INNOVATIONS IN TEACHING

Using Interactive Digital Images of Products to Teach Pharmaceutics

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Objective. To implement interactive digital images of drug products and online quizzes in a pharmaceutics course to teach students where to look on product labels for information and how to evaluate ingredients of various dosage forms, and to reinforce pharmaceutical calculations with practical problems.

Design. Interactive digital images of drug products and a database of quiz questions pertaining to the products were created and an interactive online platform was designed. The interactive digital images were incorporated in pharmaceutics lectures as examples of dosage forms studied and calculations taught. The online quizzes were administered to first-professional year pharmacy students in fall 2004 and fall 2005.

Assessment. The competency outcome data illustrates that the product-based online quizzes aided students in meeting the desired learning objectives. Modifications to increase ease of use resulted in higher student success rates in the second year of implementation. Student and faculty evaluations of the application were largely positive.

Conclusion. The development of interactive digital images and product-based online quizzes successfully adapted a traditional learning aid into a viable electronic resource for pharmacy education.

Keywords: active learning, pharmaceutics, computer-assisted instruction

INTRODUCTION

Students who have grown up in the computer age are increasingly visually oriented. Indeed, most adult learners favor visual learning modalities.¹ Accordingly, current pedagogical theory supports the incorporation of visual aids to capture students' attention and enhance learning.²⁻⁴ Students overwhelmingly feel that the incorporation of visual learning aids improves their understanding and retention of topics in pharmaceutics.⁵ Faculty members at the University of South Carolina have developed learning aids to enhance student comprehension of pharmaceutics topics, including hands-on laboratory exercises to illustrate physical pharmacy concepts and compounding techniques, in-class demonstrations and experiments during lectures to illustrate physical pharmacy concepts, interaction with virtual patients to connect the basic sciences to pharmacy practice,⁶ and product-based quizzes to connect pharmaceutical con-

cepts and calculations with actual drug products. Although each of these learning aids has been tremendously effective, increased enrollment and larger class sizes have resulted in some restriction in the exercises that can be completed during laboratory sessions. For example, the product-based quizzes had to be discontinued because the bench space was needed to accommodate the increased class size in the pharmacy compounding laboratory. Although instructors traditionally bring pharmacy products to class as examples of the dosage forms discussed, students have trouble seeing the products from their seats in a large classroom. Passing the products around the room is one solution to that problem, but this tends to disrupt the class and students often give the products only cursory review. An alternative to using real examples of pharmacy products is the use of digital photographs of pharmacy products. However, this option does not allow three-dimensional viewing and most labeling information is illegible. Interactive digital images that allow the user to zoom in on pertinent information have a distinct advantage over simple digital photographs. Interactive digital images of drug products can be incorporated with the classroom projector system, rendering them visible to the entire class and at the same time allowing the instructor to point out areas of interest. When surveyed, students overwhelmingly felt that access to examples of different dosage forms and types of pharmaceutical products would be advantageous.⁵ In this project,

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interactive digital images were therefore designed to provide students in a large classroom setting access to examples of pharmacy products.

Providing pharmacy products as examples of the dosage forms discussed in class establishes relevance and is especially important for first-semester pharmacy students unfamiliar with pharmaceutical products. Interactive digital images can also be used to illustrate the availability of drugs in multiple dosage forms and to contrast the differences between the dosage forms. Basic pharmaceuticals concepts can be “dry” if taught without visual aids, but the same concepts come to life when real pharmacy products are used for clarification. For example, instructors can use interactive digital images to reiterate which ointment bases will absorb water, predict whether ointments will be lipophilic and therefore greasy and difficult to wash off, or determine why a particular ointment does not contain a preservative. Each of these applications is based on the examination of the labeling information of the ointment, but requires the student to employ pharmaceuticals concepts, such as interfacial tension, lipophilicity vs. hydrophilicity, and preservation requirements, to a concrete example.

The interactive digital images were not only used as visual aids in lectures, but also built into online quizzes to complement the material covered in *Pharmaceutics I*. Online quizzes incorporating interactive digital images of drug products provide an alternative way to offer the product-based quizzes that had been discontinued due to lack of laboratory space, thereby converting a traditional learning aid into an electronic version that is even feasible for use in large classes.

DESIGN

Digital photographs of currently marketed pharmaceutical products were developed and telephoto capabilities incorporated in the files allowing users to zoom in on the ingredients and other specific information included in product labeling. The developed interactive digital images could be used in many pharmacy courses, but are especially useful in teaching pharmaceutics. The interactive digital images were incorporated into pharmaceutics lectures to provide relevance, stimulate student interest, and reinforce the material taught in lecture.

Drug products were selected as representative of dosage forms studied based on the active and inactive ingredients and their relevance to pharmaceutical calculations. Both nonprescription and prescription drug products were used to increase the number of available products and to accentuate the differences in labeling between the 2 types. Multiple views of the selected drug products were photographed with a digital camera (Cyber-shot DSC-

F717, Sony Corporation, New York City, NY) and the files were manipulated using Macromedia Flash technology (Macromedia Studio MX 2004, Education Version, Adobe Systems Incorporated, San Jose, Calif). Telephoto capabilities included in the Flash files allowed users to zoom in on the ingredients and other specific information included in the product labeling by moving a virtual magnifying glass around the digital photographs.

The Flash files of product photographs were then incorporated in pharmaceutics lectures to provide examples of the dosage forms studied. A large pool of questions based on the products was developed in Microsoft Access and randomized into online quizzes using an Internet-based platform developed by College of Pharmacy Information Technology personnel for use in multiple courses. The quizzes were served using Visual Basic scripting and a standard query language (SQL) server. Questions were divided into clusters; each cluster included similar questions measuring a specific competency outcome. Often the questions in a cluster would contain the same basic wording but referred to a different drug product. Students were randomly assigned 1 question from each cluster by the SQL server. This design allowed many different iterations of each student quiz to be generated and decreased the likelihood that any 2 students would receive identical quizzes. The order of the presentation of clusters in generated quizzes was also randomized. For each question, the type of question (multiple-choice or text-box entry) and whether a graphic was associated with the question was specified in the database. An example question with its associated interactive digital image is shown in Figure 1.

Each student was assigned a unique numerical student key. The key was used to authenticate the student's identity when logging into the college-supported web site and taking quizzes. Students were instructed to complete the quizzes individually and at their own pace. Students were allowed 2 tries per question and could skip questions and come back to them at a later time. The code/SQL server tracked all interactions between students and quizzes, recording whether the student had used both of his/her tries and whether the student had answered the question correctly, and retaining the student's place in the quiz if he/she chose to complete the quiz over multiple sessions. Automatic scoring and score reporting were available directly from the Internet.

The interactive digital images and product-based online quizzes were first integrated into *Pharmaceutics I* in fall 2004 and repeated in fall 2005. Ten online quizzes constituted 20% of the course grade for *Pharmaceutics I*. Students were provided access to a frequently asked question (FAQ) file that addressed student concerns as they were presented to the instructor and a rounding guide to

In what class should this product be classified?

- ☐ inorganic hydrogels
- ☒ **organic hydrogels**
- ☐ organogels
- ☐ jellies
- ☐ maggas

Figure 1. Example quiz question.

aid students in completing the online quizzes. In addition, a discussion board (WebWiz Forum, BDC Enterprises) was provided through the College of Pharmacy web site that allowed students to post questions, students and instructors to respond to posted questions, and instructors to post hints and other announcements related to the online quizzes or course material in general.

The quiz questions presented to students were organized into clusters and each cluster was evaluated for the major competency outcome addressed. Several of the competency outcomes were repeated in multiple question clusters and across several quizzes. The percent of questions answered correctly was calculated for each of the learning objectives listed in Table 1.

The percent of questions answered correctly was evaluated via chi-square analysis to determine whether the number of answer choices available affected student success. Since the quizzes were modified to increase ease of use based on instructor and student evaluation, the percent of questions answered correctly from 2004 and 2005 were compared via z test with Yates correction to determine whether student success rate was affected by the implemented modifications. Additionally, the student quiz averages from 2004 and 2005 were compared via the Mann-Whitney rank sum test to further assess any influence of quiz modifications on student success.

A *p* value of 0.05 was considered significant for all statistical analyses.

At the end of the fall 2004 semester, students completed an online evaluation of the product-based online quizzes used in *Pharmaceutics I* consisting of 2 open-ended questions: (1) What did you like best about

Table 1. Learning Objectives for Online Quizzes in *Pharmaceutics I*

- (1) Find information on product labels.
- (2) Understand basic pharmaceutics concepts and principles.
- (3) Evaluate active and inactive ingredients of various dosage forms.
- (4) Categorize dosage forms based on their ingredients and labeling information.
- (5) Perform pharmaceutical calculations related to:
 - Concentration and dilution – including mg/ml, ratio strength, percentages, and etc.
 - Dose calculations.
 - Reconstitution of dry powders.
 - Hydrophile-lipophile balance.
 - Isotonicity – including both Class I and Class II methods of adjustment.
 - Calculation of pH, buffer capacity, percent ionized, and pH of precipitation.

the online quizzes? and (2) What suggestions do you have for improvement of the online quizzes? Students completed an in-class midterm course evaluation in fall 2005 for *Pharmaceutics I*, which included an open-ended question related to the product-based online quizzes: Do the online quizzes help you to practice calculations and/or allow you to apply concepts to practical examples? Both student evaluations were formative in nature to allow the students to express their opinions freely rather than leading them with summative questions. The evaluations were designed to identify ways that quizzes could be modified to make them more user-friendly for the students, and modifications were implemented in response to student and instructor evaluation.

In order to evaluate the transferability of the interactive digital images and related quizzes, faculty members in the Department of Basic Pharmaceutical Sciences at the University of South Carolina were given access to an example quiz and were asked to complete a short survey instrument about the interactive digital images viewed and the product-based online quizzes. Faculty members were asked to respond to the questions using a Likert scale and the results were tabulated.

ASSESSMENT

Student scores on online quizzes for fall 2004 and fall 2005 ranged between 0 and 100%; students who scored 0 did not attempt the quiz. Student quiz scores ranged from 53% to 100% and averaged $82.7\% \pm 7.6\%$ in 2004 and $91.1 \pm 5.7\%$ in 2005 (mean $\pm$ standard deviation). There was a significant difference between quiz averages in 2004 and 2005 ($p < 0.001$). Table 2 summarizes the percent of questions presented to students that were answered correctly and is organized by the major competency addressed by each question. In 2005, students answered more multiple-choice questions correctly than in 2004 ($p < 0.001$). Overall, students also performed more pharmaceutical calculations correctly in 2005 than in 2004, but the difference varied with the type of calculation.

Table 3 summarizes the percent of questions that were answered correctly and is organized by the major competency addressed by each question as well as the number of answer choices available. The number of answer choices did not affect students' success rate at evaluating active and inactive ingredients of various dosage forms (learning objective 3) in 2004 but did influence the percent of questions answered correctly in 2005 ($p < 0.05$). The number of answer choices affected student success rate at categorizing dosage forms based on their ingredients and labeling information (learning objective 4) in both 2004 and 2005 ($p < 0.001$). Quiz questions pertaining to learning objectives 1, 2, and 5

Table 2. Percent of Correct Answers to Questions Corresponding to General Competency Outcomes in *Pharmaceutics I*

Competency Outcome	2004, Mean (SE)	2005, Mean (SE)	Overall, Mean (SE)
Product labeling	93.8 (0.7)	98.2 (0.4)*	96.0 (2.2)
Concepts from lecture	84.6 (1.3)	94.8 (0.7)*	89.7 (5.1)
Dosage form categories	79.4 (1.1)	93.0 (0.6)*	86.2 (6.8)
Evaluation of excipients	73.9 (0.8)	90.4 (0.4)*	82.1 (8.3)
Calculations (all types)	85.7 (0.5)	88.3 (0.5)*	87.0 (1.3)
Concentration	89.0 (0.9)	94.6 (0.7)*	91.8 (2.8)
Reconstitution	95.5 (1.4)	96.6 (1.2)	96.1 (0.6)
Dose	94.6 (1.5)	93.5 (1.3)	94.0 (0.6)
HLB	84.2 (1.7)	90.6 (1.3) [†]	87.4 (3.2)
Isotonicity	79.3 (2.7)	82.3 (2.5)	80.8 (1.5)
pH	71.7 (1.5)	68.8 (1.5)	70.3 (1.5)
Shelf-life	90.5 (0.9)	92.6 (0.8)	91.5 (1.1)
Units	88.5 (1.5)	94.1 (1.1) [†]	91.3 (2.8)

SE = standard error; HLB = hydrophile-lipophile balance

*Significant difference in the percent of correct answers between 2004 and 2005, $p < 0.001$

[†]Significant difference in the percent of correct answers between 2004 and 2005, $p < 0.05$

did not vary in the number of answer choices available; thus, these learning objectives were not included in the assessment.

Ninety-four out of 111 students responded to the online survey in 2004 resulting in a response rate of approximately 85%. Most of the responding students gave both positive feedback and suggestions for improvement. In general, students liked the practical application of course material, the provision of tangible examples of pharmaceutical calculations, the ease of completing the quizzes on their own time and at their own pace, the reinforcement of concepts learned in the lectures, and the opportunity to review for examinations. Students responding to the survey suggested that the correct answers should be provided for quiz questions, that more than 1 answer attempt should be allowed for multiple-choice questions, and that the instructor should provide more hints to aid students when looking up answers. Many of the students included positive comments about the interactive digital images and there were no suggestions for improvement.

One-hundred seventeen of 118 students responded to the mid-semester in-class survey in 2005 (99.9% response rate). More than 75% affirmed that the online quizzes helped them practice calculations and/or allowed them to apply concepts to practical examples. The most

Table 3. Percent of Correct Answers to Questions Corresponding to General Competency Outcomes in *Pharmaceutics I*

Number of Answers	Dosage Form Categories, Mean (SE)			Evaluation of Excipients, Mean (SE)		
	2004*	2005*	Overall	2004	2005 [†]	Overall
4	73.8 (1.5)	91.0 (0.9) [‡]	82.4 (8.6)	69.6 (2.2)	91.1 (1.2) [‡]	80.3 (10.8)
4 – 6	88.6 (1.7)	97.2 (0.9) [‡]	92.9 (4.3)	73.3 (2.4)	86.7 (1.5) [‡]	80.0 (6.7)
7 – 10	88.3 (2.2)	96.2 (1.2)	92.2 (4.0)	76.6 (4.0)	92.7 (1.1) [‡]	84.6 (8.0)
>10				74.7 (0.9)	90.5 (0.6) [‡]	82.6 (7.9)

*significant relationship between the percent of correct answers and the number of answer choices, $p < 0.001$

[†]significant relationship between the percent of correct answers and the number of answer choices, $p < 0.05$

[‡]significant difference in the percent of correct answers between 2004 and 2005, $p < 0.001$

^{||}significant difference in the percent of correct answers between 2004 and 2005, $p < 0.05$

common suggestions for improvement were to allow ranges for numerical answers and to review quizzes after completion.

Eight basic pharmaceutical sciences faculty members evaluated the interactive digital images and the product-based online quizzes and the results are shown in Table 4. All of the responses were positive and the surveyed faculty members indicated many alternative uses for the interactive digital images in other courses, such as biochemistry, nonprescription drug therapy, pharma-

ceutical calculations, pharmaceuticals, pharmacy compounding laboratories, and community pharmacy laboratories.

DISCUSSION

In 2005, questions that did not include pharmaceutical calculations were answered correctly 90% of the time or more, indicating successful completion of learning objectives 1 through 4. Students answered more questions correctly in 2005 than in 2004. This could have been due

Table 4. Pharmacy Faculty Members' Responses to Survey Questions Regarding the Use of Interactive Digital Images to Teach Pharmaceutics

	Result, Mean (SD)*
(1) The interactive digital images were clear and easy to manipulate.	4.9 (0.4)
(2) Interactive digital images of drug products would be good teaching tools for:	
a. Lectures.	4.1 (0.9)
b. Laboratory courses.	4.7 (0.8)
c. Distance education.	4.4 (1.0)
d. Web-based learning.	4.6 (0.8)
(3) Interactive digital images of drug products would be a good substitution for bringing products to the classroom and would bypass issues with students not being able to see products in a large auditorium.	4.6 (0.7)
(4) The quizzes developed using the interactive digital images are a good substitution for previously used product quizzes that were discontinued due to a lack of laboratory space.	4.6 (0.7)
(5) Product-based online quizzes could augment material presented in lecture and in the textbook with concrete examples.	4.8 (0.5)
(6) Product-based online quizzes could be used to teach students how to evaluate active and inactive ingredients of various dosage forms.	4.8 (0.5)
(7) Product-based online quizzes could be used to teach students where to look on product labels for information.	4.8 (0.5)
(8) Product-based online quizzes could be used to reinforce pharmaceutical calculations with practical problems.	4.9 (0.4)
(9) The online quiz format is user-friendly.	4.9 (0.4)
(10) This approach is innovative.	4.9 (0.4)

*Responses were based on the following Likert scale: 5 = strongly agree or extremely effective; 4 = agree or very effective; 3 = uncertain or somewhat effective; 2 = disagree or not effective; 1 = strongly disagree or counterproductive

to the increased ease of use of the quizzes, increased faculty instruction, or differences in the students from the 2 classes. Differences in student success rate were more striking for multiple-choice questions than for calculations questions. Questions that included pharmaceutical calculations were answered correctly 87% of the time on average, but successful performance varied with the type of calculations performed. Students struggled with the calculation of pH. Only 70.3% of questions pertaining to pH were answered correctly, indicating that the coverage of pH calculations should be re-evaluated by pharmaceuticals faculty members. It is possible that the topic is being covered too quickly or in a depth unnecessary for future pharmacists. Calculations of pH traditionally are difficult calculations and for that reason are covered in multiple courses, including biochemistry and pathophysiology. However, pH calculations are not covered in the separate *Pharmaceutical Calculations* course. All of the other calculations included in the product-based online quizzes were taught in detail in a separate *Pharmaceutical Calculations* course. On average, students answered 87% of calculations questions correctly. Since the students were concurrently enrolled in *Pharmaceutical Calculations* and *Pharmaceutics I*, students received thorough instruction, reinforcement, practice opportunities, and application of calculations to examples via the overlap.

The online product-based quizzes were modified based on student and instructor evaluation after 2004 and again in 2005 and it is possible that these modifications affected the successful completion of learning objectives by students. Students suggested that more than 1 answer attempt should be allowed for multiple-choice questions. In fall 2004, students were allowed 2 tries at calculation questions (fill-in-the-blank) and only 1 try at multiple-choice questions. In response to student suggestions, 2 answer attempts were allowed for all questions in fall 2005. As seen by Table 2, student quiz averages as well as the percent of questions answered correctly were higher in 2005 than in 2004. Since the percentage of students answering multiple-choice questions correctly greatly increased between the 2 years, it is probable that allowing 2 answer attempts influenced student success rate. However, the difference in student success could be due to other factors as well. Students also indicated that the instructor should provide more hints to aid students when looking up answers. In response to this suggestion, the instructor deliberately covered more of the excipients in lectures and included more information about excipients in the FAQ file. The increase in the percent of questions answered correctly in 2005 was largest for questions pertaining to excipients; however, it is uncertain whether this was due to

the increase in answer attempts or increased guidance by the instructor.

Many students commented on their end of semester course evaluation in fall 2005 that the quizzes were too time-consuming. The students blamed the time required on the number of answer choices presented and the difficulty in looking up answers in their textbook. In light of the relationship between student scores and number of available answer choices, the number of answer choices available for multiple-choice questions will be reduced to 6 or less to decrease any perceived time constraints. Additionally, first-professional year students will be provided more guidance on how to use drug information resources and the number of quizzes will be reduced to 3 per semester, covering both *Pharmaceutics I* and *II*.

Students also suggested that, upon completion of each quiz, the correct answer should be provided for questions. One obstacle to implementation of this suggestion is the size of the question pool; even if correct answers were supplied, no explanation for why the answer was correct could feasibly be included due to the large number of questions. A more germane objection to allowing students to view their completed quiz with correct answers is maintenance of quiz integrity. The size of the question pool results in a large number of iterations for each quiz, which is the basis for quiz integrity. Students were expected to adhere to the honor code of the University and complete the quizzes individually; however, it is probable that some students chose to work together on their quizzes. Given the number of iterations for each quiz, students choosing to work together on their quizzes would have to complete the equivalent of multiple quizzes, thereby furthering their understanding of the material. It would be very difficult for students to compile a "bank" of questions due to the large number of questions and the presentation of each question on a separate page. However, to further decrease the likelihood of the development of a "bank" of questions, the instructor also declined to provide a quiz key for each student. Instead, sample quizzes were developed with an example question from each cluster. The sample quiz included the correct answer and the mathematical solution to calculation problems and an explanation for why the answer was correct (or why alternative answers were incorrect) for multiple-choice questions. The sample quiz was available to students as they were taking the quiz during fall 2005. In spite of this accommodation, students commented on their end-term evaluation again in 2005 that they would prefer to be able to review their own completed quiz with correct answers/solutions.

As suggested by faculty evaluation results, both the interactive digital images and product-based online quizzes are easily adaptable for use in other courses and

at other institutions. The interactive digital images are versatile and can be used both in lecture and laboratory courses. A pool of product images could be organized and faculty members could use the interactive digital images in class as visual aids or incorporate them into associated learning activities. Currently, the interactive digital images of products encompass liquid and semi-solid dosage forms covered in *Pharmaceutics I*. Additional products could be added by users as new products are marketed and according to the usage requirements. Digital photographs of multiple views of additional products could be manipulated into the desired format using 2-, 3-, and 4-sided Flash templates in Macromedia Flash Studio MX.

The platform for the online quizzes has been used in multiple courses at the University of South Carolina with slight modifications. Microsoft Access is used to develop and maintain the question pool; new questions can easily be developed for existing quizzes and/or new quizzes can easily be developed using Microsoft Access. Similar adaptations and expansions could widen the use of product-based online quizzes to other courses and institutions. The development and testing of the interactive digital images of drug products and online product-based quizzes required a significant investment of staff time and energy. Once the Flash file template was established and the quiz platform was developed, the database was populated with questions and products were photographed and transferred into the Flash files. Although the time required to set up the quizzes and develop the interactive digital images was extensive, little time is required to maintain established quizzes. If the question bank is sufficiently large, new questions will only be necessitated by the emergence of new products on the market and can simply be modified from previously developed questions. Student scores are automatically generated and have only to be copied into a grade book. Students have the option at the end of the quiz to request that any incorrect answer be reviewed by the instructor. A Quiz Manager web site allows the instructor to view the student's questions and answers. From the Quiz Manager web site, the instructor can reset the quiz to allow the student an additional try on any question and can override the automatic grading system to count an answer to any question correct. The platform then updates the student scores. This automated system greatly reduces the time burden of grading by the instructor and at the same time increases student satisfaction since they have immediate scoring and can appeal the computer-generated score to the instructor at the end of each quiz. The advantages of the online quiz format include automated grading and scoring, immediate feedback on student progress, ability to pull questions randomly from a large question pool,

ability to randomize questions into individual student quizzes, and completion at students' desired time, place, and pace.

As enrollment in colleges of pharmacy increases nationally, it is expected that other colleges of pharmacy will face the same challenges that led to the development of these interactive digital images and product-based online quizzes. The South Carolina College of Pharmacy was facing increased enrollment and the associated issues of adapting learning aids that were effective with small classes to larger classes. The interactive digital images and product-based online quizzes were developed to allow instructors and students to adapt to the new learning environment necessitated by larger class size. Additionally, the interactive digital images and product-based online quizzes could be adapted for use in distance education.

The interactive digital images are exceptionally simple to manipulate but provide close-up and high-resolution views of product labeling information. Yet the files are small enough to load quickly on student computers off campus and the entire bank of files can be stored on a single CD-ROM. The idea and use of product-based quizzes has been around for years; however, this is a novel approach that broadens the scope and availability of such quizzes. This application allows a traditional learning aid to be converted to an electronic version that is more widely germane.

CONCLUSIONS

The interactive digital images and product-based online quizzes are an asset to the pharmaceutics course sequence at the University of South Carolina. The interactive digital images are ideal for showing students examples of dosage forms covered during lecture. The product-based online quizzes encourage students to apply the knowledge learned in lectures to practical examples and reinforce subject content of both pharmaceutics and pharmaceutical calculations. Although the product-based online quizzes are already fairly simple and easy to use, modifications are planned to increase the ease of use for students as well as for faculty members and support staff members. The student and faculty evaluations of the application were largely positive and included suggestions for improvement that have either been addressed or will be addressed by planned modifications. The competency outcome data illustrates that the product-based online quizzes aid students in meeting the desired learning objectives and that student success rates can be improved by increasing the ease of use. The interactive digital images and product-based online quizzes can be adapted and expanded for uses in multiple

courses, at distant campuses, and at multiple institutions. The development of interactive digital images and product-based online quizzes has successfully transformed a traditional learning aid into a viable electronic resource for pharmacy education.

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