Expanding Pharmacist and Student Pharmacist Access to Genetics/Genomics/Pharmacogenomics Competency Education

David F Kisor1 and Christopher L Farrell2

1Pharmacy and Pharmacogenomics Programs, Manchester University, Fort Wayne, IN, USA.
2Pharmaceutical and Administrative Sciences, Presbyterian College, Clinton, SC, USA.

ABSTRACT

BACKGROUND: As pharmacogenomics (PGx), a component of genetics/genomics and precision medicine, gains traction in the clinical setting, education of health care providers and health professions students must be made broadly available to improve accessibility of such services to patients. As medication experts with education in pharmacology, pharmacokinetics, and pharmacodynamics, pharmacists must further their education to include pharmacogenomics. Currently, few opportunities exist to gain this type of education, and therefore, these services are not yet broadly available to the public.

OBJECTIVE: The specific goal of this study was to evaluate pharmacists’ and student pharmacists’ self-assessed perception of competence related to genetics, genomics, and pharmacogenomics as presented via an online “pharmacogenomics certification program” (PGx program).

DESIGN: The PGx program was delivered online with the content consisting of 3 background lessons and 8 specific drug-gene lessons presented in the context of pharmacist competency statements. In addition, 11 “video modules” with competency-related PGx content were included to provide a comprehensive program. A pre- and post-course survey instrument was used to evaluate the participants’ self-assessed perception of competence related to each of 16 statements.

RESULTS: One hundred thirty-seven (137) individuals enrolled in and completed the pharmacogenomics certification program. Overall, participants reported self-perceived improved competency as evidenced by the pre-course survey as compared with the post-course survey for each of the 16 competency statements related to genetics/genomics, including pharmacogenomics. Similar results were observed for the subgroups of student pharmacists (n = 63) and pharmacists (n = 74).

FUTURE DIRECTION: This study showed that dissemination of genetics/genomics/pharmacogenomics competency statements education can be accomplished via online delivery. This delivery approach can expand genetics/genomics/pharmacogenomics content dissemination. The intent is to reach a broader population of pharmacy students, pharmacists, and other health care providers and health professions students to potentially advance the availability of such services, which can improve the safety and efficacy of medication use for patients.

KEYWORDS: pharmacogenetics, pharmacogenomics, certification, education, pharmacists

Background

Precision medicine (PM) aims to individualize medical treatment by tailoring therapeutic interventions relative to patient-specific variables to improve the safety and efficacy of medications and improve patient care. There continues to be a great need for education of current health care professionals and health professions students regarding PM.1 The application of pharmacogenomics (PGx), one of the key components of PM, is meant to identify the most effective medication while minimizing the risk of adverse drug reactions by using the genetic variants found within the patient’s genome. In recent years, pharmacogenetic (PGt) tests have become more accessible to health care professionals and patients through health care provider applications and through direct-to-consumer avenues where raw genotype data may be evaluated.2,3

With PGx continuing to gain momentum in becoming a standard practice across health care settings, it is critical that health care professionals and health professions students are educated on competencies in genetics/genomics, including PGx and its applications in PM. With recognized competency knowledge gaps in PGx, increased efforts are needed to educate a greater number of health care professionals and health professions students.4–6 Strong educational backgrounds in pharmacology, pharmacokinetics, and pharmacodynamics, as well as being recognized as drug-interaction experts, implies that pharmacists are positioned to be PGx educational liaison for physicians, other health care providers, and patients across health care settings. However, a 2012 survey indicated that 82% of pharmacists considered their current understanding of PGt testing as only “poor” or “fair.”6 Pharmacists do recognize

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the potential of PGx with the survey noting that 90% of pharmacists wanted to learn more about PGx and testing, with web-based continuing education being identified as a major delivery preference. Efforts have been undertaken to increase the breadth and depth of PGx education for pharmacists and student pharmacists. The Accreditation Council for Pharmacy Education (ACPE), as of July 2016, requires pharmacy programs to include medical genomics as part of their curricula, previously, this was only a recommendation. Specifically, Doctor of Pharmacy curricula are to address the "genetic basis for disease and individual differences in metabolizing enzymes, transporters, and other biochemicals impacting drug disposition (pharmacokinetics) and action (pharmacodynamics) that underpin the practice of personalized medicine." The role of pharmacists in applying genetics was further defined through the updating of pharmacist's competencies in genetics/genomics, including PGx. Live genetics/genomics/PGx certification programs with ACPE accredited continuing education were introduced to provide advanced genetics/genomics/PGx education. These live efforts, however, were only able to reach a fraction of the target population. In this article, we report the findings of a study to evaluate an online genetics/genomics/PGx certificate training program (PGx program) offered to increase knowledge of pharmacists and student pharmacists specifically related to pharmacist's competencies in genetics/genomics/PGx. The specific goal of this study was to evaluate pharmacists' and student pharmacists' self-assessed perception of competence related to genetics/genomics/PGx.

Methods

We modified a previously reported methodology for the administration of a certificate training program, with a self-study and live component which resulted in a statistically significant increase in pharmacist self-assessed perception of competence related to pharmacogenomics. The modification was designing the content to be delivered online. Individuals who registered for the PGx program received a textbook (postal mail or download) to be used for self-study. The online PGx program, developed by pharmacy faculty with expertise in pharmacogenomics, consisted of 2 modules, the first being "the science" of PGx. This module used the textbook, with the subject matter including the mechanisms of expression of genetic information, genetic variation from a molecular point of view, and genetics related to pharmacokinetics (PK) and pharmacodynamics (PD). Overall, there were 11 lessons in module 1 (Table 1). The second module, covering competency-related "practical applications of PGx" consisted of 11 lessons, including pharmacist competencies in genetics/genomics, the pharmacists' patient care process, PGx patient cases, and the process of buccal swabbing for collection of cheek cells as a DNA source (Table 1). While the competencies were discussed as specific lessons, the entire content of the PGx program was related to pharmacist competencies in genetics/genomics/PGx. The PGx program course content also included a study guide to be used with the course textbook, term matching exercises, links to Clinical Pharmacogenetics Implementation Consortium (CPIC) guidelines and quizzes for each of 3 science background lessons as well as 8 drug-gene interaction chapters.

In the fall of 2015, the online delivery of the PGx program was made available from an industry pharmacy education provider, with co-providership from a national pharmacy organization. On registration, the participant was required to complete an online pre-course survey related specifically to the pharmacist competency statements (Table 2). Here, 16 statements, across 4 pharmacist genetics/genomics competency domains, including "Basic Genetic Concepts (B)" (statements 1-B1 through 5-B5), "Genetics and Disease (G)" (statements 6-G1 through 8-G3), "Pharmacogenetics/Pharmacogenomics (P)" (statements 9-P1 through 10-P3), and "Ethical, Legal, and Social Implications (E)" (statements 11-E1 through 16-E5) were evaluated on a 5-point Likert-type scale of "strongly disagree," "disagree," "neither disagree nor agree," "agree," and "strongly agree." Video presentations including competency reviews and patient cases were also included as online content. In addition, chapter quizzes, the mid-term exam, and final exam were housed and completed online. The post-course pharmacist competency statement survey (identical to the pre-course survey) was made available online and completed immediately on completion of the program.

The participants were to use the online study guide and textbook and complete each chapter quiz. Missing a question on a given quiz resulted in the participant being prompted to study the material again and take the quiz again. There was no limit to the number of times a student could take a particular quiz. At the completion of the textbook lessons (1 through 11), the students took a comprehensive online mid-term exam. Participants then viewed online presentations, typically "voiced over" PowerPoint® presentations which addressed different competency-related areas. Participants viewed online clinical cases, again as narrated PowerPoint® presentations including those in the area of cardiology, pain management, neurology, and discharge planning of a more complicated patient. Participants had to complete a comprehensive online final exam including questions on specific competencies and case-related questions.

For the pre- and post-course surveys, as previously described, ordinal data related to students' self-assessed competency in PGx was noted using the median and interquartile range (IQR). Response distribution was examined between the pre- and post-course surveys for each item using the Mann-Whitney U test. For all statistical analyses, the level of significance was set a priori at a P-value of less than .05. All data were analyzed using SPSS (version 21.0, SPSS, Inc., Chicago, IL, USA). Descriptive statistics related to the Likert-type scale...
| Module 1: The Science | Lesson | Module 2: Practical Application | Lesson |
|-----------------------|--------|---------------------------------|--------|
| Section I.            |        |                                 |        |
| The purpose of section I is to provide the pharmacist with an understanding of the mechanisms of expression of genetic information in the context of personalized medicine. | 1. Introduction to personalized medicine | Module 2 takes the information from module 1 and relates the science to clinical application. This is done in a broad context of pharmacist competencies described by the NIH funded Genetics/Genomics Competency Center. Patient cases demonstrate further application. The pharmacist patient care process as related to PGx is presented. | 12. Science overview and clinical application |
| Section II.           |        |                                 |        |
| The purpose of section II is to provide the pharmacist with an understanding of the relationship between genetics and pharmacokinetics (PK) and pharmacodynamics (PD). | 2. Pharmacogenetics and pharmacokinetics | 13. Pharmacist competencies—basic genetic concepts |
| | | 3. Pharmacogenetics and pharmacodynamics | 14. Pharmacist competencies—genetics and disease |
| | | | 15. Pharmacist competencies—pharmacogenetics/pharmacogenomics |
| | | | 16. Pharmacist competencies—ethical, legal, and social implications |
| | | | 17. Pharmacogenomics and the patient care process |
| | | | 18. PGx Case: myocardial infarction |
| | | | 19. PGx Case: pain |
| | | | 20. PGx Case: central nervous system |
| | | | 21. PGx Case: discharge planning |
| | | | 22. Sample collection process: buccal cheek swab |
| | | | |
| Section III.          |        |                                 |        |
| The purpose of section III is to provide the pharmacist with an understanding of specific genes related to specific drugs, ie, drug-gene interactions. | 4. Abacavir-HLA-B*57:01 | 23. Abacavir-HLA-B*57:01 |
| | | 5. Carbamazepine-HLA-B*15:02 | 24. Carbamazepine-HLA-B*15:02 |
| | | 6. Clopidogrel-CYP2C19 | 25. Clopidogrel-CYP2C19 |
| | | 7. 5-Fluorouracil-DYPD | 26. 5-Fluorouracil-DYPD |
| | | 8. Irinotecan-UGT1A1 | 27. Irinotecan-UGT1A1 |
| | | 9. 6-Mercaptopurine-TPMT | 28. 6-Mercaptopurine-TPMT |
| | | 10. Warfarin-CYP2C9, VKORC1 | 29. Warfarin-CYP2C9, VKORC1 |
| | | 11. Codeine-CYP2D6 | 30. Codeine-CYP2D6 |

Table 1. Subject matter included in the online PGx program.
Table 2. Results of pre- and post-genetics/genomics/pharmacogenomics competencies survey related to the 5-point Likert-type scale (strongly disagree [SD 1], disagree [D 2], neutral [N 3], agree [A 4], and strongly agree [SA 5]).

|   | OVERALL (N = 137) | STUDENT PHARMACISTS (N = 63) | PHARMACISTS (N = 74) |
|---|------------------|-------------------------------|----------------------|
|   | PRE-PROGRAM (MEAN) | POST-PROGRAM (MEAN) | PRE-PROGRAM (MEAN) | POST-PROGRAM (MEAN) | PRE-PROGRAM (MEAN) | POST-PROGRAM (MEAN) |
| 1-B1. I am confident that I can demonstrate an understanding of the basic genetic/genomic concepts and nomenclature. | A (3.6) SA (4.5) | A (3.6) SA (4.5) | N (3.4) A (4.4) |
| 2-B2. I can clearly recognize and appreciate the role of behavioral, social, and environmental factors (lifestyle, socioeconomic factors, pollutants, etc.) to modify or influence genetics in the manifestation of disease. | A (3.7) SA (4.6) | A (3.7) SA (4.5) | A (3.6) SA (4.5) |
| 3-B3. I am able to identify drug and disease-associated genetic variations that facilitate development of prevention, diagnostic and treatment strategies. | N (3.2) A (4.4) | N (3.2) SA (4.5) | N (3.1) A (4.3) |
| 4-B4. I can appreciate the differences in testing methodologies and are aware of the need to explore these differences in drug literature evaluation. | A (3.5) A (4.4) | A (3.7) A (4.4) | N (3.3) A (4.4) |
| 5-B5. I am confident to use family history (minimum of 3 generations) in assessing predisposition to disease and selection of drug treatment. | N (3.1) A (4.4) | N (3.1) A (4.4) | N (3.0) A (4.2) |
| 6-G1. I have a good understanding of the role of genetic factors in maintaining health and preventing disease. | A (3.7) SA (4.6) | A (3.8) SA (4.6) | A (3.5) SA (4.5) |
| 7-G2. I can confidently assess the difference between clinical diagnosis of disease and identification of genetic predisposition to disease and understand that genetic variation is not strictly correlated with disease manifestation. | A (3.5) SA (4.5) | A (3.6) A (4.4) | N (3.4) SA (4.5) |
| 8-G3. I can appreciate that pharmacogenomic testing may also reveal certain genetic disease predispositions, such as the Apo E4 polymorphism. | A (3.6) SA (4.6) | A (3.9) SA (4.6) | N (3.4) SA (4.6) |
| 9-P1. I am confident to demonstrate an understanding of how genetic variation in a large number of proteins, including drug transporters, drug metabolizing enzymes, direct protein targets of drugs, and other proteins influence pharmacokinetics and pharmacodynamics relate to pharmacologic effects and drug response. | N (3.3) SA (4.5) | N (3.3) SA (4.5) | N (3.2) SA (4.5) |
Table 2. (Continued)

| Competency Statement                                                                 | OVERALL (N = 137) | STUDENT PHARMACISTS (N = 63) | PHARMACISTS (N = 74) |
|--------------------------------------------------------------------------------------|-------------------|------------------------------|----------------------|
|                                                                                    | PRE-PROGRAM (MEAN) | POST-PROGRAM (MEAN)         | PRE-PROGRAM (MEAN)   | POST-PROGRAM (MEAN)         | PRE-PROGRAM (MEAN)   | POST-PROGRAM (MEAN)         |
| 10-P2. I have a good understanding of the influence (or lack thereof) of ethnicity in genetic polymorphisms and associations of polymorphisms with drug response. | N (3.4)           | SA (4.6)                    | A (3.5)              | SA (4.5)                    | N (3.2)              | SA (4.5)                     |
| 11-P3. I can confidently recognize the availability of evidence-based guidelines that synthesize information relevant to genomic/pharmacogenomic tests and selection of drug therapy (eg, Clinical Pharmacogenomics Implementation Consortium, or CPIC) | N (3.2)           | SA (4.6)                    | N (3.2)              | SA (4.6)                    | N (3.1)              | SA (4.6)                     |
| 12-E1. I have a good understanding of the potential physical and/or psychological benefits, limitations, and risk of genomic/pharmacogenomic information for individuals, family members, and communities, especially with genomic/pharmacogenomic tests that may relate to predisposition to disease. | A (4)             | SA (4.5)                    | A (3.6)              | SA (4.5)                    | N (3.4)              | SA (4.5)                     |
| 13-E2. I have a good understanding of the increased liability that accompanies access to detailed genomic patient information and maintain confidentiality and security. | A (3.6)           | SA (4.5)                    | A (3.7)              | SA (4.6)                    | A (3.5)              | SA (4.5)                     |
| 14-E3. I can confidently adopt a culturally sensitive and ethical approach to patient counseling regarding genomic/pharmacogenomic test results. | A (3.7)           | SA (4.5)                    | A (3.8)              | SA (4.6)                    | A (3.6)              | SA (4.5)                     |
| 15-E4. I have a good appreciation of the cost, cost-effectiveness, and reimbursement by insurers relevant to genomic/pharmacogenomic test results. | N (3.1)           | A (4.4)                     | N (3.3)              | A (4.3)                     | N (2.8)              | A (4.3)                      |
| 16-E5. I can confidently identify the need to refer a patient to a genetic specialist or genetic counselor. | N (3.1)           | SA (4.5)                    | N (3.0)              | SA (4.5)                    | N (3.0)              | SA (4.5)                     |

The mean value rounded to the closest assigned Likert-type scale label is shown for the pre- and post-survey competency statements.
were used for the course evaluation/online delivery utility survey. The study was approved by the university Institutional Review Board.

**Results**

From September 2015 through February 2018, 287 individuals were registered to take the PGx program online. Of these, 137 participants completed the PGx program (47.7%) during the time frame of our study. The other individuals may have stopped their progression in the program for unknown reasons or were still in the process of completing the program. Of the 137 participants who completed the PGx program, 63 were student pharmacists (46%) and 74 were pharmacists. The student pharmacists were second- and third-year students from 2 pharmacy programs who used the online PGx program offering it as an elective certificate training course, with one program providing academic credit.

Across competency statements, overall (n = 137), the participants reported self-perceived improved competency as evidenced by the post-program survey as compared with the pre-program survey for each of the 16 competency statements (Table 2; Figure 1). Across the 4 domains for all competency statements, there was a statistically significant between the pre- and post-program survey responses (P < .05). Considering the 4 competency domains, there was a “shift” of approximately one (1) point along the scale toward agree/strongly agree. In the “Basic Genetic Concepts” domain, respondents’ perceived competency for statements 1-B1 and 2-B2 moved from “agree” to “strongly agree.” Respondents’ perceived competency for statements 3-B3 and 5-B5 moved from “neutral” to “agree,” while their perceived competency related to statement 4-B4 remained at “agree.” In the “Genetics and Disease” domain, respondents’ perceived competency for statements 6-G1, 7-G2 and 8-G3 moved from “agree” to “strongly agree.” Relative to the domain “Pharmacogenetics/Pharmacogenomics,” respondents’ perceived competency for each statement, 9-P1, 10-P2, and 11-P3 moved from “neutral” to “strongly agree.” In the “Ethical, Legal, and Social Implications” domain, the perceived competency related to statements 12-E1, 13-E2, and 14-E3 moved from “agree” to “strongly agree.” The perceived competency related to statement 15-E4 moved from “neutral” to “agree,” while perceived competency relative to statement 16-E5 moved from “neutral” to “strongly agree.”

Subgroup analysis revealed similar results for the student pharmacist subgroup. There were 3 differences noted. Competency statement 3-B3 moved from “neutral” to “strongly agree”; competency statement 7-G2 remained the same at “agree”; and competency statement 10-P2 moved from “agree” to “strongly agree.” Figure 2 presents the percentage of student pharmacists responding relative to the Likert-type scale for each competency statement before and after the PGx program.

For the pharmacist subgroup, in the “Basic Genetic Concepts” domain, respondents’ perceived competency for statements 1-B1, 3-B3, 4-B4, and 5-B5 moved from “neutral” to “agree.” Respondents’ perceived competency for statements 2-B2 moved from “agree” to “strongly agree.” In the “Genetics and Disease” domain, pharmacists’ perceived competency for statements 6-G1 moved from “agree” to “strongly agree.” Pharmacists’ perceived competency related to statement 7-G2 moved from “neutral” to “strongly agree,” while perceived competency related to statement 8-G3 moved from “neutral” to “strongly agree.” Pharmacists’ perceived competency related to statement 9-P1 and 11-P3 moved from “neutral” to “strongly agree.” In the “Ethical, Legal, and Social Implications” domain, pharmacists’ perceived competency related to statements 12-E1 moved from “neutral” to “strongly agree,” whereas perceived competency related to statements 13-E2 and 14-E3 moved from “agree” to “strongly agree.” Finally, perceived competency relative to statement 15-E4 moved from “neutral” to “agree” and statement 16-E5 moved from “neutral” to “strongly agree.” Figure 3 presents the percentage of pharmacists responding relative to the Likert-type scale for each competency statement before and after the PGx program.

For the entire study population, the largest absolute change in the pre- and post-program survey was related to statement 11-P3, “I can confidently recognize the availability of evidence-based guidelines that synthesize information relevant to genomic/pharmacogenomic tests and selection of drug therapy (e.g. Clinical Pharmacogenomics Implementation Consortium, or CPIC).” For this statement, the pre-program mean value was 3.19, being closest to the Likert-type scale label “neither disagree or agree” and the post-program mean value was 4.62, being closest to the Likert-type scale label “strongly agree.”

**Discussion**

Education related to genetics/genomics competency statements was successfully delivered online. Pharmacists and student pharmacists alike perceived increased competency across domains related to genetics/genomics. The PGx program covered competencies across 4 domains, with an emphasis on PGx. As competencies related to pharmacogenetics/pharmacogenomics are related to other pharmacist practice domains (eg, pharmacokinetics), it is not surprising that this domain showed the greatest increase in perceived competency overall and for each subgroup. Competency statements related to PGx are almost exclusively found in the pharmacist competency set as compared with other health care provider competency sets. As education in genetics/genomics and PGx in particular was lacking in pharmacy education, it is not unexpected that a training program would increase competency knowledge.6 The genetics/genomics competency center (G2C2) provides competency sets for pharmacists, physicians, physician assistants, nurses, and genetic counselors.8 Across these health care provider groups, competency statements are most similar when considering ethical, legal, and social implications (ELSI).
This likely speaks to the broader education related to patient care, confidentiality, and privacy. Interestingly, overall, the ELSI domain with the largest “shift,” based on the mean value, was related to the competency statement, “I can confidently identify the need to refer a patient to a genetic specialist or genetic counselor.” The PGx program emphasized the role of the pharmacist in PGx, including when to refer patients. This, along with increased interprofessional education in pharmacy education and pharmacists being more integrated in patient care, may have influenced responses.\textsuperscript{15,16} In further comparison of competency sets, PGx-related statements are found only for pharmacists and physicians. The pharmacists’ PGx competency statement (9-P1),

\begin{center}
I am confident to demonstrate an understanding of how genetic variation in a large number of proteins, including drug transporters, drug metabolizing enzymes, direct protein targets of drugs, and other proteins influence pharmacokinetics and pharmacodynamics relate to pharmacologic effects and drug response.
\end{center}

connects directly to PK and PD, subject matter that is a core component in pharmacy education, having been a standard component of professional degree programs for decades.\textsuperscript{17,18} Statement 10-P2, “I have a good understanding of the influence (or lack thereof) of ethnicity in genetic polymorphisms and associations of polymorphisms with drug response,” relates to pharmacy curricular content that was likely more recently included as mandated by ACPE, starting in July 2016.\textsuperscript{7} The
journal.com/meded/2012/11/article_11-P3.html

Figure 2. Student pharmacist percent of respondents relative to 5-point Likert-type scale labels pre- and post-genetics/genomics/pharmacogenomics competency certificate training program. Competency domains: (B) Basic Genetic Concepts; (G) Genetics and Disease; (P) Pharmacogenetics/Pharmacogenomics; and (E) Ethical, Legal, and Social Implications.

final statement (11-P3) in the “pharmacogenetics/pharmacogenomics” domain, “I can confidently recognize the availability of evidence-based guidelines that synthesize information relevant to genomic/pharmacogenomic tests and selection of drug therapy (e.g., Clinical Pharmacogenomics Implementation Consortium, or CPIC),” corresponds to the emphasis on the use of evidence-based guidelines in pharmacy education.19 Physician competency statements related to PGx include more general contexts, eg, “Discuss pharmacogenomics implications for future health,” “Treat the patient who has the disease, i.e., be aware of the patient’s needs as an individual who also has a genetic disease or pharmacogenomic variation,” and “Be familiar with the available databases and resources relevant to genetic variation, including ongoing clinical trials involving patients with genetic disorders, pharmacogenomics, and patient-oriented Internet resources from reliable organizations,” being appropriate for this discipline.8,20

Pharmacogenomics education in pharmacy has been expanding in recent years, with professional and academic certificate programs being offered, as well as advanced pharmacy practice opportunities for students.7,10–12,21 Also, pharmacy residency opportunities exist post-graduation.22 In addition, dedicated graduate programs in pharmacogenomics are an option for advanced training in PGx.23,24 Although education in the traditional sense is expanding, these efforts reach relatively few professionals and health professions students.
Approaches to expanding PGx education, whether competency-based, knowledge-based, or other, must be explored to identify ways to reach a broader audience and therefore expand opportunities to improve patient care by optimizing drug regimens based on genetic variations.

While this study showed that online delivery of PGx competency education can be successful, this study did not assess actual competency. It has been shown that self-perceived competency by medical students does not translate to actual competency as related to writing prescriptions. However, this study was intended to evaluate the education of individuals relative to the competency statement and assess their self-perceived competency. Introducing student pharmacists and pharmacists to the competency statements is intended to lead to recognition of professional responsibilities in the application of PGx.

One limitation to the online delivery is the lack of a direct experiential component where standardized patients can be employed to provide experience through simulated clinical decision-making utilizing pharmacogenomic data. Also, the PGx program here emphasized pharmacist-related material more so than subject matter related to other disciplines, eg, genetic-related disease risk. A broader online offering would likely reach an interprofessional population, thus further enforcing the team approach to patient care. Participants went through the program at different times and the time to complete the program varied among the participants. The pre- and post-program surveys were taken at different times and during

Figure 3. Pharmacist percent of respondents relative to 5-point Likert-type scale labels pre- and post-genetics/genomics/pharmacogenomics competency certificate training program. Competency domains: (B) Basic Genetic Concepts; (G) Genetics and Disease; (P) Pharmacogenetics/Pharmacogenomics; and (E) Ethical, Legal, and Social Implications.
this time, the participants may have been exposed to other PGx information. This could have influenced/biased the results. Baseline pharmacist knowledge was not assessed and therefore some participants may have had some prior PGx knowledge.

Finally, this was an acute study and the long-term effect of the training program has not been assessed and is unknown.

Conclusions
In conclusion, we described the successful online delivery of a pharmacogenomics certificate training program that expands access to genetics/genomics/PGx competency education in an effort to improve patient care by optimizing the safety and efficacy of medications based on genetic factors. Other programs for pharmacists are now being offered and further programs need to be developed to address the PGx education gap for other health care providers, health professions students, and the public.

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Author Contributions
DFK and CLF planned the research. DFK collected the data and wrote the results. DFK and CLF wrote the remainder of the paper.

REFERENCES
1. McGrath SE, Gheri D. Building towards precision medicine: empowering medical professionals for the next revolution. https://bmcmedgenomics.biomedcentral.com/articles/10.1186/s12920-016-0183-8. Accessed January 9, 2019.
2. Abbasi J. Getting pharmacogenomics into the clinic. JAMA. 2016;316:1533–1535.
3. Lu M, Lewis CM, Traylor M. Pharmacogenetic testing through the direct-to-consumer genetic testing company 23andMe. http://biorxiv.org/content/early/2017/01/05/099841.full.pdf+html. Accessed January 9, 2019.
4. Johansen TKA, Dickinson BD. Pharmacogenomic knowledge gaps and educational resource needs among physicians in selected specialties. Pharmacogenomics Pers Med. 2014;7:145–162.
5. McCullough KB, Formea CM, Berg KD, et al. Assessment of the pharmacogenomics educational needs of pharmacists. Am J Pharm Educ. 2011;75:51.
6. Roederer MW, Ripper MV, Valgus J, Knaut G, McLeod H. Knowledge, attitudes and education of pharmacists regarding pharmacogenetic testing. Pers Med. 2012;9:19–27.
7. Accreditation Council for Pharmacy Education. Accreditation standards and key elements for the professional program in pharmacy leading to the doctor of pharmacy degree. https://www.acpe-accredit.org/pdf/Standards2016FINAL.pdf. Accessed January 2, 2018.
8. Genetics/Genomics Competency Center. Pharmacist competency map. http://genomicscc.org/competency/pharmacist. Updated 2015. Accessed January 2, 2018.
9. Roederer MW, Kuo GM, Kisor DF, et al. Pharmacogenomics competencies in pharmacy practice: a blueprint for change. J Am Pharm Assoc. 2017;57:120–125.
10. RxGenomix to offer a training program in pharmacogenomics. American Pharmacists Association. https://www.pharmacist.com/press-release/rxgenomix-offer-training-program-pharmacogenomics tu_suo_called=1. Accessed January 9, 2019.
11. University of Florida pharmacogenomics certificate program for pharmacists. http://pharmacy.ufl.edu/2016/03/15/inaugural-precision-medicine-conference-spotlights-rapidly-expanding-field-of-pharmacogenomics-in-clinical-practice/. Updated January 2, 2018. Accessed July 17, 2018.
12. University of Colorado pharmacogenomics certificate program. http://www.ucdenver.edu/academics/colleges/pharmacy/AcademicPrograms/ContinuingEducation/CertificatePrograms/PGXCertificate/Pages/PGXcert.aspx/. Updated January 2, 2018. Accessed May 19, 2018.
13. Kisor DF, Bright DR, Chen J, Smith TR. Academic and professional pharmacy education: a pharmacogenomics certificate training program. Pers Med. 2015;12:563–573.
14. Kisor DF, Kane MD, Talbot JT, Sprague JE. Pharmacogenetics, Kinetics and Dynamics for Personalized Medicine. 1st ed. Burlington, MA: Jones & Bartlett Learning; 2013.
15. Boone J, Brock T. Interprofessional education in a pharmacy context: global report. International Pharmaceutical Federation. https://www.fip.org/files/fip /PharmacyEducation/1P_ED_report/FIPED_1PE_report_2015_web_v3.pdf. Accessed January 9, 2019.
16. Quesnelle KM, Bright DR, Salvatici LA. Interprofessional education through a telehealth team based learning exercise focused on pharmacogenomics. Curr Pharm Teach Learn. 2018;10:1062–1069. https://doi.org/10.1016/j.cptl.2018.05.015. Accessed January 9, 2019.
17. Wagner JG. History of pharmacokinetics. Pharmaco Ther. 1981;12:537–562.
18. Knoer SJ, Eck AR, Lucas AJ. A review of American pharmacy: education, training, technology, and practice. J Pharm Health Care Sci. 2016;2:32.
19. Brown DL. Rethinking the role of clinical practice guidelines in pharmacy education. Am J Pharm Educ. 2015;79:148.
20. Bruce R, Korf BR, Berry AR, et al. Framework for development of physician competencies in genomic medicine: report of the Competencies Working Group of the Inter-society Coordinating Committee for physician education in genomics. Genet Med. 2014;16:804–809.
21. Wetzel KWW, Aqualine CA, Johnson S. Educational strategies to provide pharmacogenomics-based care. Am J Health Syst Pharm. 2016;73:1986–1998.
22. American College of Clinical Pharmacy. Directory of residencies, fellowships, and graduate programs. https://www.accp.com/resandfel/. Accessed January 9, 2019.
23. Manchester University. Master of science degree in pharmacogenomics. https://www.manchester.edu/pgx. Accessed January 9, 2019.
24. Shenandoah University. Master of science in pharmacogenomics & personalized medicine. https://www.su.edu/pharmacy/programs/ms-pharmacogenomics-precision-medicine/. Accessed January 9, 2019.
25. Brinkman DJ, Tichelaar J, van Agtmaal MA, de Vries TPGM, Richir MC. Self-reported confidence in prescribing skills correlates poorly with assessed competence in fourth-year medical students. J Clin Pharmacol. 2015;55:825–830.