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INSTRUCTIONAL DESIGN AND ASSESSMENT

A Self-paced Course in Pharmaceutical Mathematics Using Web-based Databases

David W.A. Bourne, PhD[a] and A. Machelle Davison, EdD[b]

[a]College of Pharmacy, University of Oklahoma
[b]Office of Educational Development, Oklahoma State University Center for Health Sciences

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Objective. To transform a pharmaceutical mathematics course to a self-paced instructional format using Web-accessed databases for student practice and examination preparation.
Design. The existing pharmaceutical mathematics course was modified from a lecture style with midsemester and final examinations to a self-paced format in which students had multiple opportunities to complete online, nongraded self-assessments as well as in-class module examinations.
Assessment. Grades and course evaluations were compared between students taking the class in lecture format with midsemester and final examinations and students taking the class in the self-paced instructional format. The number of times it took students to pass examinations was also analyzed.
Conclusions. Based on instructor assessment and student feedback, the course succeeded in giving students who were proficient in pharmaceutical mathematics a chance to progress quickly and students who were less skillful the opportunity to receive instruction at their own pace and develop mathematical competence.

Keywords: mathematics, Web-based instruction, self-paced, distance education, assessment

INTRODUCTION

The *Pharmaceutical Mathematics* course is a core requirement of the professional pharmacy curriculum.[1] The instructional format varies from institution to institution. Ranging from incorporation of the mathematical calculations into the curriculum of other pharmacy courses, to self-study books/CD-ROMs, Web-based material/courses, or standalone lecture-based courses. The general consensus is that the core content of a *Pharmaceutical Mathematics* course is essential to the training of competent pharmacists. Pharmacy students should confirm competence in this area and this competence should be reinforced throughout the pharmacy curriculum.

The objective of the 2-credit course at the University of Oklahoma is that "Students will understand and become proficient in the calculations that may be encountered in the practice of pharmacy." From 2001-2002, this course was taught online by outside instructors using a remote web server with only 2 face-to-face classroom sessions held for examination review. Students complained about the lack of face-to-face contact with instructors and that if they did not understand something, the feedback and time for remediation was not adequate to keep them from falling behind in the course (and therefore in their careers since subsequent courses built on math skills). For these reasons, in fall 2003, this course was taught "in house" and presented using a lecture format with a textbook and traditional midsemester and final examinations. Although this was reasonably well received by the students because they were able to discuss problems and follow examples in class, 20 of 127 students were unable to demonstrate a satisfactory level/degree of proficiency and received a grade of D or F for the course. Upon investigating this phenomenon, several issues surfaced. First, class attendance had dwindled giving the impression that students were confident in their skills. However, conversations with students showed that the reasons for absences were twofold: those students who were quite competent in mathematics and required little instruction wanted opportunities to show proficiency without having to attend lectures while students who needed more help and advice than could be given during the class period or outside office hours had become frustrated. Furthermore, some students came into the course with the misconception that it would be easy, not realizing the magnitude of pharmaceutical mathematics compared to regular undergraduate or high school math courses. As Brown explained "the major difficulty in pharmaceutical calculations is not the math, it is the fact that the margin for error

Corresponding Author: David Bourne, PhD, OUHSC College of Pharmacy, 1110 N. Stonewall Ave Oklahoma City, OK 73117. Tel: 405-271-6481, ext. 47213. Fax: 405-271-7505. E-mail: david-bourne@ouhsc.edu

is non-existent."[1] Students underestimated the course and thought that they could miss class and still pass.

In fall 2003 semester, a small number of Web-based practice sets were developed to help those students who needed additional practice time (beyond the lecture period or office hours) and to give students a way to gauge their skills throughout the semester with the variety of calculations required. Time constraints limited the number of practice sets that could be developed at that time. However, these practice sets were quite popular with the students and they asked that more sets be developed.

Another consideration for the development of on-line instructional activities was the increase in the number of students in the course and the addition of a second site. With nearly 140 students in the fall 2004 class residing on 2 campuses (Oklahoma City Health Sciences Center and Tulsa Schusterman Center), the use of multiple versions of each examination was desirable. With this background it was decided to create a more complete collection of practice problems and use these practice problems as the basis both for student self-study and in-class assessment in fall 2004.

The development of a Web-based system was essential to the efficient presentation of the course in this new format. The objective of this report is to describe the process used to teach the *Pharmaceutical Mathematics* course in fall 2004 at the University of Oklahoma. Using a Web-based database of questions, the course instructional method was modified to provide an efficient method for competent students to demonstrate their proficiency with the course material and to provide additional instructional opportunities for students who were less comfortable with mathematical material and needed more outside class opportunities to excel.

DESIGN

For many years, the textbook *Pharmaceutical Calculations* by Ansel and Stoklosa[2] had been required for this course. Prior to the fall 2004 semester, the content was reviewed by the instructor with the help of College faculty members who decided that the course should concentrate on a major subset of the chapters provided in the textbook. Thus, chapters 1-14, 17, and 21, and appendix A were included in the course syllabus for fall 2004. Most of the material not covered in this first semester course is presented in other courses later in the curriculum. Based on page count and material commonality, the material to be covered was split into 8 modules as shown in Appendix 1.

The course consisted of two 50-minute class periods per week. These 2 class periods were split into 1 lecture/tutorial session and 1 in-class examination session per week. Additional student assistance was provided by faculty members via office hours, telephone, e-mail, and instant messages. One lecture period was replaced with an in-class examination session each week. To pass the course, the student had to complete an examination from each module with a score of at least 9 out of 10. They could miss only 1 question to get credit for a module. As with the other formats, students were held to a high standard of accuracy. Each answer supplied by students was required to have a number (within 1% of the correct answer), a correct unit, and when appropriate, a correct substance to receive full credit. Additionally, each module examination after the first included 2 of 10 questions from previous material, thereby requiring students to show continued mastery of calculations throughout the semester. This "high-stakes" examination mode was compensated for by allowing the students multiple attempts at each module examination.

During the 50-minute examination session, the instructor and another faculty member would pass out the appropriate examination for each student. Each student was allowed to attempt up to 2 modules during any given examination session. Once students completed the first module for that examination period, they would hand it in to the faculty member and ask for the next module in the sequence. The students' grades were determined by the number of missed attempts. For example, students who failed only 1 or no module examinations received a grade of A. An additional compensation was allowing the students the choice of whether they wanted to turn in an attempted examination. This was an opportunity for the students to demonstrate confidence in their answers.

Each student completed module examinations at his/her own pace; thus, the students were soon out of step with each other. To alleviate the personnel effort required to overcome this sequencing problem, a Web-based system was used to help with the preparation of examinations, determine which module examinations to prepare, assist with examination grading, and simplify the recording of results and grades for each student.

The Web-based system provided 2 access points. The instructor could access the system to create examinations with answers that could be used during the in-class examination sessions, record results or examination scores in the grade book portion of the system, modify grades in the system, track the number of examinations needed for each class period, regulate the authentication in the system, and perform other system maintenance functions as needed. The students could access the system to print the non-graded practice examinations (a new practice examination including answers was created by the system each time the student refreshed the screen), view their progression in the course, and access their results for each module

examination that they had taken. Authentication was used so that students could only access their information in the system.

Each of these steps was aided by the development of a Web-based system using php (http://www.php.net/manual/en/) as the programming language and *MySQL* (http://dev.mysql.com/) as the database language running on a web server with Apache software (http://www.apache.org/). This system was developed to provide a near infinite number of questions for student practice or for the in-class module examinations and to manage the examination preparation and grade book functions.

Problems from each covered chapter were developed and programmed in php as separate questions, with more questions from each chapter than were needed for any given examination. The numbers in each question were randomly chosen or calculated so that different values (questions) were presented each time the Web page was updated. For example, a dose value could be randomly chosen from a finite set of values. A patient weight value could be calculated randomly using a specified mean and standard deviation or uniformly between some specified low and high values. Each time these pages were visited, different random numbers were presented. Students were given instructions on how to access the practice examinations at the beginning of the semester. The process was explained during the first class period. Students were guided to review the practice examinations for examples of question types and formatting in preparation for the in-class graded examinations. The system was not set up to grade the examinations automatically online.

The examination Web pages (formatted as a single page with a slightly smaller font) were generated by the program and displayed on the examination web site for the faculty member to print for the examination session. Each examination page, so generated, included a unique identifying number to help maintain examination integrity. Examinations were created through the system, which randomly selected 8 questions from the current module and 2 questions from all the previous modules. For the first examination, all the questions were only from that first module. Considerable programming effort was expended to help ensure that the numbers and formats for each question were realistic. The Web page for each examination produced a fully formatted examination with 10 questions on 1 page and the answers on the second page. An example Module 2 examination is shown in Appendix 2. Questions within each module were segmented by the program so that a good selection of question types was available for the examination creation. This allowed the numbers, and in some cases the units and question format, to be randomly changed from examination to examination. The program randomly selected questions from the question bank appropriate to the particular module examination, including the 2 questions from the earlier modules.

In preparation for the in-class examination session, the instructor prepared 4 versions of each module examination by simply reloading/refreshing the Web page 4 times and then printing each version with the answers. The answer sheets were held in reserve for the instructor and used as a key for grading purposes. The fully formatted question page was then duplicated to produce the required number of examination sheets for the students expected to take a particular module examination. For example, if 40 students were expected to take Module 2 during an examination session, then 9 copies of each version (4 versions produced from the online system) would be copied for the examination period. The grade book described below provided the number of examinations required per module for each in-class examination session. Students could only take the graded examinations in class.

A practice page (or examination page), was available continuously for student access and practice. The students were encouraged to use the practice module page for their self-study since these pages provided example of all the questions types for that module. The examination page provided only a subset of the questions available; thus, some types of questions could have been missed as compared with the practice pages. The Web pages (practice and examination format) provided both the questions and the answers (on a separate page). Thus, the students had ready access to both questions and answers for self-study, but were encouraged to first attempt the examination without looking at the answers for maximum benefit. Each time the student visited the practice (or examination) page, random numbers were presented. In this way they had an almost infinite number of practice opportunities.

A working version of the examination preparation and student practice pages took the instructor about a month to develop using php and *MySQL* as the database language. Each question took about ½ to 2 days to develop using the php programming language depending on its complexity and similarity with previously developed questions.

Keeping track of the students' results and which examinations to prepare was aided by another series of programmed Web pages. These Web pages allowed the recording of examination results by the faculty or staff member, determination of the number of each examination modules required for any given examination day and student access to their grades for reviewing their progress.

The Web pages were programmed using php which accessed a *MySQL* database of student attempts and scores. The faculty member had access to all of the data and was able to prepare the appropriate number of examinations in 4 versions. More or fewer versions could be prepared at the faculty member's discretion. The grade entry Web page allowed the faculty member to assign a pass or fail grade for each attempt. This web page included a record of previous results for each student, pop-up buttons to select "pass" or "fail," or blank for future results. Prior success was indicated by P [*x*] where *x* is the number of missed attempts. A value of P [0] meant that students passed the module on the first attempt. Two (or fewer) pop-up buttons were available to record a pass or a fail if the module was attempted. Only 2 module examinations could be attempted during any in-class module examination session. The grade book Web pages provided a summary of the results and the summary of the total number of modules passed by all students. The student grade was based entirely on the number of missed attempts. Each student was provided access to his/her own scores through a password validation scheme. The students could view their progress throughout the semester from the course Web site. Once all the modules were completed, the number of attempts required was translated into the student's grade for the semester.

A working version of the grade-book Web pages also took the instructor about a month to develop using php as the programming language and *MySQL* as the database language.

ASSESSMENT

Student progress during the semester was steady with a number of early finishers (10 students completed all 8 module in 6 weeks). There were also a number of procrastinators. The slowest 10 students were still working on 1-3 modules during the last 6 weeks of the semester. The progress of the whole class is shown in Figure 1. Completion of Module 1 was relatively rapid, although there were a small number of students who waited several weeks to get started and complete the early modules. Three modules appeared to be more challenging for students. Module 6 had the highest number of missed attempts (80) followed by module 8 (65 missed attempts) and module 4 (48 missed attempts). The number of missed attempts for all the modules is shown in Table 1. On any given examination day the percentage of missed attempts ranged from 12% to 67% with the higher success on days with a larger number of students taking the classroom examinations. Overall student performance was much improved over the previous method of instruction. Every student was able to pass all 8 module examinations by the end of the semester. This was more favorable in comparison to the previous year when 20 students failed to satisfactorily complete the course requirements.

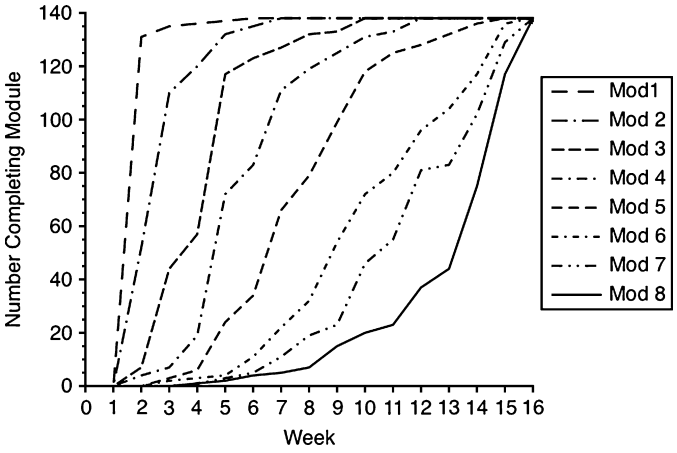

Figure 1. Plot of the number of students passing each module of a self-paced course in pharmaceutical mathematics by week (fall 2004).

The examinations for one in-class module examination session took approximately 2 hours to prepare, make copies, and send a copy to the distant site in Tulsa. Making copies at the distant site took about an hour of staff member time. One hour was required at both sites for the actual classroom examination period. Examinations from the distant site were scanned (and saved in a pdf format) and could be electronically transmitted within 10-15 minutes of completion of the examination. Two to 3 hours were required for grading, depending on how many students took examinations on a particular day. One hour was required for recording the results.

Since the instructor was only available at 1 examination site, no content questions were allowed during the classroom examination. The students were provided with the examination itself, a standard calculator, pencils, ruler, and a few pages of supplemental material. The supplemental material consisted of such information as weight set contents, BMI chart, nomograms, and some

Table 1. Number of Missed Attempts by Module

Module	Unsuccessful Attempts
1	24
2	35
3	41
4	48
5	43
6	80
7	36
8	65

equations. The students were expected to memorize various conversion factors and abbreviations.

DISCUSSION

Generally, students liked the idea of being able to complete the modules on their own schedule. Positive comments included: ''the ability to set my own pace,'' ''he had good practice problems with the answers so we could study before the tests,'' ''no final,'' ''self-paced,'' ''independent learning,'' ''done early in the semester.''

By allowing students to take up to 2 module examinations each week, students who were competent in mathematics were able to show their proficiency early. This met the first objective discussed in the introduction of giving those students who were proficient the opportunity to prove their skills (Figure 1). Giving them the choice of turning in an attempted examination meant they needed to have confidence in their ability. Also, allowing them to make several attempts at passing each module examination and allowing them to take as many practice examinations as needed gave them repeated practice and opportunity for improvement of skills until they were able to reach mastery. This met our second objective discussed in the introduction of providing additional instructional opportunities for students who were less confident in mathematics. The number of students requiring remediation was significantly reduced since this instructional method forced mastery throughout the semester. No students in fall 2004 required remediation or had a grade of D or lower.

The high pass rate (9 out of 10) required for each module examination was not popular with some students. It was good to see their rationale for this comment since it was mathematically based, but a reasonable alternative was not provided. Their argument was that if they missed 2 questions on each of 3 modules (for a total of 6 questions) they would get a grade of B (3 missed attempts). Someone else might miss 1 question from each of the 8 modules (for a total of 8 wrong questions) and still get a grade of A since they passed all the modules on their first attempt. The student's grade is determined by the number of failed module examinations. Zero to one was an A, 2 to 4 failed examinations was a B, and more than 4 failed modules examinations resulted in a grade of C. Failing to pass all the modules would have resulted in an F. However, all of the students completed all of the modules examinations successfully. They also did not recognize that the instructor expected 100% accuracy and was being ''lenient'' in allowing 1 mistake.

Since this was the first year that this approach was tried, a curve from the previous year was used in part to assign the number of modules which could be missed for each grade. The percentage of As, Bs, and Cs received by students during the previous year (using the more traditional evaluation method of only 3 examinations) was used to set the number of module examinations which could be failed for a particular grade. The students were given this information during the course orientation and they later criticized the change, saying that they were being required to compete with other students for their grades. Another problem that surfaced was that the lectures progressed through the material in the textbook in a ''linear'' fashion, which meant that it was commonly out of step with what some students were working on for their next examination. Finally, there were also suggestions to revise some of the more challenging modules, such as module 6, by moving some material to other modules. Solutions to all problems or concerns were evaluated for implementation in fall 2005.

CONCLUSION

Adjudged by the student scores and student comments, the change of format was a success. All the students, except 1 who withdrew from classes for the entire year, passed all 8 modules during the semester and were awarded a letter grade of C or better. Students who were proficient in mathematics were able to complete the work early, giving them more time to concentrate on other courses. Those who were weaker in mathematics were given more opportunities to master the required skills. Students were held to the higher standard of accuracy in calculations that is expected in the pharmacy profession. Examination preparation, grading, and recording time were significant, but with the Web-based system in place, these functions were not unmanageable and many could have been completed by staff members.

ACKNOWLEDGEMENTS

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REFERENCES

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Appendix 1. Modules included in the *Pharmaceutical Mathematics* syllabus, fall 2004.

- Module 1
  1. Some Fundamentals of Measurement and Calculation (pp 1-40)
- Module 2
  2. Interpretation of the Prescription or Medication Order (pp 31-50)
  3. The Metric System (pp 51-62)
  A. The Common Systems of Measurement and Intersystem Conversion (pp 308-320)
- Module 3
  4. Calculation of Doses (pp 63-91)
  5. Reducing and Enlarging Formulas (pp 92-100)
- Module 4
  6. Density, Specific Gravity and Specific Volume (pp 101-112)
  7. Percentage, Ratio Strength and Other Expressions of Concentration (pp 113-132)
- Module 5
  8. Dilution and Concentration (pp 133-159)
- Module 6
  9. Isotonic Solutions (pp 160-171)
  10. Electrolyte Solutions, Milliequivalents, Millimoles and Milliosmoles (pp 172-187)
- Module 7
  11. Some Calculations Involving "Units", "ug/mg" and Other Measures of Potency (pp 188-194)
  12. Constituted Solutions, Intravenous Admixtures and Rate of Flow Calculations (pp 195-217)
  13. Some Calculations in Contemporary Compounding (pp 218-225)
- Module 8
  14. Body Mass Index and the Nutrition Label (pp 226-233)
  17. Calculation of Active Drug Moiety (pp 253-259)
  21. Miscellaneous Pharmaceutics Calculations (pp 287-307)

Appendix A. The Common Systems of Measurement and Intersystem Conversion Plus Two Questions from Module I

#	The Question	Your Answer
1	Interpret: Ft. sup. No xxiv. instructions to the pharmacist (subscription)	302
2	If a 25 mL vial of a drug contains 30 units per milliliter, and a patient is to administer 20 units daily. a) how many days will the product last the patient? b) If the patient relumed to the pharmacy in 4 weeks for another vial, was the patient compliant as indicated by the percent compliance rate (compliant if > 90%)	
3	Multiply 2610 mL by 11 and express the answer in L.	
4	A solution is made from 6 L, 770 mL and 0.395 L what is the total volume in mL?	
5	Add 2 kg, 667 mg and 32 g and express your answer in gram?	
6	Given the task of weighing 904 gr of a drug which weights would you use	
7	Given the task of weighing 13283 mg of a drug which weights would you use	
8	Add together iv ii, ii, and v gr and express the total in grains.	
9	Using a graduated cylinder, a phannacist measured 45 milliliter of a liquid. On subsequent examination, using a narrow-gauge burette, it was determined that the pharmacist had actually measured 40 milliliter, what was the percentage error in the original measurement.	
10	To measure 60 mg of a drug using a balance with a SR of 10 mg to an accuracy of 5% calculate a) the minimum quantity of drug weighed (round up to the nearest 5 mg) and b) quantity of diluent required if you weigh the answer in part a in the first step and 225 mg of the mixture in the final step	Minimum weighable quantity method