Predicting performance of pharmacy calculations assessments via an algebra-based pre-test and other variables using a logistical regression model: A pilot study

Kyle Shapcott, PharmD[1]; Collin M. Clark, PharmD[1]; Richard F. O'Brocta, PharmD[1]

[1] University at Buffalo School of Pharmacy and Pharmaceutical Sciences

Abstract

Objective: Pharmacy calculations are crucial for practice and licensure examinations. This study aimed to be the first to assess the external validity of the correlation between an algebra-based pre-test, previously published, and calculation assessment performances. A secondary objective was to identify variables associated with poor assessment performance.

Methods: An 18-item survey and an 18-question algebra-based pre-test were distributed to 144 first professional-year (P1) candidates on the first day of their fall 2024's semester. This was used to characterize student-specific variables (e.g. work experience). The survey included dichotomous (yes/no) and rating (5-point Likert scale) items; the algebra-based pre-test included open-response items. Data were analyzed using linear regression and logistic regression to determine variables associated with passing (≥70%) or not passing (<70%) assessments. Pearson correlation coefficients were computed between the algebra-based pre-test and assessment performance.

Results: Ninety-one candidates (63%) completed the survey, and 139 (97%) completed the algebra-based pre-test. Variables associated with passing assessments ($p<.05$) included no prior work experience (adjusted odds ratio=6.6, confidence interval=1.3-34.3) and algebra-based pre-test performance >15/18 points (adjusted odds ratio=5.9, confidence interval=1.6-21.8). Algebra-based pre-test performance was moderately correlated with assessment scores (Pearson correlation coefficients: 0.47 for assessments one and two, 0.4 for assessment three).

Conclusions: The algebra-based pre-test had a comparable correlation to assessment performance to previously published results and could be a tool to identify those at risk for poor pharmacy calculation assessment performance across the academy. Future studies warrant utilization of this algebra-based pre-test to target interventions to those at high risk of poor performance on calculations content.

Keywords: pharmacy calculations, predictors of performance, pre-test, work experience, calculation education

Introduction

Licensed pharmacists must be able to perform pharmaceutical calculations within their practice to ensure the efficacy and safety of the medications they are dispensing. The National Association of Boards of Pharmacy (NABP) acknowledged this by contributing pharmacy calculations (formerly known as domain 4) to 14% of the overall exam (31 of the 225 questions) on the North American Pharmacist Licensure Examination (NAPLEX) blueprint from January 2021 to April 2025.[1] Unfortunately, the current blueprint does not have pharmacy calculations as its own domain and has now been made a subdomain under "Foundational Knowledge for Pharmacy Practice". The 2024 NAPLEX Calendar Year Report showed that one-third of first-time test takers scored a "Far below meeting the minimal performance" (11.1%) or "Below meeting the minimum performance" (22.2%) on, domain 4, the highest among any of the six domains of the assessment.[2]

Corresponding Author:
Kyle Shapcott, PharmD
University at Buffalo School of Pharmacy and Pharmaceutical Sciences
Email: kyleshap@buffalo.edu
Phone: 716-645-4762

With the new NAPLEX domains, the transparency of candidate's performance on pharmacy calculations will be severely diminished, and the domain's disappearance should not take away from the poor performance from candidates in previous years on this critical skill. NAPLEX first-time pass rates have had a downward trajectory across the academy and reports of decreasing math skills among K-12 students in the United States support the declining levels of math skills in first-year pharmacy students and performance in courses primarily assessing the ability to perform pharmacy calculations.[1,3-5]

Previous studies have looked at possible characteristics that may predict success in calculation education with varying characteristics of (PharmD) students being tested and analyzed across different types of pharmacy programs, such as 0-6 direct entry PharmD programs, PharmD programs with a Bachelor's degree required, and programs with hybrid cohorts of students.[6-10] Characteristics that have been analyzed include pre-tests/pre-assessments performance, high school GPA, undergraduate GPA, performance on American College Testing (ACT)/ Scholastic Aptitude Test (SAT), age, Pharmacy College Admission Test (which was sunset in January 2024), prior high school math courses, and years since high school graduation.[6-12] However, previous studies in this domain have not administered and analyzed their methods across multiple

DOI: https://doi.org/10.24926/iip.v17i1.7012

colleges and schools of pharmacy (C/SOP), resulting in a lack of certainty for what characteristics can universally predict success in calculation education across all C/SOP that make up the academy. Aronson et al. published a study conducted at Raabe College of Pharmacy at Ohio Northern University (ONU) which looked at a head-to-head analysis of the weight of some positive and negative predictors of calculation-based assessment performances, which included a calculation-based pre-test and found a moderate correlation between the variables.[6]

A call of action was recently published advocating for scholarly work in pharmacy calculations and to find institutional improvements for pharmacy calculations-based education.[3] One way for institutional improvement in pharmacy calculations-based education is to identify a tool that can be used by the academy to accurately predict those at-risk for poor performance on this topic. Following the creation of this tool, interventions intended to increase performance of pharmacy calculation-based assessments can then be accurately measured for their efficacy on an appropriate study population (those at-risk for poor performance). To properly establish this tool, both positive and negative predictors need to be established to correctly adjust a logistical regression model to create an efficient, objective, and predictable tool. The ability to predict assessment performance and perform direct interventions has the potential to improve calculation education, learning, and eliminate unhealthy anxiety, stress, and poor performance in other courses in the curriculum for students.[13]

The innovation in our study was looking at the capability and the plausibility to objectively predict PharmD students at-risk for poor assessment performance early in a course/semester using a logistical regression model with multiple variables. By accurately predicting individuals at-risk, it may provide an opportunity for faculty to provide individualized interventions to students during the early weeks of the of the semester. In turn this, theoretically, enables students to have more time to focus on these interventions compared to after assessments are administered where their workload may already exceed their capacity, or not have the capacity to participate in interventions.

For this scholarship, we first needed to show correlation to the performance of the pre-test used in Aronson et al. to our institutions assessment performances.[6] Then, we explored the ability of creating a tool to predict PharmD students at-risk for poor performance on pharmacy calculation-based assessments, using PharmD students at our institution, by analyzing multiple student variables, in addition to the pre-test used in Aronson et.al, in a logistical-regression model.

Methods

Study Setting

This study was exempt from the Institutional Review Board and is an observational study that looked at performance of pharmacy calculation-based assessments. At our institution, Pharmacy Calculations is a 2.5-credit course that is administered during the first semester of the first year of the pharmacy curriculum and is required to complete with a passing grade to continue to take courses in the second professional year (P2) curriculum. The course assessments we examined consisted of three noncumulative assessments (12% of total grade each) and a final summative exam (48%). The course focuses on prescription interpretations and basic math (conversions, ratios, exponents, etc.) on assessment 1; Compounding (density, parts per million, etc.), electrolyte solutions, and ionizations on assessment 2; And calculations involving prescriptions (flow rates, drop factor, dosage calculations, etc.), and clinical calculations (body mass index, body weight, renal function, and absolute neutrophil count) on assessment 3. Other components of the course that contributed to overall class percentage was collaborative based learning (CBL) (12%) and peer evaluations from the CBLs (4%). Our institution uses an HSU grading scale in its curriculum with an “H” (Honors) being achieved with a ≥90%, “S" (Satisfactory) being 70-89.9%, and “U” (Unsatisfactory) being <70%.

Survey

First year (P1) students were invited to complete an eighteen-item survey (Appendix A) and an eighteen-question proctored algebra-based pre-test prior to the initiation of Pharmacy Calculations. Students who repeated this course and students that were pursuing a pharmaceutical sciences degree were excluded from this study. The survey consisted of multiple-choice type items, fill-in-the-blank, and Likert-scale items. Data collected from this survey included prior higher education experience (no degree, bachelor’s degree, etc.), year graduated high school, year of last math course, and paid pharmacy work experience. Items were selected based on previous variables that have been explored to correlate with pharmacy calculation courses in previous research.[6-12]

Algebra-based Pre-test

This pre-test consisted of 17 free response, math problems and one select-all-that-apply type of question. Partial credit was not given for incorrect answers. The questions were categorized as percent, pharmacy proportion, basic proportions, unit analysis, and advanced pharmacy problems. This algebra-based pre-test was first created by faculty at ONU for their program, which at the time of publication, was exclusively a 0-6 direct entry PharmD program with students taking the pre-test prior to their pharmacy calculation-based course. This course was administered in the third semester of their program. In contrast, our institution’s program is a 4-year program that accepts a mix of those with 2-3 years of undergraduate experience, bachelor’s degrees, and other

paths. The algebra-based pre-test was administered prior to their first lecture of Pharmacy Calculation in the first semester of the PharmD program. Mirroring ONU's administration of the electronic algebra-based pre-test, our institution allowed calculators, scratch-paper, writing utensils and 20-minutes to complete the pre-test.

Statistical Analysis

Descriptive statistics were used to characterize the survey responses, pre-test, and assessment performances. Parametric and nonparametric testing was used as appropriate to find significant differences in characteristics between students who passed all non-cumulative assessments and students who failed one or more non-cumulative assessments. Logistic regression modeling used student characteristics to find association with failure (<70%) of any of the non-cumulative assessments. The model utilized characteristics meeting a threshold with a $p<0.2$ on the bivariate comparison. Then characteristics were eliminated from the model in a backwards stepwise manner based on significance until only significant predictors remained based on a $p<0.05$. Linear regression modeling was used to understand the correlation between pre-test and assessment performances. Pearson correlation coefficients were computed between pre-test and assessment performances. Statistics were computed using SAS, version 9.4 (SAS Institute Inc., Cary, NC).

Results

One hundred thirty-nine of the 144 students (97%) completed the pre-test, while 91 students (63%; 91 of 144) completed both the pre-test and survey. Of the 91 students, 15 of those students (19%) failed one or more non-cumulative assessment in the course. Performance on the pre-test and the assessments can be found in Table 1. The mean score of the pre-test in the group without a failed assessment was 15.6 (SD=±2.5), while the group with one or more failed assessments was 12.3 (SD=±3.2) ($p<.001$). Survey data collected can be found in Table 2, which compares those without a failed assessment to those with at least one failed assessment. Table 3 shows the frequency of failed performances of non-cumulative assessments. Two students failed all three assessments with pre-test scores of 8 and 9, while three students failed two (pre-test scores 10, 11, 15), and the remaining 10 students had one failing performance. Characteristics with statistical difference *($p<.05$)* between groups on an adjusted logistic regression model (adjusting for pharmacy work experience or none, and pre-test score) included no prior work experience and pre-test performance greater than 15 out of 18 points (83%), which both correlated to an increase in the likelihood of no failed assessments (adjusted odds ratio [aOR]=6.6, CI=1.3-34.3 and aOR=5.9, CI=1.6-21.8). Additionally, when looking at a pre-test performance of 14 out of 18 points (78%) it also correlated to an increase in the likelihood of no failed assessments (aOR=16.9, CI=3.5-82.6) as well as 16 out of 18 points (89%) (aOR=10.4, CI=2.1-52.8). No differences were found in the comparator groups rates of students' prior higher education experience, whether they're early admits (2 years + 4 years), bachelor's degree holders, or non-traditional (coming from the workforce, took gap years, etc.).

Table 1. Pre-test and Assessment Performance of 139 First Year PharmD Students

Assessment	Range	Mean	Median
Pre-test (points)	0-18	15.2	16.0
Assessment 1 (%)*	0-100	89.7	88.5
Assessment 2 (%)*	0-100	85.5	92.0
Assessment 3 (%)*	0-100	88.7	91.0
Average Assessment 1-3 (%)	0-100	87.9	90.1
Final Summative Assessment (%)	0-100	86.6	90.0

*Non-Cumulative Assessments

Table 2. Frequency of Characteristics Among Comparator Groups

Characteristic	No failed assessments (n=76)	One or more failed assessments (n=15)	Total (n=91)	P-value
Pre-test Performance [n (%)]				
≤13	6 (7.9)	8 (53.3)	14 (15.4)	<.001[a]*
14	11 (14.5)	1 (6.7)	12 (13.2)	
15	15 (16.7)	4 (26.7)	19 (20.9)	
≥16	44 (57.9)	2 (13.3)	46 (50.5)	
Work experience [n (%)]				
Paid pharmacy experience	43 (56.6)	13 (86.7)	56 (61.5)	0.04[b]*
No paid pharmacy experience	33 (43.4)	2 (13.3)	35 (38.5)	
Years since last math course [n (%)]				
≤ 1	24 (31.5)	2 (13.3)	26 (28.6)	0.17[a]
> 1 - ≤ 2	26 (34.2)	9 (60)	35 (38.5)	
>2	26 (34.2)	4 (26.7)	30 (32.9)	
Years since high school graduation [n (%)]				
≤2	39 (51.3)	8 (53.3)	47 (51.6)	0.47[a]
3	7 (9.2)	3 (20)	10 (11)	
≥4	30 (39.5)	4 (26.7)	34 (37.4)	

*Statistically significant (p<.05)
a Kruskal-Wallis test
b Mann-Whitney U test

When analyzing the performance of the 139 students (97%, 139 of 144) who completed the pre-test, Pearson correlation coefficient (*p<.001*) was 0.47 for assessment 1 and 2, 0.4 for assessment 3, 0.53 for the average noncumulative-assessment, and 0.39 for the final cumulative assessment performances to the pre-test performances. Linear regression modeling showed correlation (*p<.001*) between the pre-test performance and all other assessments' performances, including the average performance of the three non-cumulative assessments (Table 4). Standardized regression coefficients of the linear regression model were statistically significant for the variables/characteristics utilized (pharmacy work experience and pre-test). The results from linear regression models for the average non-cumulative assessment performance and the final summative assessment are displayed in Table 5.

Discussion

This study was able to show moderate correlation between pre-test and all assessment performances at both C/SOP.[6] This pre-test demonstrated comparable correlation between ONU and our institution. Despite the different pharmacy curricula, a correlation was observed between the timing of the initiation of pharmacy calculation course (3rd semester vs. 1st semester) and demographic of students (direct entries from high school vs. early admits [2 years +4 years] and bachelor's degree holders). Additionally, this study supports that an algebra-based pre-test may independently predict students at risk for poor performance of pharmacy calculation-based assessments at our institution.

Multiple different thresholds are presented in the results section, due to the exploratory nature of this study. It cannot be determined with certainty, due to the study's sample size, the threshold (i.e., 13+ points, 14+ points, etc.) with superior predictability to identify those at-risk for poor performance on calculation-based assessments. However, when the lowest end of the confidence intervals are analyzed, we can determine that there is a 30% higher likelihood of students passing all noncumulative assessments if they score 15 or higher out of 18 on the pre-test compared to those that do not. The 14- and 16-point thresholds also can be interpreted conservatively as having a 250% increase and 110% increase of not having a failing assessment.

PharmD students are required to obtain a minimum number of hours of pharmacy experience that can differ among different states.[14] These differences among states do encourage students to pursue paid pharmacy work experiences in order to qualify for licensure in a given state and to sit for a particular state's MPJE to become a fully licensed pharmacist. Paid pharmacy work experience data was collected during the first week of the pharmacy curriculum and may not accurately represent all students that were working in a pharmacy by the end or throughout the semester. Current evidence supports the negative correlation found in our study between work experience and performance in C/SOP.[15,16] This variable needs to account for possible confounders (total time working within semester, type of pharmacy, responsibilities at worksite, etc.) and to properly analyze and interpret the data for paid pharmacy work experience's negative impact on pharmacy calculation-based assessments' performance more specific data will need to be collected in future studies.

Correlation between the algebra-based pre-test performance and pharmacy calculation-based assessment performance were comparable to previously published results.[6] At our institution we focused on the analysis of non-cumulative assessments over the cumulative final assessment. Since the final exam introduces no new content, students have already been evaluated on the material and have had the opportunity to learn from their previous performance. This shows that despite differences in student population demographics, timing of content in curriculum, and different courses, this pre-test can still be used as a predictor for performance of pharmacy calculation assessments. Additionally, our study showed variables such as age, time since last math course, and undergraduate GPA have been shown to correlate to success at some C/SOPs, it may not at other C/SOPs, likely due to different demographics of PharmD Candidates (e.g. undergraduate experience, time since high school graduation, etc.). The result of this study warrants future research for this algebra-based pretest to be utilized by other C/SOP to create a larger sample size with a variety of student baseline characteristics, administration of pharmaceutical calculation-based content, and assessment strategies for the logistical regression model to derive from. Future research that examines a broader sample of C/SOP and students may be able to make a claim for this algebra-based pre-test to be a predictive tool across all United States C/SOPs to identify those at risk of poor performance on calculation education-based assessments.

Innovations to current practice that can be made from the results of this study include the ability to target the administration of interventions at students with a baseline risk for poor performance, measure the success of different interventions, and allow for comparisons of different interventions that are trialed across the academy at different curriculums. It also allows for possible interventions to be performed earlier in the semester (compared to waiting for assessment results), prior to students' workload peaking, and in-turn can potential alleviate or eliminate anxiety, stress, and poor performance in other courses.[13] This makes implementing possible interventions into students' and instructors' schedules easier, as other responsibilities may be limited earlier in the semester and waiting to implement interventions later in the semester can interfere with other responsibilities that tend to accumulate as the semester progresses. Some possible interventions that could be explored include, but are not limited to, group tutoring

sessions, one-on-one tutoring sessions, additional practice problems, targeted practice problems, and team-based learning-based interventions.

One limitation of this study includes a small sample size which led to large confidence intervals in the logistic regression models. Although the odds ratios are statistically significant for work experience and pre-test performance, the true magnitude of the likelihood of a student having no failed assessments based on these variables is still ambiguous. Additionally, as is true for most studies that utilize survey data, it is difficult to confirm the reported responses of respondents for accuracy, such as prior paid work experience and with only 63% of the cohort completing both the pre-test and survey there is potential for response bias in this study. Some characteristics analyzed in this study may still be predictors for pharmacy calculation-based assessment performances. Further analysis and data collection is required to ensure that confounders are identified and properly adjusted for and to increase a proper sample size to evaluate the characteristic's impact or lack thereof on calculation education. Further research needs to be carried out across the academy to find other possible characteristics that show strong (or poor) performances in pharmacy calculation-based assessments.[3]

Conclusion

Student characteristics should continue to be analyzed to allow proper sample sizes to be obtained to analyze relationships between them and ensure success in calculation education. The characteristic of whether a student has paid pharmacy work experience prior to the initiation of calculation education may negatively correlate to the performance of assessments on this material. Further scholarship is needed to properly analyze confounders to understand the rationale behind this correlation.

Future scholarship should consider use of an 18-item, primarily, open-response pre-test, with similar rigor, style, and design of the one developed by ONU, as it may be a benchmark to help identify their sample with an increased likelihood of failing pharmacy calculation-based assessments. Future work analyzing the effects of interventions to increase success in calculation education should be encouraged and published.

Acknowledgements: This study would not have been possible without the groundwork that was created by Dr. Ben Aronson, PharmD, PhD and Dr. Emily Eddy, PharmD and the rest of their team at Ohio Northern University College of Pharmacy
Funding/Support: None.
Disclaimer: The statements, opinions, and data contained in all publications are those of the authors.
Conflict of Interest: None.
Treatment of Human Subjects: This study was exempt from the Institutional Review Board and is an observational study that looked at performance of pharmacy calculation-based assessments.

References

1. National Association of Boards of Pharmacy, NAPLEX. Calendar year report. January 31, 2024; 2024.
2. National Association of Boards of Pharmacy, NAPLEX. Calendar year report. January 21, 2025; 2025.
3. Crawford AN, Anksorus HN, Clark Dula CA, et al. Counting on change: conquering challenges in teaching pharmaceutical calculations. Am J Pharm Educ. 2024:101259. https://doi.org/10.1016/j.ajpe.2024.101259
4. National Association of Boards of Pharmacy, North American Pharmacist Licensure Examination Passing Rates for 2022-2024 Graduates. 2025.
5. Frankart LM, Dell KA, Matulewicz AT, Caldas LM, Wantuch GA. Deficiencies in Mathematical Skills Identified in First-Year Students at Two Pharmacy Institutions. American Journal of Pharmaceutical Education. 2025;89(8):101448. https://doi.org/10.1016/j.ajpe.2025.101448
6. Aronson B, Eddy E, Long B, Welch O, Grundey J, Hinson J. Identifying Low Pharmaceutical Calculation Performers Using an Algebra-Based Pretest. Am J Pharm Educ. 2022;86(1):8473-undefined. https://doi.org/10.5688/ajpe8473
7. Bhatt P, Lull M, Birnie C, Leonard S, Camenisch T. A Pre-Matriculation Pharmacy Calculations Module Enhances Student Performance in First Year Pharmacy Calculations Course. Am J Pharm Educ. 2023;87(8):100255-undefined. https://doi.org/10.1016/j.ajpe.2023.100255
8. Conn KM, Birnie C, McCaffrey D, Brown J. The Relationship Between Prior Experiences in Mathematics and Pharmacy School Success. Am J Pharm Educ. 2018;82(4):6257. https://doi.org/10.5688/ajpe6257
9. DeGracia CM, Hardinger KL, Ruehter V. Predictors of Performance in a Pharmacy Calculations Course. Am J Pharm Educ. 2024;88(9):101040. https://doi.org/10.1016/j.ajpe.2024.101040
10. Dell KA, Wantuch GA. Predicting success in pharmaceutical calculations. Curr Pharm Teach Learn. 2019;11(10):972-978. https://doi.org/10.1016/j.cptl.2019.06.002
11. Pharmacy College Admission Test. American Association of Colleges of Pharmacy. Accessed February 5th, 2025. https://www.aacp.org/resource/pharmacy-college-admission-test
12. Fincher TK, Weldon AJ, Breese CR, Burmeister MA. Examination of the utility of an algebra-based interview day math assessment to predict academic outcomes in an accelerated pharmacy curricula; A retrospective observational cohort study. Currents in Pharmacy Teaching and Learning. 2025;17(10):102409. https://doi.org/10.1016/j.cptl.2025.102409
13. Erhun WO, Jegede AO, Ojelabi JA. Implications of failure on students who have repeated a class in a faculty of pharmacy. Curr Pharm Teach Learn. 2022;14(2):166-172. https://doi.org/10.1016/j.cptl.2021.11.022

14. 50-State Healthcare and Pharmaceutical Licensing Compliance Guide. March 2025. Accessed February 4, 2025. https://www.harborcompliance.com/pharmacist-license
15. Mar E, Barnett MJ, T TLT, Sasaki-Hill D, Kuperberg JR, Knapp K. Impact of previous pharmacy work experience on pharmacy school academic performance. Am J Pharm Educ. 2010;74(3):42. https://doi.org/10.5688/aj740342
16. Okogbaa J, Allen RE, Sarpong DF. Time Spent at Work and Its Impact on the Academic Performance of Pharmacy Students. Int J Environ Res Public Health. 2020;17(2). https://doi.org/10.3390/ijerph17020496

Table 3. Failed Assessments Characterized by Pre-Test Performance and Specific Assessment

Characteristic	Assessment 1 (n=7)	Assessment 2 (n=10)	Assessment 3 (n=5)	Total (n=22)
Pre-Test Performance [n (%)]				
≤13	5 (71.4)	6 (60)	3 (60)	14
14	1 (14.3)	0	0	1
15	1 (14.3)	3 (30)	1 (20)	5
≥16	0	1 (10)	1 (20)	2

Table 4. Pre-Assessment and Assessment Performances' Pearson's Correlation Coefficients of 139 First Year PharmD Students

	Pre-test	Assessment 1	Assessment 2	Assessment 3	Average Assessment 1-3	Final Summative Assessment
Pre-test	1					
Assessment 1	0.47*	1				
Assessment 2	0.47*	0.54*	1			
Assessment 3	0.4*	0.61*	0.58*	1		
Average Assessment 1-3	0.53*	0.82*	0.86*	0.86*	1	
Final Summative Assessment	0.39*	0.61*	0.59*	0.7*	0.75*	1

*All are statistically significant (p<.05)

Table 5. Standardized Regression Coefficients

	Average Assessment 1-3		Final Summative Assessment	
Independent Variable	Standardized Coefficient	Regression p-value	Standardized Coefficient	Regression p-value
Pharmacy Work Experience	-0.24	<.01	-0.05	<.01
Pre-test	0.53	<.01	0.36	<.01

*All are statistically significant (p<.05) correlated through linear regression modeling.