RESEARCH

Implementation of an Active-Learning Laboratory on Pharmacogenetics

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Objective. To evaluate students' knowledge, confidence, and skills after implementation of an active-learning laboratory session in clinical pharmacogenetics.

Methods. Third-year pharmacy students (n=130) participated in an active-learning laboratory session on pharmacogenetics. In the laboratory activity, students evaluated patients' pharmacogenetic profiles and documented recommendations to providers based on their findings. Students also counseled a simulated patient on the interpretation of their pharmacogenetic profile. Students' knowledge and confidence were assessed before a lecture on clinical pharmacogenetics, after the lecture, and then after the laboratory activity. The assessment included 10 knowledge-based questions and five confidence questions regarding clinical pharmacogenetics. An evaluation of the laboratory activity was completed after the session.

Results. On average, students correctly answered 70.3% of the knowledge-based questions before the lecture, 82.8% after the lecture, and 88.7% after the laboratory session. Additionally, students' confidence improved in each of the five areas assessed. Based on evaluations (response rate: 98.5%), students found that the laboratory activity contributed to their professional development, was taught at an appropriate level for their understanding, and was relevant to pharmacy practice.

Conclusion. An active-learning laboratory session to teach pharmacy students about clinical pharmacogenetics improved students' knowledge, confidence, and skills.

Keywords: pharmacogenetics, laboratory, active learning, knowledge, confidence

INTRODUCTION

Since the completion of the Human Genome Project in 2003, scientists have learned a lot about how genetics affects medication responses. Thus, pharmacogenetics is an important topic to include in the Doctor of Pharmacy (PharmD) curricula. The 2001-2002 American Association of Colleges of Pharmacy (AACP) Academic Affairs Committee included recommendations on teaching pharmacogenetics in colleges of pharmacy to ensure students were adequately prepared with the necessary skills for future practice.[1] The Accreditation Council for Pharmacy Education (ACPE) standards and guidelines and the American Society of Health-System Pharmacists also encourage including pharmacogenetics in pharmacy school curricula. Likewise, the American College of Clinical Pharmacists includes pharmacogenetics as one of the competencies for clinical pharmacists.[2-4]

As advances continue to be made, the future of pharmacogenetics has been getting national attention. The Precision Medicine Initiative, introduced by the Obama administration 2015, addresses the need for individualized patient care.[5] Likewise, the Food and Drug Administration (FDA) now includes pharmacogenetics information in the labeling of many medications.[6] Therefore, it is imperative for pharmacists to be able to assess patients and apply pharmacogenetics information in their clinical practice. Survey data show that the majority of pharmacists agree on the importance of pharmacogenetics; however, few feel confident in their ability to apply it.[7] This uncertainty among pharmacists raises the question of how pharmacogenetics education and training occur across pharmacy schools in the United States.

Despite widespread agreement on the importance of pharmacogenetics in the field of pharmacy, studies have found inconsistencies in how and to what extent

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pharmacogenetics is taught in pharmacy school curricula.[8,9] While a 2010 survey found that most colleges of pharmacy in the United States included pharmacogenetics content in their curriculum; several important topics were not covered at all by many colleges.[9] Furthermore, the relatively small number of practicing pharmacogeneticists in the United States is a severe limitation to providing the education. A search of the pharmacy education literature found only one paper describing the successful implementation of an elective course to provide pharmacy students with the basic knowledge necessary to make clinical decisions regarding pharmacogenomic data.[10] Ongoing education in pharmacogenetics for all health care professionals is also will be important as this field continues to evolve.[11]

At Virginia Commonwealth University School of Pharmacy, pharmacogenetics is taught as a required course in the third professional year. An active-learning laboratory was developed to support the course. Few application-based laboratory sessions on applying clinical pharmacogenetics material have been discussed in the pharmacy education literature.[12,13] Knoell and colleagues reported a laboratory assignment in which students conducted genotype analysis on 10 randomly selected DNA samples and then completed a patient counseling activity.[12] Krynetskiy and Calligaro describe a laboratory activity where students' saliva samples were collected, genotyping analysis was performed, and the clinical significance of the findings was discussed.[13] These studies indicate that a pharmacogenetics laboratory activity enhanced students' learning of pharmacogenetic principles. However, none of these studies directly assessed changes in student knowledge and confidence with regards to clinical pharmacogenetics.

Unlike these two genotyping analysis activities, we conducted an active-learning laboratory session focused on clinical case-based pharmacogenetics. The session included cases that mimicked the real patient cases that a clinical pharmacogenetics specialist sees in practice and included a patient counseling component. The ACPE standards and guidelines support the use of active-learning laboratories to aid in the development of critical thinking and problem-solving skills.[2] An active-learning laboratory in this setting allows students to gain hands-on experience with simulated patient cases. The objective of this study was to measure changes in students' knowledge, confidence, and skills in clinical pharmacogenetics resulting from completion of an innovative active-learning laboratory session.

METHODS

The active-learning laboratory included 130 third-year pharmacy students enrolled during the 2016 fall semester. The skills laboratory was a one-credit course intended to provide third-year pharmacy students with opportunities to improve skills and practice new skills necessary to be a competent, caring pharmacist. It is the fifth course in a six-semester practice-based laboratory course sequence. The students were divided into two-hour laboratory sections offered three times per week. Each of the three laboratory sections on the main campus had 35 to 36 students, and the two satellite campuses in Fairfax and Charlottesville had 19 students and 5 students, respectively. This laboratory activity was designed in parallel with a one-credit semester-long pharmacogenetics course that met once weekly.

The students watched a 50-minute recorded lecture on clinical pharmacogenetics given by a trained and practicing clinical pharmacogeneticist during the pharmacogenetics class on the Friday before the laboratory activity. The lecture included a section on how to interpret a patient's genetic profile in terms of polymorphisms in the CYP450 enzyme, which was similar to what the students would see in the laboratory exercise the following week.

The laboratory portion was developed in concert with the clinical pharmacogenetics lecture by the clinical pharmacogeneticist. The cases and counseling assignment were selected based on what the pharmacogeneticist encountered in daily practice. The specific objectives for the laboratory session were for the pharmacy students to be able to define pharmacogenetics, use appropriate references to obtain pharmacogenetic information, identify medications that are affected by CYP450 polymorphisms, recommend appropriate pharmacotherapy based on a patient's pharmacogenetic information, and counsel a patient on their personal pharmacogenetic information.

On the day of the active-learning laboratory session on pharmacogenetics, the course instructors spent approximately five minutes discussing the logistics of the laboratory, explaining the objectives for the activity, and answering questions. The remainder of the two-hour laboratory was divided into two parts: team cases and a counseling activity. Students in teams of five to six completed three patient cases. Students were given a patient's genetic profile and a short clinical case scenario. Students were asked to review the patient's' current medications and list the gene, transport effect, and severity of the genetic polymorphism for each of them. The students then had to write recommendations to a provider on the safety and efficacy of using the medications and any changes that needed to be made to the patient's pharmacotherapy regimen. The students were advised to use the following resources to answer the cases: PharmGKB,[14] the FDA's Table of Pharmacogenomic Biomarkers in Drug Labeling,[15] and the Pharmacist's Letter Cytochrome P450 Drug Interactions table (PL Detail-Document #320506).[16] The team cases were graded by one of the course coordinators

using a standardized rubric developed by the clinical pharmacogeneticist.

The last case was a patient with recurrent deep vein thrombosis who had been taking warfarin. Depending on the warfarin case, the students had to counsel a simulated patient played by either an advanced pharmacy practice experience (APPE) student or a graduate teaching assistant. The students had roughly five minutes to counsel the simulated patient. Feedback was given using a modified rubric, which is used in communication-related competencies in the skills laboratory course series. The APPE and graduate teaching assistants evaluated the students, and the course coordinators reviewed scoring to ensure consistency. The purpose of the counseling activity was to help students develop their communication skills when discussing sensitive topics. The students were asked to discuss the patient's genetic profile in relationship to the patient's current medications, as well as sensitive topics like "Does this mean I'm ill?" "Is something wrong with me?" "Do I need to stop taking my medication?" "Why is genetic testing important?" and "What should I do with this information?"

A preassessment that included 10 knowledge-based, multiple-choice questions on clinical pharmacogenetics and a confidence survey were administered on Blackboard (Washington, DC) immediately prior to the clinical pharmacogenetics lecture. Students had no advanced knowledge of this assessment and therefore answered questions solely based on their knowledge prior to the laboratory session. After watching the lecture, the students were given a few hours to complete the same knowledge and confidence questions again on Blackboard. The students then participated in the laboratory activity the following week. Three weeks later, at the end of the semester, a postassessment survey, which included the same confidence questions and an evaluation of the laboratory session, was administered via Blackboard during the final laboratory session. The same knowledge-based questions were administered as part of the final examination in the skills laboratory course.

Five confidence questions were used that related to the students' ability to: interpret a patient's CYP450 results, identify medications that use the CYP450 pathway, appropriately recommend therapy changes based on a patient's medication profile and CYP450 results, find up-to-date information on pharmacogenetics, and counsel a patient on their CYP450 results. The students rated their level of confidence in their ability using a Likert scale on which 5=completely confident, 4=very confident, 3=somewhat confident, 2=not very confident, and 1=not at all confident.

The evaluation of the laboratory session consisted of five questions which used a Likert scale, ranging from 1=strongly disagree to 5=strongly agree, and one question regarding students' overall rating of the laboratory session using a Likert scale ranging from 1=very poor to 5=excellent. The laboratory evaluation included questions on whether the laboratory was well organized, contributed to the student's professional development, was relevant, was interesting and/or stimulating, and contained information that was presented at an appropriate level for the student's understanding. Two free response questions were also part of the evaluation and students could respond on what they liked or did not like about the laboratory.

Students completed a prelecture, postlecture and postlaboratory assessment for knowledge and confidence, thus data could be linked and statistical comparisons conducted. Students' performance on the knowledge-based questions was described using the test grade they received, and the results for the confidence assessment were calculated as a sum of individual scores. Data were presented as means and standard deviations in the figures to facilitate visualization of time points and clusters. Knowledge and confidence scores were analyzed using the Wilcoxon signed rank test. The percentage of correct answers for each question at each time point was calculated and analyzed with ANOVA with repeated measures. Confidence was analyzed for each question and expressed as a median and interquartile range as well as a percentage of confidence. Confidence was assessed as either completely confident, very confident, or confident, and analyzed via Wilcoxon signed rank test for repeated measures.

To explore the relationship between students' knowledge and confidence responses prior to the lecture, a hierarchical cluster analysis was used resulting in the division of students into two clusters: cluster one (lowest grades and confidence levels) and cluster two (highest grades and confidence level). Difference over time for each cluster was tested for knowledge and confidence. The Wilcoxon signed rank test was used for comparison at each time point, and difference between clusters was tested with the Mann-Whitney test. For all analyses, a level of $p<.05$ was considered significant. Students were not included in the analysis if their assessment from one or more of the three time points was missing. The data were analyzed using JMP Pro 12 (SAS Institute Inc, Cary, NC). This study was approved as exempt research by the Institutional Review Board of Virginia Commonwealth University.

RESULTS

One hundred twenty-one (93.1%) students completed all three assessments (Figure 1) Significant increases in knowledge ($p<.002$) and confidence ($p<.0001$) were observed. Students' performance on all 10 knowledge questions improved significantly from baseline or prelecture

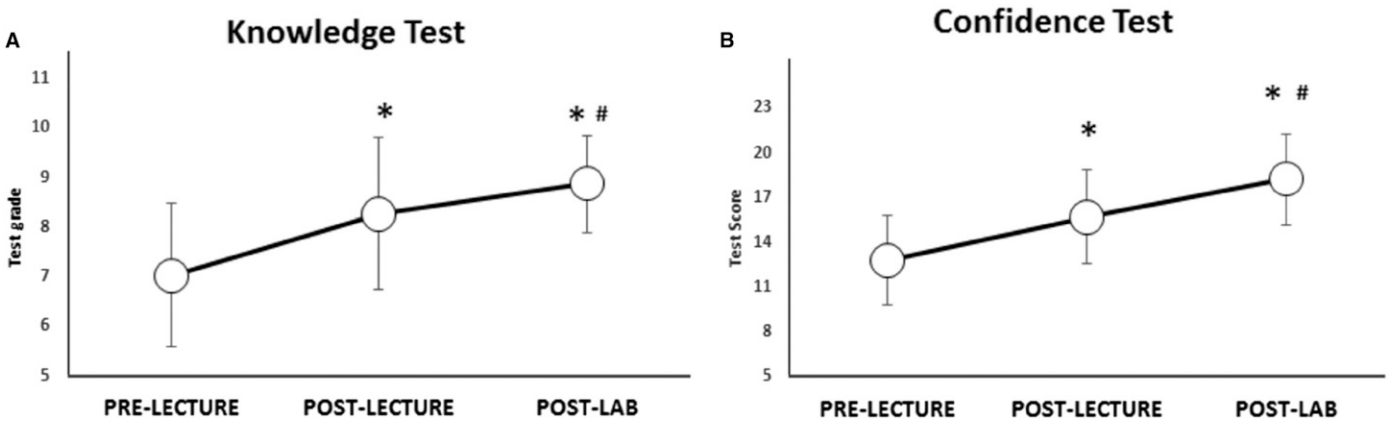

Figure 1. A Combination of a Lecture and an Associated Laboratory Component is Required for the Complete Grasp of Subject Matter Concerning Clinical Pharmacogenetics

Students were tested with respect to their knowledge in clinical pharmacogenetics prelecture, postlecture and postlaboratory. Significant increases in knowledge with respect to subject matter was observed postlecture with further significant gain in knowledge observed postlaboratory (Panel A). The same students were also tested with respect to their confidence in the subject matter prelecture, postlecture and postlaboratory. Significant increases in confidence with respect to delivery of clinical pharmacogenetics services was observed postlecture with additional significant gains observed postlaboratory (Panel B). Data are depicted as the mean of measures ± standard deviation and tested with matched pairs Wilcoxon Signed Rank test ($p=.0002$).
* significantly different from prelecture
# significantly different from postlecture
N=121

after completing the laboratory activity ($p<.05$). The percentage of students accurately responding to five of the 10 questions also significantly improved from the postlecture to the postlaboratory time point (Table 1). For individual confidence questions, there was a significant increase ($p<.05$) in confidence for all five questions from prelecture to postlecture, and this increase remained significant postlaboratory. Three of the five confidence questions also

Table 1. Number of Pharmacy Students Who Correctly Responded to Questions on a Knowledge Assessment Administered Before and After a Pharmacogenetics Lecture and After an Active-Learning Laboratory Session (N=121)

Description of Question	Prelecture No. (%)	Postlecture No. (%)	Postlaboratory No. (%)
Definition of pharmacogenetics (PGx).	113 (93.4)	117 (96.7)	119 (98.3)[a]
Identification of the best resource for pharmacogenetic information.	99 (81.8)	107 (88.4)	117 (96.7)[a,b]
Identification of the polymorphisms that are important to warfarin.	50 (41.3)	104 (86.0)[a]	119 (98.3)[a,b]
PGx Case: Interpretation of patient profile and effect on hydrocodone/ acetaminophen.	48 (39.7)	61 (50.4)[a]	59 (48.8)[a]
PGx Case: Alternative medication to use instead of hydrocodone/ acetaminophen.	68 (56.2)	100 (82.6)[a]	100 (82.6)[a]
PGx Case: Identification of another medication that may be affected in patient's PGx profile.	78 (64.5)	95 (78.5)[a]	97 (80.2)[a]
Determination of what will happen to a CYP2C9 major substrate if a patient is a poor metabolizer of CYP2C9.	106 (87.6)	109 (90.1)	116 (95.9)[a,b]
Determination of what will happen to a CYP2D6 prodrug if a patient is a poor metabolizer.	111 (91.7)	112 (92.6)	118 (97.5)[a]
Determination of what will happen to a CYP2C19 major substrate if a patient is a rapid metabolizer.	104 (86.0)	106 (87.6)	118 (97.5)[a,b]
PGx Case: Interpretation of thrombophilia risk factors and how you would counsel a patient.	74 (61.2)	91 (75.2)[a]	110 (90.9)[a,b]

Abbreviations: PGx=Pharmacogenetic
Data was analyzed by ANOVA for repeated measures with $p<.05$ as threshold
[a] Significantly different from prelecture
[b] Significantly different from postlecture

Table 2. Pharmacy Students' Confidence Before and After a Pharmacogenetics Lecture and After an Active-Learning Laboratory Session (N=121)

	Prelecture		Postlecture		Postlaboratory	
Confidence Question	**Median Score [IQR]**	**% Confident**	**Median Score [IQR]**	**% Confident**	**Median, Score [IQR]**	**% Confident**
I am confident in my ability to interpret a patient's CYP450 results.	3 [2-3]	51.2	3 [3-4][a]	86[a]	4 [3-4][a,b]	98.3[a,b]
I am confident in my ability to identify medications that utilize the CYP450 pathway.	2 [2-3]	41.3	3 [3-3][a]	83.5[a]	3 [3-4][a,b]	95[a,b]
I am confident in my ability to appropriately recommend therapy changes based on a patient's medication profile and CYP450 results.	3 [2-3]	52.1	3 [3-3][a]	85.1[a]	4 [3-4][a,b]	90.9[a]
I am confident in my ability to know where to look to find up-to-date information on pharmacogenetics.	2 [2-3]	43.8	3 [3-4][a]	93.4[a]	4 [3-4][a,b]	94.2[a]
I am confident in my ability to counsel a patient on their CYP450 results.	3 [2-3]	57.9	3 [3-3.5][a]	84.3[a]	4 [3-4][a,b]	95.9[a,b]

Abbreviations: IQR=interquartile range

Data presented as median and IQR and also as percentage when a student responded "completely confident," "very confident," or "confident." Data were analyzed using the Wilcoxon signed rank test for repeated measures with $p<.05$ as the threshold

[a] Significantly different from prelecture

[b] Significantly different from post-lecture

significantly increased from postlecture to postlaboratory (Table 2).

The results of the cluster analysis revealed two distinct clusters of students. Cluster analysis was used to subdivide the cohort in subgroups based on their performance prelecture regarding knowledge and confidence. To keep the clustering algorithm with no manual intervention, no attempt was made to relocate cases after running the analysis. Cluster one contained a majority of students with low knowledge and confidence scores on the assessments and cluster two contained a majority of students with higher knowledge and confidence scores on the assessments (Figure 2). As expected from the cluster analysis, the prelecture performance between the two clusters was significantly different ($p<.0001$) with students from cluster one having significantly lower scores than students from cluster two (Figure 3A). The lecture material significantly increased the pharmacogenetics knowledge of students in both clusters (cluster one, $p<.0001$ and cluster two, $p=.0036$), although the gain in knowledge was more pronounced in students from cluster one (Figure 3). However, the lecture content alone was not enough to equalize the knowledge gap between students of clusters one and two as there was still a

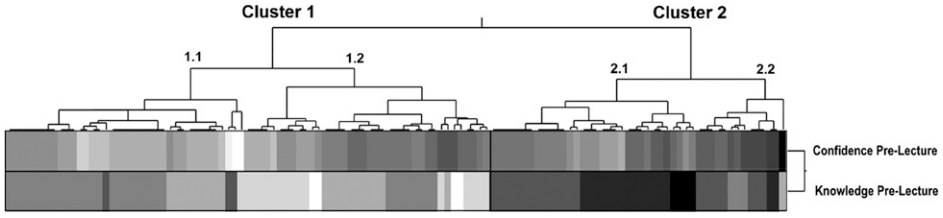

Figure 2. Hierarchical Cluster Analysis of the Results from Prelecture Student Assessment Enables Unsupervised Stratification of Students with Respect to Their Baseline Knowledge

The data obtained from the prelecture assessment of the 2016 student cohort with respect to their baseline knowledge and confidence regarding clinical pharmacogenetics was subjected to hierarchical cluster analysis. The data indicate the presence of two distinct clusters (cluster 1 and cluster 2) of students that are stratified according to their relative knowledge and confidence regarding the subject matter. Black and white gradient represents the Euclidian distance from high to low, respectively. Therefore, cluster 1 defines students with lower knowledge and confidence scores, and cluster 2 defines students with higher scores. Inside each main cluster, it is possible to observe subclusters that further help to define students with low (subcluster 1.1), medium (subcluster 1.2), intermediate (subcluster 2.1), or higher (subcluster 2.2) performance in the tests. Students' identifications are omitted, but can be implied by vertical strips. In depth investigation of the clusters provided detailed information with respect to the makeup of the student population regarding their baseline knowledge and confidence regarding clinical pharmacogenetics.

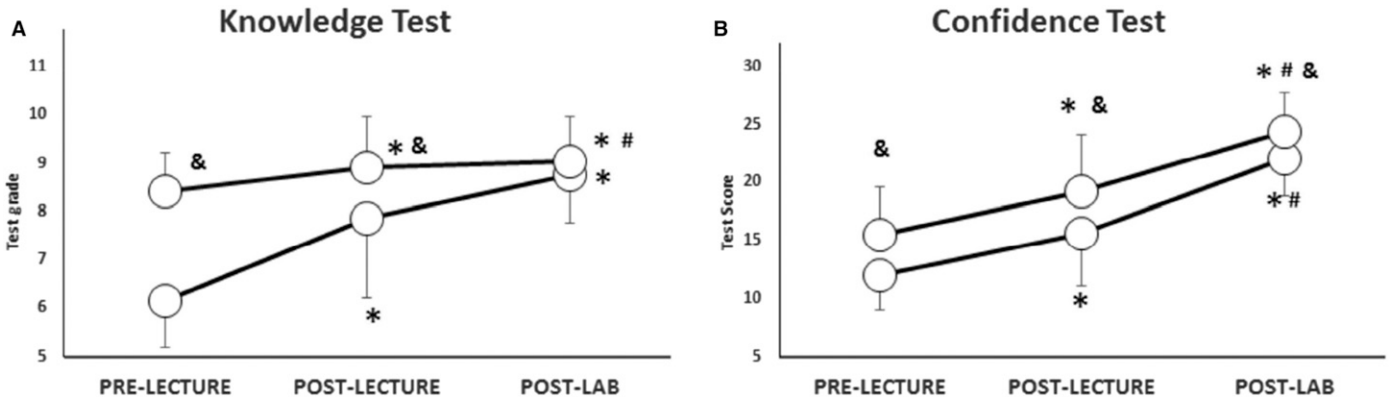

Figure 3. Both the Lecture and Laboratory Component are Essential for Students who had Low Baseline Knowledge and Confidence Concerning Clinical Pharmacogenetics

Assessment results were plotted separately for cluster 1 and cluster 2 students with respect to their knowledge in clinical pharmacogenetics prelecture, postlecture and postlaboratory session. The lower line represents cluster 1 and the upper line represents cluster 2. Significant increases in knowledge with respect to subject matter was observed postlecture with further significant gain in knowledge observed postlaboratory session for all students. Cluster 1 students also showed significant increase in knowledge postlaboratory compared to their postlecture scores. Statistical differences in performance was observed between the prelecture and postlecture students from different clusters while no significant difference was observed at the postlaboratory assessment, indicating a laboratory component is crucial for equalizing the knowledge in the student cohort (Panel A). Assessment results were also plotted separately for cluster 1 and cluster 2 students with respect to their confidence in delivering clinical pharmacogenetics services prelecture, postlecture and postlaboratory session. Significant increases in knowledge with respect to confidence in service delivery was observed postlecture, with further significant gain in knowledge observed postlaboratory for all students. However, statistical differences in confidence were observed between the prelecture, postlecture and postlaboratory assessments, indicating that the curriculum provided was not sufficient to overcome the confidence difference between the two clusters of students (Panel B). The Wilcoxon signed rank test was used for comparisons at each time point, and differences between clusters was tested with Mann-Whitney test.

* significantly different from prelecture

significantly different from postlecture

& significantly different from other cluster at same time point

significant difference ($p=.0002$) in their knowledge scores postlecture. Participation in the laboratory activity significantly increased the knowledge of students in cluster one ($p<.0001$). Furthermore, students' completion of the laboratory activity appeared to be what equalized pharmacogenetics knowledge as their was no significant difference between the two clusters' postlaboratory test scores (Figure 3). However, a significant difference ($p=.0002$) was found between the two clusters with respect to confidence level postlaboratory (Figure 3). As a group, the students in cluster one were less confident in their knowledge of the subject matter at the end of the study than those in cluster two, despite that the two groups appeared to have the same level of knowledge of the subject matter.

The clinical skills from the laboratory session were evaluated using team cases and a counseling session. Team performance on the pharmacogenetics clinical cases ranged from 52.5% to 93.5%, with an average score of 78.5%. Student individual performance on the pharmacogenetic counseling activity ranged from 75% to 100%, with an average score of 96.1%.

Overall the majority of students (74.2%) who completed the postlaboratory evaluation (n=128, response rate 98.5%) rated the laboratory activity "good" or "excellent." Three students rated the laboratory session as "poor" and the rest as "fair." On the laboratory evaluation questions, students "agreed" or "strongly agreed" that the laboratory session was well organized (77.3%), contributed to their professional development (87.5%), had content that was relevant (90.6%), had information that was interesting and/or stimulating (71.9%), and presented information at a level appropriate for student understanding (90.6%).

Some of the student comments regarding what they liked about the laboratory session included: that it was relevant to pharmacy practice and the future of pharmacy; that they learned how to research medications and counsel patients on the interactions; that they found the counseling session helpful because it showed how patients could be confused about drug interactions and CYP450

enzymes and that the session gave them a better perspective on how to explain pharmacogenetic results in practice. Student comments about what they did not like about the laboratory session focused on wanting clearer explanations for grading the cases, more practice on recommending alternative medications, and additional laboratory demonstrations on how to walk through a pharmacogenetics profile.

DISCUSSION

Personalized medicine is fast becoming a standard practice in many disciplines of medicine. In this regard, pharmacogenetics-based personalized medicine is used in the customization of patient drug therapy. However, the number of trained pharmacogeneticists that can successfully translate pharmacogenetic data into an actionable treatment decision is limited, stressing the need for more trained pharmacists skilled in this aspect of precision medicine. Our study found that implementing an active-learning laboratory session following a lecture on clinical pharmacogenetics is one way to increase the knowledge, skills, and confidence of student pharmacists in this area before they become practicing pharmacists.

The data provides strong evidence that the inclusion of a laboratory component provides significant improvements in students' knowledge and confidence with respect to clinical pharmacogenetics. While knowledge significantly increased from before the lecture to the postlaboratory assessment, participating in the laboratory activity helped further increase knowledge as indicated by improved scores on five of the knowledge-based questions. When reviewing the improvement in students' responses to the questions, we noted that the hands-on activities in the laboratory session (ie, counseling a patient and using resources to search pharmacogenetics databases) may have been what drove this increase in knowledge. The improvement in students' responses to other questions may have been because the team cases incorporated these concepts. Of note, the question on which students performed the lowest at baseline and postlaboratory was related to hydrocodone polymorphisms. This medication was only briefly covered in the lecture and not reinforced within the clinical cases in the laboratory session, although similar principles were covered in both. Possibly incorporating this medication into the cases in the future might help students understand this commonly prescribed medication better.

The students had a relatively high (70.3%) prelecture baseline knowledge of the material. This may have been because this lecture and laboratory session occurred late in the semester, after the students had been in the course for many weeks and already had a basic theoretical knowledge of pharmacogenetics. Notably, this lecture was the first application of clinical pharmacogenetics that the students received. Thus, while the students' scores were high on the prelecture session test, they did not reflect the students' ability to employ pharmacogenetics methods in practice.

Students' confidence increased significantly from before the lecture to after, with the laboratory activity further increasing scores on three of the confidence questions. Scores on the confidence questions on interpreting a patient's CYP450 results, identifying medications that use the CYP450, and counseling a patient on their CYP450 results significantly increased after students completed the lecture, indicating that completing the laboratory activity played a role in these three items. This may be because these activities were reinforced with the clinical cases and patient counseling activity. The question on where to find up-to-date phamacogenetic material was covered in the lecture and used in the laboratory and remained high for both the postlecture and postlaboratory assessments. The item with the lowest confidence score (90.9%) was the question on recommending therapy changes based on a patient's medication regimen and pharmacogenetic profile. While the scores indicated that students were more confident than at baseline, this question was mentioned in student feedback as an area in which they would like more practice. Additional practice may help improve confidence in this area.

Results from the cluster analysis indicated that lecture content alone is insufficient and an integrated laboratory component is essential for all students to gain a complete grasp of pharmacogenetics subject matter. However, those students who had low confidence in the subject matter (cluster one) continued to struggle and have low confidence despite performing as well as their better performing peers by the end of the class. Apparently, those students who had low confidence in the subject matter even after the laboratory session may have benefitted from additional instruction specifically tailored to boost their confidence and self-awareness in delivering pharmacogenetics-based care. Overall, cluster analysis appears to be a useful tool that allows an educator to quickly identify specific groupings among students learning pharmacogenetics and tailor the educational content to optimize the learning experience for and confidence of those students.

Grades from the team cases indicate that some teams struggled with the activity. As this was a new concept for students, possibly incorporating a prelaboratory assignment following the lecture would ensure that all students understand the material prior to the laboratory activity. Students did well with the counseling activity, with many

students commenting in the evaluation on how important it was to include this piece in the learning exercise, just as was seen in the study with Knoell and colleagues.[12]

This laboratory helps students experience what real-world clinical pharmacogeneticists do on a daily basis in their pharmacy practice. The laboratory session was well received by the majority of students. The session can be easily replicated in other schools of pharmacy without needing to obtain samples from students to perform genetic analysis. Incorporation of the counseling activity may be a challenge for some schools as that requires additional manpower to conduct. Graduate teaching assistants and APPE students were used as patients in our laboratory session. Alumni or other volunteers also could be used. If schools can afford to hire standardized patients, this activity could be turned into an objective structured clinical examination.

One possible shortcoming of our study is test-retest bias as the same set of knowledge and confidence questions were used at three different time points. This may have led to students becoming familiar with the assessment and thereby contributed to the increase in scores. However, the students were not provided with the correct answers to the questions until after the final time the assessment was administered. Furthermore, between the postlecture assessment and the postlaboratory assessment, there was a lengthy gap in time during which the material was not brought to the students' attention. Finally, the fact that the confidence scores between students of cluster one and cluster two remained significantly different at the final testing argues against the repeated testing having a major impact on the improvement in scores. A control group could be used in future studies to better see the specific effects of adding an active-learning laboratory session.

CONCLUSION

In this era of personalized medicine, a properly trained workforce capable of interpreting pharmacogenetics laboratory results and making medication management decisions based on those results is a necessity. In this study, a lecture with an active-learning laboratory session on clinical pharmacogenetics increased students' knowledge, confidence, and skills in this area. Pharmacy schools should consider including an active-learning laboratory on clinical pharmacogenetics to their PharmD curriculum to better meet the expanding knowledge requirements for all pharmacy graduates.

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