Personal Pharmacogenetic Testing Enhances Pharmacy Student Knowledge and Attitude Towards Precision Medicine

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Funding statement: This manuscript was funded by generous contributions from the UCSF School of Pharmacy by Dean B. Joseph Guglielmo, PharmD, and by the School

of Pharmacy, Department of Bioengineering and Therapeutic Sciences Department Chairs Kathleen Giacomini, PhD, and Tejal Desai, PhD.

ABSTRACT

Objective: To evaluate if pharmacy students' participation in personal pharmacogenetic testing enhances their knowledge and attitude towards precision medicine (PM).

Methods: First-year pharmacy students were offered personalized pharmacogenetic testing as a supplement to a required curricular pharmacogenomics course. Ninety-eight of 122 (80%) students completed pre- and post-course surveys assessing knowledge and attitudes regarding PM; 73 students also volunteered for personal pharmacogenetic testing of the following drug metabolizing enzymes (*CYP2C19*, *CYP2D6*, *UGT1A1*) and pharmacodynamics-relevant proteins (interleukin (IL)-28B & human lymphocyte antigen HLAB*5701).

Results: An online Likert-based survey was distributed to 1st-year PharmD students. Using a linear mixed effects model, we observed significant improvements in 100% of knowledge and 70% of attitude-related questions for students who decided to undergo pharmacogenetic testing.

Conclusion: Personal pharmacogenetic testing significantly enhances knowledge of and attitude toward pharmacogenomics among PharmD trainees. This study demonstrates the feasibility and importance of educating future pharmacists by incorporating pharmacogenetic testing into professional school curricula.

Keywords: pharmacogenomics, genotyping, pharmacy curriculum, pharmacogenetics, personal pharmacogenetics

INTRODUCTION

The Human Genome Project laid the groundwork in 2003 for an innovative approach in medicine that we today call Precision Medicine.[1] This new era of medicine is centered around combating human diseases through prevention and treatment, based on lifestyle, environment and genetics, serving as the basis for President Obama's Precision Medicine Initiative in 2015.[2] The idea of tailoring patient care to an individual based on his/her lifestyle is not novel, but the incorporation of large quantities of genetic, environmental, and personal tracking data into the patient profile allows clinicians to make much more efficacious, safe, and cost-effective health care decisions.

The impact of precision medicine in the clinical setting today can be observed through the lens of pharmacogenetics. This term was used as early as 1959, when inter-individual drug response was attributed to genetic variation[3] and is particularly apparent today in the setting of clinical oncology.[4] For example, specific cell surface receptors (e.g., Her2) on tumors, mutated intracellular proteins (e.g., Ras), or unique chimeric proteins (e.g., Bcr-Abl) are novel gene-specific targets[4] that have been markedly successful at providing more targeted therapies and improved patient outcomes. Similarly, widespread HLA-B*1502 testing has dramatically reduced the rate of Stevens-Johnsons syndrome in susceptible populations.[5] Moreover, incorporation of pharmacogenetics information into drug development represents an opportunity to improve the drug candidate pipeline.[6]

Traditional genetic testing for educational purposes is often accompanied by ethical concerns with regards to individuals learning about their potential risks for developing various genetic diseases; this type of testing should be supplemented by

well-planned multi-disciplinary support efforts for students, and a means for them to access genetic counselors regarding their genetic data.[7–9] We wanted to avoid these controversial issues by focusing solely on pharmacogenetics, which does not carry the ethical concerns regarding disease risk. Our study was approved by the University of California, San Francisco (UCSF) Committee on Human Research.

Pharmacists, physicians and other health care professionals must be adequately trained to understand and appropriately communicate personal genetic data with other clinicians and patients in order to clinically incorporate the benefits of our rapidly expanding understanding of pharmacogenetics. Professional organizations such as the National Coalition for Health and Professional Education in Genetics, the Association of American Colleges Contemporary Issues in Medicine, the American College of Physicians, the American Nurses Association, and the American Association of Colleges of Pharmacy have defined core competencies relating to pharmacogenomics for inclusion in their respective professional school curricula.[10–12] Due to the recognition from these large professional organizations on the importance of educating our future health care professional, efforts to consistently incorporate pharmacogenomics education into medical and pharmacy school curricula have been attempted at various institutions,[3,11,13–16] but further research is necessary to determine the most appropriate structure to systematize the approach.[7,8]

Investing in the early education of future health professionals is critical in order for clinicians to keep up with technological and genomic advances. Pharmacists are essential in helping to usher in this new era of medicine, as they are the recognized drug experts[17] who specialize in a number of areas: pharmacokinetics,

pharmacodynamics, patient care, managed care, and pharmacogenomics.[18] Pharmacists are the ideal clinicians to spearhead this movement, and the healthcare system is beginning to accept this paradigm shift as legislation is passing in numerous states (California, Montana, and Washington among others) to expand the role that pharmacists will play in the changing landscape of medicine created by the Affordable Care Act. The American Society of Health-System Pharmacists (ASHP) and an increasing number of physicians recognize the importance of pharmacists' role in evaluating pharmacogenetic tests to guide and improve patient outcomes.[18] ASHP "believes that pharmacists have a responsibility to take a prominent role in the clinical application of pharmacogenomics" and recommends that "this emerging science be spearheaded…by pharmacists to promote safe, effective and cost-efficient medication practices."[19] With the natural fit of pharmacogenomics under the purview of pharmacists, it was inevitable for us to empirically determine the impact of personal pharmacogenetic testing on PharmD students' knowledge and attitude towards precision medicine at a large, public school of pharmacy.

Based on previous literature demonstrating the benefit of interactive learning in education,[13,16,17,20] we hypothesized that personal pharmacogenetic testing would enhance PharmD students' knowledge and attitudes regarding precision medicine.

METHODS

Background

Prior to our current assessment, a smaller pilot study was conducted among first-year PharmD students at UCSF in the spring of 2013. Twenty-two students enrolled in a

required pharmacogenomics course (Biopharmaceutical Sciences (BPS) 115 “Genetics and Pharmacogenetics”) volunteered to have their DNA isolated from blood samples and genotyped for variants in *CYP2C19*, a common drug metabolizing enzyme that is important in metabolizing several therapeutic agents including clopidogrel, a widely used anti-platelet agent. The course directors chose to genotype *CYP2C19* because mutations in this gene are known to vary by race, and aside from the ability to metabolize certain drugs, the mutations are not known to convey disease risk. This circumvents potential ethical issues that may arise when disclosing disease risk. Some Universities offering genomic testing for genetic diseases were criticized for failing to provide genetic counseling or conducting testing in a non-CLIA-certified laboratory.[21]

The BPS 115 course directors held a lecture session to disclose the results of the students’ genotypes. During this session, course directors reviewed the clinical implication in terms of drug metabolism of different variants of *CYP2C19*. Following the session, students organized a focus group to ask faculty more questions and create a space for students to continue sharing their learnings and genotypic information with other interested classmates. Students provided a substantial amount of feedback, which was recorded and used to develop a formal study protocol. They unanimously expressed the value of the testing and use of the results as teaching material for the course. Students discussed why it was compelling and crucial to their future as pharmacists and the future of their profession. A sample of representative, unsolicited student comments regarding their experience include:

- *“I see personal pharmacogenetic testing in the future of pharmacy. It can be time saving. It is going to be dependent on factors like whether MDs are willing to order genotyping*

tests instead of starting empirical therapy and dosing, and if we will begin educating our future clinicians. Implementation will require a new generation of MDs/pharmacists to lead this movement."

- *"Information outside of academia regarding pharmacogenomics is limited. Many people in the public are not aware that testing is even available. As leaders/graduates from this university, we have to communicate our knowledge to outside communities and the rest of the world. Having a diverse group of people communicating this information will spread the word about needing research in more ethnically diverse populations. Pharmacists will be the most easily accessible group of healthcare practitioners, so questions about testing will go to us before many in the hospital."*

- *"I genuinely enjoyed the class, and I learned a lot. This information inspires me to want to look further into why certain populations are fast metabolizers, or slow metabolizer or do not respond well to certain medications. I would like to personally be involved in pharmacogenomics in the future during my career."*

Survey assessment

Based on the pilot study's overwhelmingly positive feedback, personal pharmacogenetic testing was incorporated into BPS 115 the following year on a volunteer basis. One month before the start of the spring 2014 term, a survey was administered to 122 first-year UCSF School of Pharmacy (SOP) students enrolled in BPS 115. Selected demographic characteristics of the students are summarized in Table 1. The survey was designed to assess students' attitudes and knowledge towards precision medicine and was re-administered to the same students following completion

of the 10-week course. In addition to knowledge- and attitude-assessment questions in the post-course survey, we also reflection questions, allowing us to assess students' opinions about participating in pharmacogenetic testing. The knowledge, attitude, and process measure questions are listed in Supplemental Table 1.

Survey design

The voluntary pre- and post-course survey and pharmacogenetic testing were approved by the UCSF Committee on Human Research. Written consent and email addresses were collected from all students who were interested in participating in the survey. Email addresses were entered into UCSF's Research Electronic Data Capture (REDCap) system, a secure online utility for conducting surveys. Once a student logged on to REDCap to take their survey, REDCap would automatically generate and assign an anonymized, unique identifier linked to the subject's email address. The same identifier was associated with all surveys that the subject completed.

While the survey asked for basic personal information, REDCap only exported the assigned identifier with the survey data. To ensure that participation was voluntary, the names and email addresses associated with the survey results remained restricted from both primary researchers and course faculty members. Only the primary researchers were authorized to access the full REDCap data (the course directors were not involved in the survey-based assessment).

Pharmacogenetic testing

During the course, students had the opportunity to volunteer to have their own DNA genotyped for several drug metabolizing enzymes as a “hands-on” personal pharmacogenetic learning experience. This information was used as a teaching supplement to the course. Participation in the survey and testing was blinded to the course directors and had no impact on students’ grades or performance in the course. Several days were coordinated to collect de-identified saliva samples from students. The samples were analyzed in a CLIA-certified laboratory. Students were given the option to have genotyped either a gene for a drug metabolizing enzyme (*CYP2C19*, *CYP2D6*, or *UGT1A1*) or a pharmacodynamics-relevant protein (*IL28B* or *HLAB*5701*). Each of the genes coding these enzymes/proteins has its own unique clinical implication and varying allele frequency (and therefore varying activity) among ethnic groups (Table 2). Genotyping results for these genes allow clinicians to properly develop an appropriate medication regimen tailored for individual patients.

Unveiling of pharmacogenetic results

Once genotyping was completed, students were given their personal pharmacogenetic information during a regularly scheduled class period for BPS 115; the class session was divided into two sessions. During the first session, a pharmacogeneticist was invited to review and discuss each of the genes under evaluation, their mutations, clinical significance, and how this information might be incorporated into clinical practice. The first part of the session was didactic, while the teaching methodology used in the second half of the session emphasized an *active learning classroom model* in which students were given 15 minutes to share and

discuss among each other, and then initiate an open discussion. During the open discussion, students engaged in an active question and answer session with each other and the pharmacogeneticist. Students based many of their questions on their personal pharmacogenomic data, and expressed interest in strategies for pharmacists to play a more active role in the future of this specialty. This session did not require specific preparatory work besides completing assigned readings pertaining to the course and basic concepts of pharmacogenetics.

Statistical analysis

We defined our outcome as change in knowledge or attitude regarding precision medicine. Specifically, we assigned integer values to the 5-point Likert scale (i.e., 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree and 5 = strongly agree) and then examined the change in Likert scores for each knowledge and attitude question by calculating the difference between pre- and post-survey responses. For example, a pre-survey response of 3 (neutral) followed by a post-survey response of 4 (agree) to the same question would be a gain of 1 Likert point. This difference served as our dependent variable. Our analysis was stratified into two groups: (1) students who participated in the personal genotyping and the survey (the genotyped group), and (2) those who participated in the survey but not in personal genotyping (the non-genotyped group). The effect of the pharmacogenetic testing on knowledge and attitude was estimated using linear mixed effects analysis. Variables for sex and race were included as fixed effects, with a random intercept for student. Estimates whose confidence intervals excluded the null value were considered statistically significant at an alpha

level of 0.05. Survey results were analyzed using the lme4 package[22] in the R statistical programming language (R Core Team, 2015).[23]

Expected outcomes included the following three objectives: (1) increasing understanding of pharmacogenetic concepts and clinical applications, (2) changing attitude toward precision medicine and clinical integration of pharmacogenetics, and (3) enhancing classroom learning of the subject matter (pharmacogenomics).

RESULTS

In total, 98 (80%) of the 122 students enrolled in the spring 2014 BPS 115 course voluntarily completed the pre- and post-course surveys. Of these 98, 73 (74.5%) students also took part in genotyping, leaving 25 students (25.5%) to comprise the surveyed but not genotyped group. Attitudinal and knowledge assessment was performed via an electronic online survey using a Likert scale response format. The 6 knowledge and 10 attitude questions (Supplementary Table 1) are listed in order of appearance on the pre- and post-course surveys. Baseline scores in knowledge and attitude were similar for both groups. The mean baseline Likert score for knowledge questions was (3.03) in the genotyped group and (3.14) in the non-genotyped group. For the attitude questions, the mean baseline score was (3.85) in the genotyped group and (3.83) in the non-genotyped group.

Results for change in knowledge and attitude are stratified by genotyping status in Tables 3 and 4, respectively. To keep our results clinically meaningful, we limited our analysis to results with a minimum effect size of 0.25 Likert points (i.e., a difference in means between pre- and post-survey results of 0.25 Likert points). Effect estimates

whose confidence intervals excluded the null value (i.e., 0) were determined to be statistically significant.

One-hundred percent of responses to the knowledge questions showed significant improvement between pre- and post-survey assessments, regardless of whether students participated in genotyping. The smallest increase in estimates was 0.64. The mean change in knowledge across all knowledge questions was not significantly different between the genotyped (0.99) and non-genotyped (1.05) groups ($p = 0.68$). Seventy percent of the attitude questions in students who underwent genotyping showed a considerable improvement in the pre- and post-Likert scores (Table 4). Forty percent of the attitudinal questions showed significant improvement among students in the non-genotyped group. While the mean change in attitude was slightly higher among those who did not participate in genotyping (0.36) versus those who did (0.30), the difference was not statistically significant ($p = 0.31$). The correlation between pre- and post-survey responses was fairly consistent for knowledge (Pearson's $r = 0.63$) and attitude ($r = 0.62$) questions.

In the genotyped group, the knowledge assessment question with the largest increase (1.32 Likert points, 95% confidence interval [CI]: 1.10-1.53) asked students to identify with the following statement: "I am aware of the types of knowledge and resources needed to interpret a pharmacogenetic test" (Knowledge Question 4, Supplementary Table 1). Among the non-genotyped group, the knowledge assessment question with the largest increase (1.32, 95% CI: 1.01-1.63) asked students whether they "…understand how to evaluate the clinical validity and utility of a pharmacogenetic test" (Knowledge Question 5, Supplementary Table 1). The attitude assessment

question with the largest increase was the same for genotyped (0.52, 95%CI: 0.34-0.70) and non-genotyped (0.52, 95%CI: 0.20-0.84) students. This question asked students whether “Pharmacogenetic testing, when applicable, should be integrated into patient care” (Attitude Question 6, Supplementary Table 1).

An examination of students’ attitudes (n = 98) revealed that students were more likely to have favorable impressions of precision medicine among those who had volunteered for personal genotyping versus those who did not get genotyped. Among the 73 students who were genotyped, 89% said that they were glad to have participated, and 85% stated that they had a better understanding of the principles of pharmacogenetics. Furthermore, 76.7% of the genotyped group said they felt more engaged during BPS 115, and 83.5% agreed that their participation in genotyping reinforced the concepts taught in the course (Table 5).

For students who did not volunteer to be genotyped, 60% regretted their decision and the same 60% stated that they would choose to undergo pharmacogenetic testing if it was offered to them again. Sixty-eight percent of students in the non-genotyped group stated that concepts taught in the course were reinforced after seeing their classmates receive their genetic results. Lastly, 68% of students in the non-genotyped group said they would be interested in participating in more comprehensive genetic testing to learn about other traits.

DISCUSSION

We found that incorporating genetic testing as an adjunct to School of Pharmacy PharmD curriculum significantly enhanced students’ knowledge and attitudes of

precision medicine. In both the genotyped and non-genotyped groups, there was an increase in all of the knowledge assessment questions before and after the course. The significance of this finding is extraordinary as it demonstrates that an interactive hands-on approach to educating future pharmacists about pharmacogenetics is a fundamental curricular change that should become commonplace across all professional doctorate programs in the country. As pharmacogenomics becomes increasingly fundamental for pharmacists in our health system, knowledge and acceptance of this new era of precision medicine is required for pharmacists to begin designing and developing personalized pharmacotherapy.

There were 132 AACP (American Association of College of Pharmacy) recognized and accredited schools of pharmacy in 2015.[20,24] In 2008-2009, 75 of 109 accredited schools of pharmacy surveyed revealed that 69 (92%) included pharmacogenomics in their curriculum and 67 (89.3% of total) taught the material at a PharmD level,[20] but the depth of inclusion was limited. Among these 69 schools surveyed, the most time spent on the topic of pharmacogenomics was between 31-60 hours, which was observed for only 10 (14.5%) of the schools. Topic coverage was less than 10 hours in 28 (40.6%), and between 11-30 hours for 29 (42%) of the schools (2 schools did not respond to this question).[20] Based on these numbers, it is evident that there is much room for pharmacogenomics to be incorporated into pharmacy school curricula, particularly since the degree of inclusion is still quite low and the majority of the colleges surveyed did not “have plans for faculty development in the area of pharmacogenomics content expertise.”[20]

In 2009, a study conducted at Temple University School of Pharmacy took a different approach to increase pharmacy student understanding of pharmacogenomics. The study involved 70 second-year PharmD students and an analysis of single nucleotide polymorphisms of the *NAT2* gene based on DNA extracted from their saliva.[16] The study concluded that a laboratory session in pharmacogenomics was beneficial in helping students understand the relevance of pharmacogenomic analysis in designing/creating a patient medication regimen.[8]

Another study by Salari and colleagues conducted at Stanford University's School of Medicine aimed to increase the depth of pharmacogenomics understanding by including personalized pharmacogenetic testing as an interactive supplement to an elective course. That study found a statistically significant impact on enhancing medical student knowledge and attitudes towards personal genome testing and precision medicine.[13] It is important to attempt to replicate these results in other graduate programs across the country, and in the current study we showed that the benefits of pharmacogenetics testing are applicable to PharmD programs.

Physicians are often unable to address pharmacotherapy based on a patient's genetics due to time constraints,[25] further justifying the importance of pharmacists in this new area of precision medicine. Given that pharmacists are the most extensively trained drug experts[17] in the health care system, the ability to interpret and understand this type of information falls directly under the purview of their pharmaceutical training. The role of pharmacists in the healthcare system is expanding, as reflected by recent legislation. More than 30 states have proposed provider status legislation[26] and two federal bills H.R. 592 and S. 314 have been introduced to Congress to amend the Social Security

Act to cover pharmacist services under the Medicare program. These types of legislative initiatives are steps in the right direction to ultimately increase patient access to care through expansion of pharmacy services.

The results presented in this innovative curricular approach to increasing knowledge and improving attitudes towards pharmacogenetic testing and precision medicine are promising. The overwhelming majority (80%) of students completed pre- and post-course surveys, and 75% of them took part in personal pharmacogenetic testing, which is significant considering the novelty of this idea to students. In our experience, the feasibility of implementing personal pharmacogenetic testing across all US pharmacy school curricula would not be arduous. Student participation was very high in the absence of incentives; the effort dedicated toward collection and processing of DNA was fairly minimal; and discussion of genotyping results was limited to only one class session. Instructors could limit their selection of genetic tests to inexpensive ones to optimize widespread dissemination of an educational session of this type. Educating our future providers and providing them with tools to adequately adapt and provide for their patients in an ever-changing healthcare landscape is an investment that will have major implications in the future health of our nation.

One of our most noteworthy findings was in regard to Knowledge Question #4 (Supplementary Table 1): “I am aware of the types of knowledge and resources needed to interpret a pharmacogenetic test.” The effect size was fairly large among genotyped students, (1.32, 95%CI: 1.10-1.53), demonstrating that students felt confident utilizing their resources to interpret a pharmacogenetic test. This observation suggests that a curriculum designed to include similar personal pharmacogenetic testing will prepare

students to keep up with the precision medicine revolution and ensure that patients are being treated by a confident and knowledgeable health care professional.

Sixty-eight percent of non-genotyped students reported that their classmates' participation in genotyping positively impacted their learning in the course, as described in the evaluation and assessment section above. This underscores the impact that the shared experience of personal pharmacogenetic testing had and the potential it has in educating our providers who do not wish to undergo pharmacogenetic testing themselves. This information is important when considering curricular redesign as it allows various interventions or combinations of them to be utilized to achieve maximal learning outcomes. Sixty percent of the non-genotyped students also mentioned that they regretted their decision not to volunteer for personal pharmacogenetic genotyping. It is evident that the experience is a shared and interactive one that not only stems from one's own personal pharmacogenetic information, but also from that of his/her peers.

Potential biases should be considered when reviewing the results of our study. Some unmeasured characteristics of genotyped students (e.g., attitudes toward providing biological samples) may have differed from non-genotyped students such that comparison of pre-/post- results between these two groups would not be valid (i.e., selection bias). However, we found no significant difference in baseline knowledge or attitude between the two groups. Nonetheless, it is possible that participants who elected to be genotyped would be more receptive to pharmacogenetics and thus that their attitudes would improve by a larger share than those who elected not to be genotyped. Although we found that 40% of the attitude questions showed a significant improvement among students who elected not to be genotyped, compared to 70% for

those students in the genotyped group, the results for the non-genotyped group may have been underpowered given the smaller number of students who chose to be genotyped (25 versus 73). Given that the effect estimates for all knowledge and attitude assessment questions were positive, regardless of genotyping status, we feel that the influence of this type of selection bias is minimal. Our analyses were conducted under the assumption that the intervals between Likert values are equal. We felt it reasonable, for example, to assume that “Agree” is halfway between “Neutral” and “Strongly agree;” this is a common assumption practiced in analysis of survey results.[27]

Our study did not show significant differences between the genotyped and non-genotyped groups with respect to attitudes or knowledge of pharmacogenetics testing. This may have been due to the relatively few number of students who elected not to be genotyped (n = 25), which reduced statistical power to detect a difference. In addition, it is likely that even students who elected not to be genotyped benefitted from the exercise of discussing the results of their classmates and also from the *active classroom model* in which genotyped students were given 15 minutes to share and discuss results with all students, followed by an open discussion. Our results appear to be consistent with a recent report, which described the incorporation of cadaver exome sequencing into first-year medical student curriculum as a form of active learning. It was demonstrated that this active and team based type learning was a potentially powerful educational innovation which helps to improve their genetic knowledge base.[28] In that report, students benefitted from a discussion of genetics made relevant to them without being genotyped directly. Thus, it is possible that pharmacogenetics testing of a subset of students had benefits on the entire classroom.

In order to overcome these limitations, a future cluster-based randomized study with several pharmacy school curricula could be implemented. In addition, long-term follow-up with these students would allow study of the lasting effects that personal pharmacogenetic testing has had on their personal and professional lives. Furthermore, we hope that this study serves as a means to further accelerate the dissemination of personal pharmacogenetic testing into US pharmacy school curricula.

SUMMARY

Pharmacy students in their first year of the PharmD curriculum showed significant enhancements in their knowledge and attitudes towards precision medicine after participating in personalized pharmacogenetic testing. Even students who were enrolled in the course but did not partake in personalized pharmacogenetic testing had an enhancement in knowledge and attitude about precision medicine, likely as a result of engagement with their classmates and faculty regarding the results.

Incorporation of personal pharmacogenetic testing into pharmacy school curricula is a simple and efficacious method of educating our future health care professionals. Personal pharmacogenetic testing continues at UCSF through the School of Pharmacy's BPS 115 course with further goals of incorporating it into the core curriculum. We believe that the new era of Precision Medicine ushered in by President Obama's Precision Medicine Initiative will only be successful if coupled with education of a new generation of health care providers. Herein, we have demonstrated that this novel educational approach has a profoundly positive impact on the next generation of

pharmacists, who by law will have an expanding role as the front line providers of healthcare.

ACKNOWLEDGEMENTS

We are grateful to Sandra Salazar for her support and contributions toward this effort.

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Table 1: Gender and Race/Ethnicity of Participants and Nonparticipants		
Characteristic	**Genotyped Group N = 73**	**Non-Genotyped Group N = 25**
Percent female	71.2	60.0
Race/Ethnicity	N (%)	N (%)
Hispanic	0 (0.0%)	1 (4.0%)
Black	1 (1.40%)	1 (4.`0%)
White	15 (20.5%)	4 (16.0%)
Asian	41 (56.2%)	17 (68.0%)
Other*	14 (19.2%)	2 (8.00%)
Pacific Islander	2 (2.70%)	0 (0.00%)

Table 2: Drug Metabolizing Enzymes, Function, and Mutation Frequencies		
Enzyme (reference)	**Function**	**Decreased Function Mutation Frequency by Race**
CYP2D6[29–31]	Affects large numbers of drugs, notably analgesics, tamoxifen, and antidepressants and medications for attention deficit disorder.	Black:0-5% Caucasian: 5-14% Asian: 0-1%
CYP2C19[30–32]	Affects cardiovascular drugs including clopidogrel and proton pump inhibitors and some antidepressant medications	Black: 5% Caucasian: 2-5% Asian: 19%
UGT1A1[33]	Affects some anticancer drugs and is responsible for hyperbilirubinemia induced by Gilbert's syndrome.	Black: 19% Caucasian: 8% Asian: 2%
HLAB*5701[34]	When present can cause Stevens Johnson Syndrome and delayed hypersensitivity mostly among Asians.	Black: 1% Caucasian: 6-7% Asian: up to 20%
IL28b[35]	C/C Alleles predicts drug efficacy towards chronic hepatitis C infections	Black: 24-50% Caucasian: 8-13% Asian: 0-1%

Table 3: Knowledge Assessment in Participants and Non Participants [a]

	Genotyped Group N = 73		Non-Genotyped Group N = 25	
Question	**Estimate Change**	**95% CI**	**Estimate**	**95% CI**
I am aware of the types of knowledge and resources needed to interpret a pharmacogenetic test result.	1.32[a]	1.10 – 1.53 [a]	1.12 [a]	0.81 – 1.43 [a]
I understand how to evaluate the clinical validity and utility of a pharmacogenetic test.	1.18 [a]	0.95 – 1.41 [a]	1.32 [a]	1.01 – 1.63 [a]
I understand how a pharmacogenetic test differs from a genetic test for disease risk.	1.18 [a]	0.96 – 1.40 [a]	0.96 [a]	0.61 – 1.31 [a]
I understand what a pharmacogenetic test is.	0.89 [a]	0.72 – 1.06 [a]	1.20 [a]	0.81 – 1.59 [a]
I understand the risks, benefits, and ethical considerations of personal genetic testing.	0.71 [a]	0.51 – 0.91 [a]	0.84 [a]	0.43 – 1.25 [a]
I understand what precision medicine is.	0.64 [a]	0.48 – 0.80 [a]	0.84 [a]	0.44 – 1.24 [a]

[a]Statistically significant, clinically meaningful effect sizes

.

Table 4: Attitude Assessment in Participants and Non Participants [a]

	Genotyped Group N = 73		Non-Genotyped Group N = 25	
Question	**Estimate Change**	**95% CI**	**Estimate**	**95% CI**
Pharmacogenetic testing, when applicable, should be integrated into patient care.	0.52 [a]	0.34 – 0.70 [a]	0.52 [a]	0.20 – 0.84 [a]
I would recommend pharmacogenetic testing for a patient.	0.41 [a]	0.17 – 0.65 [a]	0.48 [a]	0.09 – 0.87 [a]
I would recommend pharmacogenetic testing for a family member.	0.40 [a]	0.17 – 0.62 [a]	0.44 [a]	0.05 – 0.83 [a]
Pharmacogenetics should be integrated into the curricula at all pharmacy schools.	0.38 [a]	0.22 – 0.55 [a]	0.36	-0.05 – 0.77
The use of personal genetic information in health care is beneficial to patients.	0.33 [a]	0.16 – 0.50 [a]	0.20	-0.16 – 0.56
Pharmacists should be trained to interpret and apply pharmacogenetic test results.	0.30 [a]	0.13 – 0.48 [a]	0.44 [a]	0.16 – 0.72 [a]
In addition to factors like age, race, and drug interactions, genetic information is an important consideration during routine clinical practice.	0.26 [a]	0.04 – 0.48 [a]	0.28	-0.03 – 0.59
Pharmacists play a crucial role in the future of precision medicine.	0.22	0.06–0.38	0.24	-0.09 – 0.57
Pharmacogenetics will likely play an important role in my future career.	0.10	-0.10 – 0.29	0.28	-0.07 – 0.63
The use of personal genetic information in health care may cause unnecessary harm to patients.	0.03	-0.26 – 0.31	0.32	-0.21 – 0.85

[a]Statistically significant, clinically meaningful effect sizes

Table 5: Reflections of Participants and Non Participants

	Genotyped Group N = 73			Non-Genotyped Group N = 25		
Question	**Disagree + Strongly Disagree, N (%)**	**Neutral, N (%)**	**Agree + Strongly Agree, N (%)**	**Disagree + Strongly Disagree, N (%)**	**Neutral, N (%)**	**Agree + Strongly Agree, N (%)**
I am glad that I participated in the pharmacogenetic testing.	2 (3%)	6 (8%)	65 (89%)	na	na	na
I believe that I have a better understanding of the principles of pharmacogenetics on the basis of having undergone personal pharmacogenetic testing	1 (1.4%)	10 (13.6%)	62 (85%)	na	na	na
I felt more personally engaged during BPS115 because I had undergone the pharmacogenetic testing.	3 (4%)	14 (19%)	56 (77%)	na	na	na
My participation in the pharmacogenetic testing reinforced the concepts taught in BPS115	2 (2.7%)	10 (13.8%)	61 (83.5%)	na	na	na
I regret that I did not participate in the pharmacogenetic testing.	na	na	na	5 (20%)	5 (20%)	15 (60%)
Seeing my classmates' genetic results reinforced the concepts taught in BPS115	na	na	na	1 (4%)	7 (28%)	17 (68%)
I would be interested in participating in more comprehensive genetic testing to learn about other traits.	na	na	na	1 (4%)	7 (28%)	17 (68%)
If offered to me again, I would choose to undergo pharmacogenetic testing.	na	na	na	2 (8%)	8 (32%)	15 (60%)

Supplementary Table 1. Knowledge and Attitude Assessment Questions from Pre and Post Survey
Knowledge
1. I understand what precision medicine is.
2. I understand what a pharmacogenetic test is.
3. I understand how a pharmacogenetic test differs from a genetic test for disease risk.
4. I am aware of the types of knowledge and resources needed to interpret a pharmacogenetic test result.
5. I understand how to evaluate the clinical validity and utility of a pharmacogenetic test.
6. I understand the risks, benefits, and ethical considerations of personal genetic testing.
Attitude
1. The use of personal genetic information in health care is beneficial to patients.
2. The use of personal genetic information in health care may cause unnecessary harm to patients.
3. In addition to factors like age, race, and drug interactions, genetic information is an important consideration during routine clinical practice.
4. I would recommend pharmacogenetic testing for a patient.
5. I would recommend pharmacogenetic testing for a family member.
6. Pharmacogenetic testing, when applicable, should be integrated into patient care.
7. Pharmacists should be trained to interpret and apply pharmacogenetic test results.
8. Pharmacogenetics should be integrated into the curricula at all pharmacy schools.
9. Pharmacogenetics will likely play an important role in my future career.
10. Pharmacists play a crucial role in the future of precision medicine.
Reflection
1. I am glad that I participated in the pharmacogenetic testing.
2. I believe that I have a better understanding of the principles of pharmacogenetics on the basis of having undergone personal pharmacogenetic testing
3. I felt more personally engaged during BPS115 because I had undergone the pharmacogenetic testing.
4. My participation in the pharmacogenetic testing reinforced the concepts taught in BPS115
5. I regret that I did not participate in the pharmacogenetic testing.
6. Seeing my classmates' genetic results reinforced the concepts taught in BPS115
7. I would be interested in participating in more comprehensive genetic testing to learn about other traits.
8. If offered to me again, I would choose to undergo pharmacogenetic testing.