.

Assessment of the tutorial during the 1998 spring semester was very limited due to the fact that the tutorial was still under development. While efforts were primarily directed toward completing chapters prior to examination dates, several surveys were conducted throughout the development process to gather student opinions. Initial responses were very positive and led to a more formal assessment during the 1999 spring semester.

METHODS

The authors had several objectives in assessing the use of the tutorials. The first objective was to assess the number of students who utilized the tutorials (users) and the amount of time and level in which users participated. At the same time, the authors desired to ascertain from nonusers their primary reason for not utilizing the tutorials. Secondly, they wished to gain an understanding of student perceptions of the tutorial’s utility across a variety of applications, including studying and retaining course material, preparing for examinations, and applying their use toward higher-order thinking and problem-solving skills. Additionally, the authors wanted to gather student opinion about

Incorrect!

Except for the newer, non-sedating antihistamines, compounds in this class of antihistamines offer the lowest sedation potential and are the best selection for daytime use. This compound would therefore not be the best for the patient's request. In the space below, enter the chemical classification for this compound.

Fig. 7. Feedback page containing “hidden questions.”

particular “graphic” or “hi-tech” features of the program. Finally, additional objectives of this study were to correlate use of the tutorials with actual student performance on examinations, investigate the possibility of sustained or continued use and overall performance, and determine what changes might be made so that future use may better facilitate success in the class.

Two survey instruments (henceforth referred to as “Assessment One” and “Assessment Two” were developed and administered at different times during the course. The instruments were quite similar in composition, with parts one, two, and three being identical. Students completed Assessment One following the first course examination and Assessment Two following the third examination.

Students who did not utilize the tutorials were asked to complete part one, which queried their primary reason for not utilizing the tutorials. Part two was comprised of thirteen items used to measure student perceptions of utility on a five-point, Likert-type scale ranging from one (strongly disagree) to five (strongly agree). Part three contained an additional three items soliciting student feedback about particular design features of the tutorials on a similar five-point scale with “no value” and “extremely valuable” serving as the anchors. Part four in both instruments was designed to ascertain to what extent students utilized the tutorials. Both instruments contained two forced choice questions, one asking for a range of the time spent going through the tutorials, the other asking students to pick the behavior most representative of their level of involvement in answering chapter questions and seeking hidden questions and summaries. Assessment Two had one additional question, which required respondents to indicate how many flag icons they located while going through the tutorials. Additionally, Assessment Two was comprised of a part five which asked students to respond to an open-ended question as to what changes they might suggest to make the tutorials more useful in achieving better examination scores. This question was added following the lack of significant correlation between the level of participation and examination scores after the first examination.

Analysis

Data were input into SPSS 9.0⁴ for analysis. Means and standard deviations were calculated for the utility and special feature scales. Following the administration of Assessment

⁴Available from SPSS, Inc., Chicago IL 60606.

Table II. Items in the utility scale, means, standard deviations, and rotated factor loadings from Assessment One

Item statement	Mean ± SD	Factor	
		One	Two
1. The tutorial helped me to learn the subject matter in the course.	4.44 ± 0.71	0.633^a	0.477
2. The tutorial was well written and easy to follow.	4.82 ± 0.45	0.877	0.211
3. The tutorial serves as a useful supplement to the information provided in lecture.	4.63 ± 0.68	0.724	0.395
4. The tutorial was designed at an appropriate level of difficulty.	4.44 ± 0.78	0.185	0.732
5. The tutorial was easy to navigate through.	4.71 ± 0.54	0.870	0.179
6. The tutorial helped me to prepare for exams.	4.66 ± 0.75	0.778	0.409
7. This tutorial should continue to be made available for future students.	4.85 ± 0.49	0.869	0.213
8. The tutorial helped me to retain information and concepts taught in this course.	4.59 ± 0.66	0.736	0.469
9. The tutorial enhances my problem-solving skills.	4.18 ± 0.96	0.396	0.763
10. Using this tutorial enhances my thinking skills.	4.10 ± 0.80	0.322	0.804
11. Using this tutorial allows me to apply knowledge from this course to help me in other courses.	3.95 ± 0.90	0.202	0.684
12. Tutorials such as this one will ultimately help prepare me to become a good pharmacist.	3.92 ± 0.92	0.260	0.758
13. Over, the tutorials is a useful learning tool.	4.70 ± 0.57	0.829	0.371

^a Bold print indicates the loading of the row item onto the column factor.

Table III. Means and standard deviations of items representing particular program features

Program feature	Mean ± SD
The hidden questions and summaries (<i>i.e.</i> , those that appear after selecting specific responses).	4.56 ± 0.67
Having different types of question formats (drawing arrows, depositing money in the safe, etc.).	4.23 ± 0.81
Incorporation of 3-D molecular models.	4.04 ± 0.95

One, principal components analysis with Varimax© rotation was performed on the items comprising the utility scale to determine whether student perceptions of the utility of the tutorials could be categorized into dimensions and if any items warrant exclusion from further analysis based on inability to load successfully with other scale items.

Frequency data were tabulated for level of participation and were tested for correlation against student examination scores for both assessments. The degree of correlation between student perceptions of utility and level of participation was also tested. Differences in examination scores for users and nonusers of the tutorials were tested via student *t* tests. Additionally, one-way ANOVAs were used to compare examination scores between users and nonusers by their reason for not utilizing the tutorials.

RESULTS

Ninety-two (78.0 percent) of 118 students enrolled in the course completed Assessment One, which was administered just prior to a class session. It is not known how many students were in attendance that day. Seventy-two (78.3 percent) of 92 students indicated that they had utilized the tutorials. Of the twenty who had not, 11 (12.0 percent) cited “didn’t have time” as their primary reason for not doing so. Four students indicated that they did not feel the need for extra review, three had problems accessing the tutorials, one did not like working with computers, and still one student indicated “other” as a reason without further elaboration. The distribution of responses was very similar following the administration of Assessment Two.

Student perceptions of the utility of the tutorials following Assessment One were overwhelmingly positive. Students were most agreeable ($\mu = 4.85$) with the statement, “The tutorial should continue to be made available for future students) and

Table IV. Correlations among examination one scores, perceived utility, time spent on utilizing the tutorials, and level of involvement

	Exam score	Utility	Time
Utility	0.139(0.251)	—	—
Time	-0.040 (0.745)	0.155 (0.192)	—
Involvement	0.161 (0.186)	0.418** (0.000)	0.309** (0.008)

**Indicates significance at $P < 0.01$.

least agreeable ($\mu = 3.92$) to the statement, “Tutorials such as this one will ultimately help prepare me to become a good pharmacist.” Item statements, means, standard deviations, and factor loadings are reported in Table II. Principal components analysis revealed successful loading by each of the items onto one of two factors. The first factor, accounting for 41.89 percent of the variability in responses, was comprised of eight items dealing primarily with the use of the tutorials as an aid for study in the medicinal chemistry course, hence titled the “learning” factor. Five items loaded onto a second factor characterized by the usefulness of the tutorials in enhancing higher-order skills such as critical thinking and problem-solving. This factor, which explained an additional 29.51 percent of the variance, is called the “application” factor. Interestingly, Item #4, which addresses the level of difficulty of the tutorials, loaded onto this factor. This may indicate that students who believed the tutorials were designed at a sophisticated enough level feel that the utility of the tutorials transcends their direct benefit as a study aid to the medicinal chemistry course.

The means of responses from Assessment Two were similar to Assessment One. In fact, paired *t* tests revealed no significant differences among the two assessments across any of the 13 scale items. Similarly, examining the factor loadings

Table V. Summary of student performance on a medicinal chemistry examination covering tutorial objectives

Group	Sample size	Mean	Median	SD	SE
Users	83	88.06	90.48	10.22	1.12
Nonusers	20	85.36	88.09	10.72	2.40
All Students	103	87.54	90.48	10.32	1.02

Table VI. Student performance by user and nonuser reason type

Group	Sample size	Mean	SD	SE	Lower 95% CI	Upper 95% CI
Users	83	88.06	10.22	1.12	85.83	90.30
Not enough time ^a	11	79.65*	11.24	3.39	72.10	87.20
Problems with access ^b	3	94.44	5.50	3.17	80.79	108.10
Didn't need review ^c	4	92.86	1.94	0.97	89.77	95.95

*Significant difference at the 0.05 level of confidence via Bonferonni post-hoc comparison.

^aStudents who indicated their primary reason for not using the tutorials as "I didn't have enough time."

^bStudents who indicated their primary reason for not using the tutorials as "I had problems accessing the tutorials."

^cStudents who indicated their primary reason for not using the tutorials as "I didn't need any extra review."

from Assessment Two revealed no differences in factor structure from Assessment One.

Table III reveals students' perceived value of various components of the tutorial program. Students appeared to value each of the three program features, but especially the hidden questions and summaries that are associated with a higher level of involvement when participating in the program. Similar results were observed following administration of Assessment Two.

Table IV provides the correlation coefficients between the students' scores on the first examination, their perception of the tutorial's utility, the amount of time they spent utilizing the tutorial, and their level of involvement when participating in the tutorials. On average, students indicated a high level of involvement despite spending only about one hour utilizing the tutorials. The correlations indicate that although a higher level of involvement in utilizing the tutorials was associated with a higher level of perceived utility, this did not necessarily translate into better examination scores.

Overall analysis of examination scores failed to reveal any significant differences between users and nonusers of the tutorials, although a positive trend was observed for users. Examination scores for users and nonusers are shown in Table V. The authors suspected that students who had different reasons for not utilizing the tutorials might have fared differently on the examination, particularly if some of the "better" students did not feel that they needed to spend any extra time in preparation for the examination. Therefore, a one-way ANOVA was performed on student examination scores, with the user group and the nonuser groups, differentiated by reason, serving as the explanatory variable. The results shown in Table VI support the contention that the groups may differ. Students who indicated that they did not utilize the tutorials because they did not have enough time to do so scored significantly lower on the examination than did users and the other nonuser groups. The results following Assessment Two were similar, though not quite as pronounced.

The authors had also hypothesized that students who utilized the tutorials throughout the semester would see a more significant improvement in test results between the first and third examinations. A one-way ANOVA on the mean difference of examination scores showed no significant differences between nonusers, users through part of the course, and users

Table VII. Student responses to how the tutorials may be improved for future use

1. Make longer/more questions. (11)*
2. Don't change anything. (6)
3. Include material from other parts of the course (other professors). (6)
4. Make questions more difficult. (4)
5. Provide more encouragement to use them. (3)
6. Give extra credit because of the effort it takes to go through it.
7. Make tutorial questions more similar to exam questions.
8. Emphasize chemical classifications.
9. Make questions like you would see on NAPLEX.
10. Tutorials fail to address problem of not knowing what to look for in exam questions.
11. Have question box for questions on the tutorial.

*Number in parentheses indicates the frequency that response was given.

throughout the entire medicinal chemistry course offering.

Finally, following an initial analysis of data from Assessment One, the authors had determined that students thus far had perceived the tutorials to be very useful, despite a lack of significant improvement on examination scores. Thus, on Assessment Two, an additional open-ended question was asked of students for them to report any changes that could be made to the tutorials so that their use could facilitate better performance on examinations for future students. The authors recorded all responses and coded them into the responses provided in Table VII. Many students felt that the tutorials are quite useful just as they are, and in fact, several students expressed some desire that other faculty in the course make similar programs available. There were a large minority of students, however, who indicated that the tutorials should contain more questions, particularly at a greater level of involvement. This reinforces the results of the factor analysis, which revealed that students who believe the tutorials were at an appropriate level of difficulty perceived even greater utility in their use than students who did not.

Limitations

The results of the study should be interpreted with some caution. In an attempt to assess the effectiveness of the tutorials as a supplement to traditional study methods, examination scores between users and nonusers of the tutorials were sub-

jected to statistical tests. As the investigators did not randomly assign students into user and nonuser groups (i.e., use of the tutorials by students was optional), there exists a selection bias between the two groups. Even the post-hoc analysis comparing users with various groups of nonusers does not fully account for the differences that may have existed between the two groups.

DISCUSSION

Current trends in pharmacy education suggest that both the pharmacy student and the educational process are becoming less "traditional". Pharmacy students are increasingly older, female, employed part to full time, and concomitantly involved in raising families. Successful nontraditional PharmD and graduate degrees attest to academia's continued need to respond to a changing student population, one whose responsibilities extend far beyond the classroom and whose sophistication in information technology and computer literacy grow in leaps and bounds. For many pharmacy students, more exciting, interactive, and time-saving techniques for studying and learning course material, beyond memorizing written notes, must be incorporated into teaching philosophy. The "consumerism movement" which in the past couple of decades has made its way into the health care market(18) appears to be making its way into the market for education. It is understandable that students are looking for other means of study besides staring at ink on white paper for hours on end.

The tutorials described in this paper were developed to provide students with such an alternative to more "traditional" forms of study. In doing so, the instructor also hoped that students would enjoy utilizing these tutorials and benefit from them by improving their performance on examinations and enhancing their thinking and problem-solving skills. Student responses to the 13-item scale certainly indicate that these objectives were achieved, at least in part. Students were overwhelmingly agreeable to item statements referring to the tutorial's design, use as a supplement to lecture, and as an aid for study. Moreover, mean scores to those item statements to which students expressed the least agreement were still well above the median scale value of 3.0.

The factor analysis revealed an interesting decomposition of students' perceptions toward the use of the tutorials that the authors had not necessarily anticipated, but in hindsight, appear quite logical. Items comprising the learning factor directly implicate the tutorials for what students probably discern as their primary use - that is, for helping them study and learn course material. The second factor, application, is quite momentous though in its ability to have explained nearly 30 percent of the variability in responses. Students apparently conceptualize the usefulness of the tutorials in fostering higher order thinking and problem-solving skills under a separate domain. The loading of Item #4 onto the application factor would indicate that students must perceive the tutorials at an appropriate level of sophistication in order for them to believe that it engenders improvement in these skills. Student responses would indicate that although many of them felt that they were designed at this level, a significant minority did not.

Several advantages of the new Toolbook program were manifest in student reactions toward the program. Students responded quite favorably to the design features incorporated into the tutorials, including the use of 3-D models and graphics that enabled the instructor to instill a bit of "gaming" activity that sparked variety into question design. Students perceived the most value from hidden questions and summaries

that typically do not present themselves unless the student becomes significantly involved in working through the tutorials. This is not surprising given that most students indicated a high level of involvement while accessing the program.

Results indicate a positive trend in examination scores between tutorials users and nonusers. The mean improvement in scores of 2.7 percent, though not statistically significant, can be considered quite relevant. Given that scores on the medicinal chemistry examination were high even for nonusers, improvement momentous enough to achieve statistical significance would have been difficult to attain. The fact that tutorial utilization resulted in even higher examination scores lends credence to their usefulness as a learning tool. Moreover, further analysis into the examination scores of the types of nonusers provides even further evidence of their utility. Mean examination scores between users and students who indicated "not enough time" as their primary reason for not utilizing the tutorials represented a difference of nearly an entire letter grade and were significantly different. Anecdotally, students in the other two nonuser groups consisted mostly of students near the top of the class, academically.

All of the above results are consistent with a recently published study of computerized medicinal chemistry case study modules(19). While these modules were not Internet-based, student performance and survey results from this study strongly support the contention that computer-based modules and tutorials can be both educationally beneficial and fun to use.

The overall results of the current study provide encouragement for the instructor to design similar tutorials for the other four PHBMS courses in which he is involved and to make continual improvements on the current tutorial. Results of the factor analysis coupled with student responses to an open-ended question on how to improve the tutorials for future use suggest a few needed changes. For one, the instructor will incorporate additional questions and case study scenarios that require a more sophisticated level of thought into their answer. Hopefully, this will further improve examination performance and foster higher order thinking skills and problem-solving capabilities in students, although the latter may be difficult to observe empirically. Additional efforts, especially ones which showcase the more interactive and entertaining aspects of the tutorial, will also be used to encourage all students to use the tutorials. It is the authors' opinion that the tutorials offer something for everyone. Students who may not necessarily need extra review for an examination can still benefit from this alternative study method. As previously mentioned, it is interactive, entertaining, incorporates a variety of learning techniques, and has the potential to make the subject material more palatable for some students.

Plans to incorporate materials from other course instructors participating in the PHBMS 423 modules are currently being developed. This would inevitably further enhance the utility of the tutorial. The ability to access information concerning a particular disease state from all disciplines involved should be a very helpful and efficient method of examination preparation. Moreover, it would allow the instructors to incorporate cases and other questions that require interdisciplinary knowledge and skills into the tutorials. The recent inclusion of pharmacology questions into a new tutorial for PHBMS 424, the cardiovascular module, represents some progress in this area.

CONCLUSION

In summary, an Internet-based tutorial developed to highlight the medicinal chemistry aspects of an integrated disease-based

course has been enthusiastically accepted by the instructor's students. Designed as a multifaceted educational tool, the tutorial reinforces key lecture concepts, provides extensive feedback for all user responses, and incorporates case studies and aspects of 3-D molecular modeling in an interactive and entertaining format. In addition to identifying the tutorial as a useful study aid, assessment results indicate that a significant number of students perceive the tutorial to be useful in fostering higher order thinking and problem-solving skills. Despite the fact that a statistically significant difference was not seen between the examination scores of users and nonusers, an overall positive trend was noted. Assessment results as well as suggestions garnered from student surveys will be used by the instructor to develop more integrated and sophisticated tutorials.

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