RESEARCH ARTICLES

Pharmaceutical Calculations Instruction and Assessment in US Colleges and Schools of Pharmacy

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Objective. To characterize the current strategies used in the instruction and assessment of pharmaceutical calculations content through the administration of a nationwide survey.

Methods. Instructors of pharmaceutical calculations were invited to complete a 34-item questionnaire designed to gather information on course logistics, content delivery, covered topics, homework, examinations, and retention measures.

Results. Seventy-two colleges and schools responded to the survey. Exactly half of the respondents indicated that they had a standalone pharmaceutical calculations course, while the other half indicated this material was integrated into other coursework. An average of 24.8 hours was devoted to calculations topics. A minimum passing examination score of 70% was reported by 53% of programs. Knowledge retention was formally measured in 16% of programs, while 27% responded that they did not measure retention.

Conclusion. This survey provided the first assessment of the strategies used to teach and assess pharmaceutical calculations content. Further work is needed to determine the optimal teaching and assessment strategies for pharmaceutical calculations, as well as optimal methods of evaluating and promoting retention of this material.

Keywords: calculations, pharmaceutical calculations, survey, assessment

INTRODUCTION

Accurately performing pharmaceutical calculations is a crucial skill of pharmacists. The development of pharmaceutical calculation skills in students plays a significant role in building a competent practitioner.¹ Traditional live lectures, the Internet, CD-ROM, and other computer-assisted instructional methods have been used to deliver calculations course content.²⁻⁵ Others have employed self-study paper-based materials in the instruction of this content.⁶ The use of a knowledge retention examination has been described.⁷ However, no summary of the strategies employed to teach and evaluate pharmaceutical calculations content in colleges and schools of pharmacy across the United States has been published. The aim of this study was to characterize the current strategies used in the instruction and assessment of pharmaceutical calculations content through a nationwide survey.

METHODS

A survey instrument was developed to gather information regarding the instruction and assessment of pharmaceutical calculations content in colleges and schools of pharmacy in the United States. The survey instrument consisted of 4 sections: (1) general information, course logistics, content delivery, and covered topics; (2) homework; (3) examinations, and (4) application and retention. A draft of the survey instrument was sent to 4 faculty members, 1 at our institution who is knowledgeable about survey research, and 3 who teach pharmaceutical calculations at other institutions. Their feedback and suggestions were incorporated into a final 34-question online survey instrument.

The dean's offices of 89 colleges and schools were contacted via telephone to obtain the contact information for the faculty member or primary instructor responsible for teaching pharmaceutical calculations content. This individual was called (preferably) or e-mailed (if no telephone number was provided) and invited to complete the survey instrument. Faculty members and instructors who agreed to participate were sent a link to the survey instrument. If the survey instrument was not completed within 4 weeks, up to 3 follow-up contacts were made to

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encourage participation. Prior to any recruitment of participants, this project was submitted to the University of Minnesota Human Subjects Committee, who determined that it was exempt from review. Survey responses were managed with a server-side Microsoft Access database and analyzed using SPSS (SPSS, Chicago, Ill).

RESULTS

Seventy-two colleges and schools of pharmacy completed the survey instrument, for a response rate of 81%. The calculations topics covered within the calculations course or module of the 72 colleges and schools are given in Table 1.

The majority of programs (88%) place the calculations content in the first-professional year of the program, while 7% place it in the preprofessional years and 6% place it in another part of the curriculum. Exactly half of the 72 respondents reported that they delivered calculations content in a standalone calculations course, while the other half reported that they did not have a course dedicated to calculations but delivered this content as part of a broader course or courses. The mean number of hours spent on calculations content, including examinations, was 24.8 (range 0-88, SD = 18.1). Those with standalone calculations courses averaged 30.0 hours of calculations content, compared to 18.9 for those without a standalone course ($p = 0.01$).

Of the 72 respondents, 40 (56%) reported that they were the sole instructor for calculations content. Another 17 (24%) reported they were 1 of 2 instructors for calculations material. Eight colleges/schools used 3 instructors and 7 colleges/schools used 4 or more instructors. On average, the courses that included calculations content had 111 students enrolled (range 27-300; SD = 49.7).

Sixty-eight (94%) programs used live lectures and/or discussions to deliver content. Twenty (28%) delivered at least some content via paper-based study packets and 9 (13%) used web-based study packets. Of the 4 colleges that did not use live lectures and/or discussions, 2 used solely paper-based study packets and 2 use solely web-based study packets.

At least 1 textbook was required by 67 (93%) of the colleges/schools responding, with 4 programs requiring 2 texts. The required textbooks included Ansel and Stoklosa's *Pharmaceutical Calculations*⁸ (56 programs), O'Sullivan's *Understanding Pharmacy Calculations*⁹ (6 programs), Zatz and Teixeira's *Pharmaceutical Calculations*¹⁰ (4 programs), and Khan, Strauss, and Reddy's *Pharmaceutical and Clinical Calculations*¹¹ (3 programs).

Sixty-four respondents (89%) completed the portion of the survey addressing homework. Eight (13%) reported that they did not include homework as a component of the

Table 1. Calculations Topic Areas and the Number of Programs Covering Each Within Their Identified Calculations Content (N = 72)

Subject	Part of the Calculations Course/Module, No. (%)
Percent concentration	72 (100)
System of measure-metric	69 (95.8)
Aliquot calculations	68 (94.4)
Abbreviations	67 (93.1)
Specific gravity	67 (93.1)
Conversions between systems of measure (Metric, English, etc)	66 (91.7)
Ratio strength	66 (91.7)
Interpreting a prescription	65 (90.3)
Alligation method	64 (88.9)
Milliequivalents	64 (88.9)
Proportion calculations	64 (88.9)
Infusion rates	63 (87.5)
Diluting/concentrating	62 (86.1)
Osmolarity	62 (86.1)
Isotonicity	60 (83.3)
System of measure-apothecary	56 (77.8)
System of measure-avoirdupois	56 (77.8)
Avoiding trailing zeros (1.0) and naked decimal points (.1)	55 (76.4)
Molarity	54 (75.0)
System of measure-English	53 (73.6)
Algebraic method	52 (72.2)
Use of prefabricated dosage forms in compounding	52 (72.2)
Estimating doses	49 (68.1)
Dimensional analysis	47 (65.3)
Ideal body weight	38 (52.8)
Normality	38 (52.8)
Medication errors (concept of, methods of minimizing, etc)	38 (52.3)
Proof strength	35 (48.6)
Thermometry	33 (45.8)
Alcohol, USP calculations	42 (44.4)
Concentrated acids (and formaldehyde)	32 (44.4)
Powder volume	32 (44.4)
Caloric parenteral requirements	30 (41.7)
pH	28 (38.9)
Buffer systems	25 (34.7)
DEA number	25 (34.7)
Creatinine clearance calculations	23 (31.9)
Estimation of solubility	19 (26.4)
Other	12 (16.7)
Radiopharmaceuticals	9 (12.5)

calculations material. For the 56 programs that did, the mean number of homework sets was 10.3 (range 3-36, SD = 6.6). The number of problems given in each homework set is presented in Table 2.

When asked about the feedback provided to students, 44 (79%) of the 56 programs indicated that they provided students with the correct answers to problems, while 12 (21%) indicated they did not provide the correct answers to students. Only 35 (63%) indicated that they provided students with example solutions and only 24 (43%) indicated that they provided individualized comments on each student's homework.

Twenty-four (43%) indicated that homework was optional and 32 (57%) indicated that it was required. One program included in the optional group indicated that homework became required if test performance was below 50%. Fifteen (47%) of the 32 programs requiring homework indicated it counted toward 10% or more of the course grade. It was not clear how the required homework influenced the course grade at 8 (25%) colleges/schools, while 7 (22%) programs indicated it counted for less than 10% of the course grade and 2 (6%) indicated it did not count at all toward the course grade despite being required.

Of the 32 programs requiring homework, 26 (81%) provided the correct answers to the problem sets to students. Of the 24 programs in which homework was optional, 18 (75%) provided the correct answers to students. The difference in proportion between required homework programs providing the correct answer (81%) and optional homework programs providing the correct answer (75%) was not statistically different ($p = 0.744$). Programs with optional homework were substantially more likely to provide example solutions to their students (19 of 24 for optional homework vs. 16 of 32 for required homework, $p = 0.03$). On the other hand, programs with required homework were more likely to provide individualized comments, although this did not reach statistical significance (17 of 32 for required homework vs. 7 of 24 for optional homework, respectively; $p = 0.103$). There was no significant association or trend between standalone/integrated courses and required/optional homework.

A total of 71 of the 72 respondents completed the portion of the survey instrument regarding examinations. Of these, 1 college/school did not give any examinations in the course. Only the 70 colleges/schools that indicated they administered 1 or more examinations were included in the examination analyses.

The median number of examinations given was 4 (range 1-27; mean 5.4; SD = 4.3). One program gave 27 examinations (essentially 1 each week over 2 semesters) with the next highest number of examinations given by a college/school being 13. Thirty-five (50%) of the programs gave 2, 3, or 4 examinations. Six programs (8.6%) administered only 1 examination.

The median number of problems on each examination was 15 (range 5-50; mean 18.4; mode 10; SD = 10.4). Twelve programs did not provide a quantitative answer, indicating only that the number of problems on each examination varied. Table 3 summarizes the types of problems on examinations, the number and percent of programs using each type, the number and percent exclusively using each type, and the mean percent of questions of each type on the examination(s). Table 4 summarizes the time allocated for examinations. There was no statistically significant difference or nonsignificant trend seen in examination times for those using or not using any of the various types of examination questions listed in Table 3.

Figure 1 shows the distribution of the minimum criteria for passing an examination for the 53 responses providing specific criteria. The mean passing examination score was 71% (range 60-90, SD = 6.3). Slightly more than half of the programs (28 of 53) set the minimum criteria at 70%. There was no statistically significant difference in the mean minimum criteria for passing between courses that were standalone and courses that were integrated (71% vs 71% respectively, $p = 0.647$).

Figure 1 also shows the distribution of the minimum passing criteria for the course (or portion of the course related to calculations) for the 57 programs that reported having pass/fail criteria. The numbers were similar to those for examinations, with a mean passing score of 71% (range 60-90, SD = 6.4) and a median passing score of 70% reported by 25 of the 57 programs. Of the 13 programs giving examinations that did not give specific numeric criteria for passing the course or module, 6 reported that there were no minimum criteria, 6 gave responses that were not interpretable, and 1 did not respond to this question. Similar to the examinations, there was no difference between standalone and only integrated courses.

Twenty-four (34.3%) of the 70 programs reported providing at least 1 make-up examination if an examination was not passed, while 46 (65.7%) did not allow

Table 2. Number of Problems on Each Homework Set

Problems on Each Homework Set	Colleges Reporting, No. (%)
1-5	6 (10.7)
6-10	21 (37.5)
11-20	16 (28.6)
More than 20	13 (23.2)

Table 3. Types of Problems Included in Examinations (N = 70)

Type of Question	Respondents Using This Type of Question, No. (%)	Respondents Exclusively Using This Type of Question, No. (%)	Percent of This Type of Examination Question,* Mean (Range)
Short answer (including showing calculations work)	49 (70.0)	29 (41.4)	87.8 (10-100)
Fill in the blank	21 (30.0)	6 (8.6)	42.5 (2-100)
Multiple choice	20 (28.6)	5 (7.1)	67.0 (10-100)
True/False	8 (11.4)	0 (0)	8.5 (3-20)
Matching	2 (2.9)	0 (0)	15 (15)

*For respondents using this type of question

make-up examinations. For the 52 respondents answering both the question regarding provision of make-up examinations and the question regarding specific minimum criteria for passing, the mean minimum score to pass was 75% (SD = 8.5) for those offering at least 1 make-up examination and 69% (SD = 4.2) for those not offering a make-up examination ($p = 0.023$). For the 59 respondents answering both the make-up and average student score questions, the mean student score was 85.9% for those offered a make-up examination and 80.4% for those not offered a make-up examination ($p = 0.038$).

The mean percent of students passing an examination on the first attempt was 86% (range 60-100, SD = 10.4) and the median was 89% (58 programs responding). When analyzing the 45 programs that both reported this mean and provided minimum passing criteria, there was no difference in the percent of students passing on the first attempt for programs with minimum passing criteria below or above the mean passing score of 71.1%. Offering a make-up examination was not associated with a difference in the percent of students who passed an examination on the first attempt, as the mean percent passing was 85% for the 23 programs offering a make-up examination and 87% for the 35 programs not offering a make-up examination ($p = 0.351$).

When asked about the feedback provided to students regarding their examination performance, 62 (89%) in-

dicated that they provided the correct answers to students. Forty-three (61%) provided example solutions to the students and 40 (57%) provided individualized comments to each student.

Sixty-six (92%) of the 72 respondents answered the question related to application of calculations material later in the program. Thirty-nine (59%) individuals described the application of calculations material in multiple disciplines including in pharmaceuticals, clinical sciences, and teaching laboratories, but only 7 of these mentioned its application in experiential programs. Twenty (30.3%) of the 66 responded with only 1 discipline for later application. Of these 20, 15 (75%) listed teaching laboratory, 4 (20%) pharmaceuticals courses, and 1 (5%) clinical courses. Seven (10.6%) specifically commented that they were unsure of how the material was applied in their concurrent or subsequent curriculum.

Retention of calculations material was formally measured by an annual comprehensive assessment in 11 (16%) of the 68 colleges and schools responding to the question on knowledge retention. Thirty-five (52%) of the respondents loosely described that retention of calculations material was done in other courses, but little detail was provided on any system for measuring

Table 4. Length of Time Allocated for Each Examination (N = 70)

Length of Time	Number (%) Respondents
30 to 45 minutes	8 (11.4)
45 minutes to 1 hour	25 (35.7)
1 to 1½ hour	15 (21.4)
1½ hour to 2 hours	13 (18.6)
More than 2 hours	3 (4.3)
Other*	6 (8.5)

*Includes 1 program with a non-timed take-home examination and 5 who reported that multiple examinations were not equal in length

Figure 1. Minimum passing criteria for any given calculations examination and the calculations course/module.

retention. Eighteen (27%) respondents specifically noted that retention was not measured and 4 (6%) responded that they were unsure whether knowledge retention was measured.

DISCUSSION

The results of this survey provide a useful snapshot of the current educational and assessment strategies for pharmaceutical calculations. As one considers the role of pharmaceutical calculations as part of the patient care process, there are several aspects of the currently employed strategies that merit reflection and consideration for possible revision. The most striking of these is the 70% benchmark for passing a given examination or calculations course/module. Slightly more than half of all the programs used this benchmark as a minimum competency for passing, and it likely comes from the traditional academic standard for passing in higher education. Instructors of calculations-related content throughout pharmacy curricula should consider elevating the 70% passing benchmark as it is inconsistent with the level of accuracy required to ensure optimal patient outcomes and minimize errors. Despite the fact that less than 10% of programs use a benchmark greater than 90%, implementation of a 90% benchmark would certainly be more consistent with (albeit still lower than) the level of accuracy our future pharmacists will strive to attain. One could argue that students in their first-professional year are not advanced enough to be held to a level closer to acceptable practice standards, but these authors would challenge the profession to be aggressive and raise the bar for current and future students.

The attention to feedback among the colleges and schools responding has significant room for improvement as well. Feedback is a critical component of the learning process,¹² yet one third of programs did not provide example solutions for students to compare to their own methods and approximately half did not provide students with individualized feedback when errors occurred. Even the most basic feedback on calculations, providing the correct answer, is not given in one fourth of programs using homework as a learning tool, despite the fact that such feedback would be optimally timed before the summative assessment occurs. The survey was in no way designed to answer the question of whether increased feedback would result in improved student outcomes on examinations or retention. In fact, analyses of estimated student scores for those providing various types of feedback was not done because the lack of standardization of topics, examination difficulty, and grading procedures among the colleges and schools responding would have confounded such analyses. Nevertheless, maximizing

feedback opportunities would likely maximize students' learning opportunities,¹² and programs should revisit this component of the teaching and learning experience.

The results of this survey suggest that programs as a whole could do a better job reflecting on and articulating areas where this material is used in the patient care process. Notably, less than 10% of all programs described the application of this material in experiential learning in actual patient care settings. Presumably students are receiving the same message regarding application of pharmaceutical calculations material, which may inadvertently overemphasize intrinsic and academic motivations for learning and underemphasize extrinsic and professional motivations, including patient outcomes.

The final issue is that of retention. It is positive that 11 programs described formal retention measures and about half described some informal measures of retention. On the other hand, the absence of retention measures in about a fourth of all programs is a concern, particularly since this material is largely being taught in the earliest part of the professional curriculum. Integrating calculations material in subsequent coursework and experiential learning is likely not the challenge, given the ubiquitous nature of this content in the patient care process. However, systematically developing, archiving, analyzing, and acting on retention measures will require resources and effort.

This survey had some limitations. The topics identified by the respondents may not perfectly reflect (and in some cases, almost certainly did not reflect) the full scope of calculations content in pharmacy curricula. For example, it is extraordinarily unlikely that only 32% of programs teach estimated creatinine clearance calculations. Many of these topics will come up throughout the curriculum in areas that are beyond the immediate realm of the respondents. Despite this limitation, the topics described accurately reflected the content most prominently associated with pharmaceutical calculations at these institutions.

As with any survey, respondents could elect not to answer all of the questions. However, the high overall response rate ensured that despite some nonresponses, the number of responses in each subsection of the survey instrument (homework, examinations, application, and retention) represented more than 70% of the invited participants.

While the survey does suggest some areas that warrant attention and possibly adjustments, it was not designed to answer the question of whether the currently employed instructional and assessment methods for calculations are contributing to optimal or suboptimal patient outcomes. There is evidence in the literature that calculation mistakes in pharmacy practice do contribute

to suboptimal or even harmful patient outcomes.¹³⁻¹⁵ Future work should investigate any association between instructional and assessment methods competency in performing calculations when true patient outcomes are at stake.

CONCLUSION

Pharmaceutical calculations are taught both in stand-alone courses and integrated throughout other courses in doctor of pharmacy curricula. The vast majority of programs continue to use live lectures/discussions to deliver content. More than half of programs continue to use 70% as a passing score for examinations. A few programs have formalized retention measures, and even more have no retention measures at all. Future work should look to identify optimal methods for teaching, evaluating, and promoting retention of this material.

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