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# Pharmacogenomics workshop: a mixed methods evaluation of trainee pharmacist knowledge and skill development, and workshop facilitator needs

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## Abstract

**Objectives:** This study evaluated the impact of a pharmacogenomics (PGx) workshop on UK trainee pharmacists' knowledge, confidence, and application of PGx to simulated cases. The study also examined the experiences and support needs of workshop facilitators.

**Methods:** A mixed-methods design was employed, including surveys of workshop participants and focus groups (FGs) with workshop facilitators. Quantitative data were analyzed using descriptive statistics and paired *t*-tests, while qualitative data from FGs were thematically analyzed.

**Key findings:** A total of 229 trainee pharmacists attended one of five workshops. Of these, 199 completed the pre-workshop survey, and 157 completed the post-workshop survey. Pre-, post-workshop surveys indicated a significant increase in self-reported knowledge of PGx ( $P < .01$ ) and an increase in the confidence to apply this knowledge in clinical practice, although not statistically significant ( $P = .06$ ). Workshop facilitators identified challenges related to participant engagement, especially in online settings, and expressed a need for more comprehensive preparatory materials and technical support. Despite these challenges, the workshops were well-received, with participants appreciating the interactive format and case studies which incorporated pharmacogenomic results.

**Conclusions:** The findings show that a PGx workshop effectively enhanced trainees' knowledge but revealed ongoing gaps in their ability to apply this knowledge clinically. Facilitator feedback highlights the need for improved training and resources to support effective delivery, particularly in online environments. Iterative sessions and additional supportive materials are recommended to consolidate learning and application of PGx in clinical practice.

**Keywords** education; pharmacogenomics; clinical pharmacy < clinical practice; workforce < professional

## Introduction

Pharmacogenomics (PGx) is the study of how genetic variation influences the response to medicines, both in terms of medicine effectiveness and likelihood of adverse effects [1]. PGx is based on an understanding of how natural genetic variation can affect pharmacokinetics (what the body does to the drug) and pharmacodynamics (what the drug does to the body). Leveraging PGx information alongside other clinical factors can help guide dose

and selection of a medicine, increasing the probability that individuals receive the most effective medicine for them, at the most appropriate dose, the first time they are treated [1].

Although robust evidence-based recommendations for multiple gene–drug pairs are available, widespread adoption of PGx testing in the United Kingdom (UK) is limited to specific examples (e.g. *DPYD*, *TPMT*, *NUDT15*, *HLA-B\*57:01*, *MT-RNR1*, *CYP2C19*), and thus PGx remains relatively novel for most practicing healthcare professionals [2]. However, the “Fit for the future: 10 Year Health

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Plan for England” sets out the ambition of extending pharmacogenomic testing and integrating into everyday healthcare [3]. “*Pharmacogenomics will be integrated into routine clinical practice. Pre-emptive testing and integration with the Single Patient Record will optimise medication effectiveness for individual patients and prevent adverse drug reactions that cause patients harm and cost the NHS up to £2.2 billion per year.*”

Pharmacists, as medicine experts, are well equipped to play an integral part in the development of PGx, from system leadership to implementation of services [4, 5, 6]. Despite this, PGx is an emerging topic within pharmacy education in the UK, with limited integration into existing training pathways. A recently published survey of UK-based pharmacists indicated a lack of confidence in applying PGx clinically and cited a desire for guidelines and increased PGx education [7]. Similar findings have been reported in a 2022 survey of pharmacy staff assessing education and confidence in genomic medicine more broadly, with only 13% of the 1552 respondents having received formal training in genomics [8]. This work suggests that there is a growing need to develop and evaluate PGx educational interventions for pharmacists, to ensure they are confident and competent in this evolving area.

Developing PGx education, which is timely, relevant, up-to-date, concise, and effective, is essential to overcoming adoption barriers [9–12]. Internationally, PGx programs have utilized a variety of educational methods to support proactive and reactive learner types, to varying success [11]. Approaches to PGx education include didactic teaching, point-of-care prescribing support software, online modules, workshops, experiential, case-based, and blended learning [9, 13–17]. PGx education programs from institutions in the United States with established PGx services have cited the value of delivering PGx education focused on competencies and aligned to “real world” clinical application to support with knowledge retention over time [14]. Literature also highlights the importance of PGx training for educators, with educators serving as trainers for students, and healthcare professionals in post-registration education programs and continuing professional development [18, 19].

At this time, there is limited research on pharmacist PGx education in the UK context. Furthermore, understanding the effectiveness of different training models is critical to informing the development of a comprehensive PGx educational offer and enabling the implementation of widespread PGx services.

In this study, we aim to evaluate the impact of a PGx workshop on UK trainee pharmacists’ knowledge, confidence, and application of PGx to simulated cases. The study will also examine the experiences and support needs of workshop facilitators.

## Methods

### Design

Mixed methods have been used in this study, where survey data was collected from participating trainees in parallel to focus group (FG) data collection from workshop facilitators across March–May 2024. A contiguous approach to integrating data at the interpretation and reporting level was adopted, where the findings of each data collection point will be reported in different sections [20]. The Consolidated Criteria for Reporting Qualitative Studies Checklist (COREQ) [21] has been used to inform the reporting of the FG.

## Intervention

A national project team of educationalists ( $n = 3$ ) and PGx subject specialists ( $n = 2$ ) convened to discuss the content and design of the workshop. The educational intervention comprised of two e-learning modules completed in advance of the workshop, focused on genomics in the healthcare context and genomics in pharmacy practice. These were followed by a three-hour interactive workshop that began with a survey including seven multiple-choice questions (MCQs) based on the online content. Each workshop was delivered by the two workshop leads and 4–5 facilitators based in the North of England. The workshop leads were specialist pharmacists in genomic medicine. The facilitators were educational staff working in Genomic Medicine Service Alliances and Schools of Pharmacy and Medicines Optimisation. The workshop included didactic presentations and two structured patient case studies featuring a patient with pharmacogenomic results, which attendees worked through in small groups. The same MCQs were administered at the end of the session, along with additional case-based questions designed to assess the workshop learning outcomes. The workshop educational elements are displayed in [Table 1](#), and further details of the case studies are available from the corresponding author upon reasonable request.

An invitation to attend one of five workshops was circulated to 235 trainee pharmacists employed in the National Health Service (NHS) in the North of England (either the North West or North East and Yorkshire administrative regions of England), by the respective teams in the NHS England Workforce, Training and Education School of Pharmacy and Medicines Optimisation (NHSE WTE SoPMO). There was a range of dates for the delivery of five workshops, with one being offered in-person and four online.

Participation in the study was based on an opt-out consent approach. Those who signed up to a workshop were emailed an outline of the workshop, indicating pre-workshop exercises, the study participant information sheet, and provided with a link to opt out of the study if they did not wish their data to be included in the research.

An email to recruit workshop facilitators was circulated to educational staff working in Genomic Medicine Service Alliances and NHSE WTE SoPMO across the North of England.

Facilitators were provided with a facilitator guide and were briefed about the workshop in an online session 2–4 weeks before the workshop.

### Pre/post-workshop survey

A survey was conducted to evaluate changes in participant knowledge, confidence, and application of PGx to simulated cases before and after the workshop ([Supplementary Material 1](#)). These incorporated self-administered questionnaires used as data collection tools, comprising demographic questions, self-reported knowledge and confidence questions using a Likert scale 1–5 (1 = strongly disagree, 5 = strongly agree), and a series of MCQs informed by the pre-workshop online learning packages and the workshop material. Five of the MCQs were knowledge-based, and two required the workshop participants to apply their knowledge to case-based scenarios. These questions were adapted from existing educational packages developed for pharmacists and healthcare professionals, i.e. online learning developed by the Centre for Pharmacy Postgraduate Education and The NHS England Genomics Education Programme (these are

**Table 1** Workshop educational elements, including pre-work, assessments and learning outcomes.

Timing of educational elements	Nature of the educational elements	Learning outcomes
<b>Before the session (2 hours 30 mins)</b>	<p>Online learning packages:</p> <p><b>1. Genomics 101—genomics in healthcare</b></p> <p>Description: a short online course about the fundamental principles of genomics and the applications in healthcare.</p> <p>Education provider: Genomics Education Programme</p> <p>Completion time: 30mins</p> <p>Available at: <a href="https://www.genomicseducation.hee.nhs.uk/education/online-courses/genomics-101-genomics-in-healthcare/">https://www.genomicseducation.hee.nhs.uk/education/online-courses/genomics-101-genomics-in-healthcare/</a></p> <p><b>2. Introduction to genomics in pharmacy</b></p> <p>Description: online learning program to provide an introduction to genomics and PGx, and to highlight the opportunities of their application to the provision of person-centered care.</p> <p>Education provider: Centre for Pharmacy Postgraduate Education</p> <p>Completion time: 2 hours</p> <p>Available at: <a href="https://www.cppe.ac.uk/programs/l/genomics-e-01">https://www.cppe.ac.uk/programs/l/genomics-e-01</a></p>	<ol style="list-style-type: none"> <li>1. To explain what a genome is and where it is found.</li> <li>2. To describe the role of genomics and PGx in the healthcare context.</li> <li>3. To list appropriate genomic medicine supporting resources.</li> </ol>
<b>Beginning of the workshop (10 mins)</b>	Readiness MCQs test.	Assess learning outcomes 1–3 covered in the before session online learning.
<b>Within the workshop (3 hours)</b>	Didactic presentation, supported navigation of clinical guidelines and resources, plus two structured patient case studies.	<ol style="list-style-type: none"> <li>4. To describe the concept of star allele nomenclature in PGx.</li> <li>5. To develop PGx communication skills.</li> <li>6. To apply clinical guidance in the context of a case study with pharmacogenomic results.</li> </ol>
<b>End of the workshop (10 mins)</b>	Repeated MCQ test plus additional case-based questions that assessed knowledge, application, and patient counseling.	Assess learning outcomes 1–6.

freely available with appropriate registration and logins but are copyright protected).

The pre/post-workshop surveys were deployed at the start of the workshop after a brief introduction by the workshop leads and again at the end of the workshop. The post-workshop version of the survey included additional case-based questions covering content delivered only during the workshop that tested knowledge (part a), application of knowledge (part b), and patient counseling (part c). The final section of the post-workshop survey also included feedback questions on the design and delivery of the workshop using free text boxes against the following questions:

- Please tell us what you think went well with this workshop?
- Please tell us what you think did not go so well?
- How could this workshop be improved?
- Can you provide any further feedback on this workshop?

Workshop participants were provided with a quick response (QR) code or direct link to the online survey and provided 10 minutes to complete and submit it electronically. Only answers of those who had not opted out of the study were included in the study data collection and analysis.

Quantitative data was descriptively analyzed. For respondents who completed both pre- and post-workshop surveys, responses were statistically analyzed using paired t-tests to investigate

impact on knowledge, confidence, and application of knowledge at the individual level. Free text boxes were analyzed using content analysis [22].

The pre/post workshop surveys were designed and tested by educationalists ( $n = 3$ ) and subject matter specialists ( $n = 2$ ).

### Focus groups

A FG topic guide (Supplementary Material 2) was developed to investigate the experience of the workshop facilitators, understand the barriers and facilitators to this mode of delivery, and identify training and resource requirements to enhance successful workshop facilitation. The topic guide was a series of prompts relating to these points of interest, but was otherwise flexible, and dialogue was responsive to the discourse of the FG. The discussion was facilitated by a researcher independent to the educational intervention.

All (17) workshop facilitators were emailed an invitation to participate in an online FG after their workshop. This included a participant information sheet, an electronic consent form, and a poll to find a mutually agreeable time to conduct the FG. Three FGs were arranged where a minimum of four facilitators could attend.

FGs were conducted using Microsoft Teams, where the recording and transcription functions were employed. Transcripts

were checked and revised for accuracy whilst watching the recording. Transcripts were then thematically analyzed by the researcher independently according to the stages outlined by Braun and Clarke [23]. Both inductive and deductive coding were employed, where the broad topic guide informed initial deductive coding, and inductive coding ran alongside to draw out additional information and themes.

## Ethics approval

This study received ethical approval through the Newcastle University institutional ethical committee, 25 February 2024 (Reference: 43394/2023).

## Results

### Intervention

Two hundred twenty-nine out of 235 trainee pharmacists attended one of five workshops across the iterations.

### Survey

Of the 229 individuals who attended one of five workshops, two individuals formally opted out of the study, leaving 227 study participants.

### Pre-/post-workshop self-reported knowledge and confidence of genomics and PGx

The pre-workshop questionnaire for self-reported knowledge and confidence of genomics and PGx received 199 responses, representing a response rate of 88% (199/227), and the post-workshop questionnaire received 157 responses, representing a response rate of 69% (157/227). Demographic information for respondents is presented (Supplementary Material 3).

Workshop participants reported a statistically significant increase in self-reported confidence about their knowledge of genomics and PGx ( $P < .01$  and  $P < .01$ ) after the workshop when analyzed using the paired t-test. Although the participants' confidence in applying this knowledge to provide patient care had improved post-workshop, it was not statistically significant ( $P = .06$ ). Participants' desire to improve their knowledge and application of PGx was high both pre-and post-workshop (there was a statistically significant ( $P < .01$  and  $P < .05$ ) decrease in this desire post-workshop). Participants thought it was important to develop their PGx knowledge and that PGx will be increasingly important for patient care (there was a statistically significant ( $P < .01$  and  $P < .05$ ) increase in these statements) (Table 2).

### Pre-/post-workshop knowledge and application

The pre-workshop MCQ received 205 responses, representing a response rate of 90% (205/227), and the post-workshop MCQs received 166 responses, representing a response rate of 73% (166/227) (Table 3).

The paired t-test analysis shows that the answers to questions 1, 2, 4, 6, and 7 (knowledge questions on the human genome, cancer genomics, PGx reference sources, and a question on application of PGx to fluoropyrimidines) significantly improved post-workshop ( $P < .05$ ,  $.05$ ,  $.01$ ,  $.01$ , and  $.05$ , respectfully). Whereas answers to questions 3 and 5 (a knowledge question on the human genome

and on the application of PGx to carbamazepine) improved without any statistical significance ( $P = .10$  and  $P = .21$ ) (Table 3).

On the additional case-based question in the post-workshop questionnaire, participants scored 49.6%, 72.7%, and 50.4% across knowledge, application of knowledge, and patient counseling, respectively.

## Workshop feedback

The themes generated from analyzing the survey open text boxes, aiming to capture feedback on what went well, what did not go well, and areas of improvement, are displayed in Table 4 with some example statements. Feedback from participants indicated that the session was informative and well organized, with respondents particularly valuing the interactive format and patient cases, studies that provided a real-world context. However, some found the content very complex and reported difficulties navigating unfamiliar resources, as well as feeling that parts were rushed due to time constraints and minor technical issues online. Suggested improvements included incorporating more case-based examples, increasing opportunities for small group engagement, extending the session duration or multiple sessions, and providing a resource pack with additional materials.

## Focus group

Three FGs were conducted across March–May 2024 and were attended by 14 facilitators (P) (FG 1 and FG 2 included five facilitators, and FG 3 included four).

Thematic analysis generated some themes that were directly related to the challenges and enablers faced by facilitators, potential recommendations for improving the workshop, how the group dynamic between participants impacted the workshop experience, and the general approach of facilitators toward their role.

### Theme 1: preparedness of participants and facilitators

The level of preparedness among participants varied, with some having done the pre-reading and others not. This affected their ability to engage meaningfully during the sessions. Ensuring that all participants come prepared was seen as a critical factor for the success of the workshop.

This was particularly problematic in online sessions where it was harder to ensure participants were following along with the materials.

*“It was crucial to do the pre-work to be able to fully engage with the workshop. Sometimes it seemed that they were so unprepared, and it was difficult to fix that in the session.”* (FG2, P4)

Facilitators expressed feelings of anxiety and being overwhelmed, especially those who felt underprepared or lacking in subject-specific knowledge. The emotional and cognitive load on facilitators was significant and affected their ability to effectively manage the sessions.

*“I felt a little anxious about delivering it as a non-specialist”* (FG1, P2)

*“I found it hard because the content was so unfamiliar and so difficult”* (FG2, P3)

**Table 2** Workshop participant self-reported knowledge and confidence of genomics and PGx.

Statement	Median (IQR) pre-workshop rating (n = 199)	Median (IQR) post-workshop rating (n = 157)	Paired t-statistic	P-value
I am confident in my knowledge of genomics	2.3 (1–4)	3.9 (2–5)	3.5	.001 <sup>a</sup>
I am confident in my knowledge of PGx	2.3 (1–3)	3.9 (2–5)	2.78	.007 <sup>a</sup>
I am confident in applying my knowledge of PGx to help provide patient care	2.1 (1–3)	3.9 (2–4)	1.9	.06
I would like to improve my knowledge of PGx	4.4 (2–5)	4.1 (1–4)	3.9	.0002 <sup>a</sup>
I would like to improve my ability to apply my knowledge of PGx to help provide patient care	4.5 (2–5)	4.2 (1–4)	2.5	.02 <sup>a</sup>
I think it is important to develop my knowledge about PGx	4.3 (2–5)	4.5 (1–4)	3.0	.004 <sup>a</sup>
I think PGx will play an increasing role in patient care	4.4 (2–5)	4.7 (1–4)	2.3	.03 <sup>a</sup>

IQR: interquartile range <sup>a</sup>Indicates statistical significance

**Table 3** Participant responses to the MCQs pre- and post-workshop: Percentage of correct answers and paired t-test results for individual responses.

Question	Correct answers pre-workshop (n = 205) (n,%)	Question topic	Correct answers post-workshop (n = 166) (n,%)	Paired t-statistic	P-value
1 (K)	167 (81.5)	The human genome	151 (91.0)	2.3	.02 <sup>a</sup>
2 (K)	198 (96.5)	The human genome	163 (98.1)	2.2	.03 <sup>a</sup>
3 (K)	177 (86.3)	The human genome	157 (94.6)	1.7	.10
4 (K)	153 (74.6)	Cancer genomics	129 (77.7)	3.1	.005 <sup>a</sup>
5 (A)	163 (79.5)	PGx of carbamazepine	148 (89.2)	1.2	.21
6 (K)	99 (48.3)	PGx reference sources	141 (84.9)	3.0	.008 <sup>a</sup>
7 (A)	98 (47.8)	Fluoropyrimidine PGx	103 (62.0)	2.6	.01 <sup>a</sup>

K, knowledge-based question; A, application of knowledge-based question <sup>a</sup>Indicates statistical significance

The pre-session training and resources provided to facilitators helped to some extent in preparing them for their roles. This training helped alleviate some of the initial anxiety and provided a framework for facilitating the sessions.

*“The pre-session did make me feel better about what I was expected to do and the support materials were really good.”* (FG1, P4)

Facilitators suggested additional training to deepen their understanding of genomics, which would boost their confidence and ability to handle difficult questions or disengaged participants. Providing recordings of background information and key genomic concepts could help facilitators review and prepare more thoroughly.

*“More training would help, especially for difficult situations where students are not engaged”* (FG1, P2)

Facilitators suggested the creation of a comprehensive facilitator guide with explicit answers and a step-by-step process to follow during the workshop. Including worked examples and simulations could help both facilitators and participants understand the material better.

*“Having a comprehensive facilitator guide would be beneficial. And a workbook for participants might make it more seamless.”* (FG1, P2)

## Theme 2: technical workshop constraints

Facilitators encountered challenges related to technical aspects of online workshop, such as managing breakout rooms, screen sharing, and navigating online resources. These technical hurdles often disrupted the flow of the session and added to the facilitators' stress.

*“We did have a few teething issues with using the online version, it was just about trying to work out how best to tackle the activities and signpost to resources and talk through them”* (FG2, P2)

Simplifying the technical aspects of the sessions or providing additional technical support could alleviate some of the burden on facilitators. This could include dedicated technical staff to manage breakout rooms and other online tools.

*“Technical support for managing breakout rooms would be helpful”* (FG1, P3)

Time limitations within the sessions posed a challenge, especially for addressing the needs of participants who were struggling. Facilitators felt that more time would have been beneficial for thorough engagement and support.

*“Sometimes, there wasn't enough time, like in the breakout rooms. That made it difficult because you didn't get time to go to the person that was maybe struggling”* (FG1, P3)

**Table 4** Themes and participant quotes from the open text feedback post-workshop (identifier: WS1 = respondent from workshop 1).

What went well	Example statements	What went not so well	Example statements	Areas for improvement	Example statements
<b>Inclusion of engaging case studies to apply knowledge</b>	<i>"Good number of activities that relate to genomics and a good number of case studies that helped reiterate how this can help patients in a practical sense."</i> (WS 2)	A lot of new, complicated information was covered	<i>"We received quite a lot of information in a short space of time that we had to digest quite quickly."</i> (WS 3)	More cases to practice further application of knowledge	<i>"Maybe do more cases or challenging cases or maybe how it [PGx] might be used in other cases"</i> (WS 4)
<b>Informative, well-explained, and relevant content</b>	<i>"Workshop was well run and relevant to our training year."</i> (WS 1)	Some of the background information was boring and/or confusing	<i>"The initial talking phase of being taught was a bit tedious."</i> (WS 1)	More encouragement/requirement for engagement in breakout rooms	<i>"Cohesion the breakout rooms, need more interaction."</i> (WS 3)
<b>Well-organized and supportive facilitation</b>	<i>"Very interactive- I liked how we had a supervisor in each breakout room."</i> (WS 4)	Challenging to navigate the unfamiliar resources	<i>"I didn't really understand the guidelines and the relevance of looking at them for practice."</i> (WS 2)	Longer session to undertake all activities and facilitate understanding	<i>"Make the sessions longer with more case studies; it's an important topic and we need more time."</i> (WS 3)
<b>Very interactive format with group activities</b>	<i>"Felt I was able to speak to others in my group and discuss answers and problem solve."</i> (WS 3)	Rushed pace, which limited understanding	<i>"Time given to undertake tasks was too short."</i> (WS 1)	More support to navigate guidelines and resources	<i>"More explanation and better signposting of the resources and the relevant information."</i> (WS 5)
<b>Useful contextual information about genomics and relevance to pharmacy</b>	<i>[the workshop] "gave an insight into how genomics plays a role in healthcare and how it can help make decisions regarding medicines."</i> (WS 5)	Limited engagement and technical issues with breakout rooms (online)	<i>"The breakout rooms were quite large, so people were intimidated to discuss, lack of involvement from some team members."</i> (WS 2)	Resource pack to support pre- and post-workshop activities and include all necessary resources	<i>"A resource pack with the tables to look at and patient cases to refer to, as felt rushed for time finding the tables with the information on and then didn't have enough time to discuss."</i> (WS 5)
<b>Helpful signposting to useful resources</b>	<i>"Explaining resources that can be used to see how testing can impact clinical decisions."</i> (WS 1)			More in-depth explanation of background information and answers to the case studies	<i>"Would have been useful to work through an example all together before being put into breakout rooms."</i> (WS 3)

### Theme 3: group dynamics impacting the workshop experience

There was a noticeable variation in group dynamics, with some groups of participants being more engaged and interactive than others. Facilitators observed that certain groups naturally participated more, whereas others were significantly quieter, which influenced the overall workshop experience.

*"Some groups naturally interacted more than others and this meant the activities were easier to facilitate, and you felt you could observe them learning something."* (FG2, P3)

Facilitators suggested that, if feasible, it would be good to group participants who know each other, which could foster more comfortable and interactive group dynamics.

*"If you have trainees that really don't know each other... they just won't talk. It would be better to put the students that know each other in a group."* (FG1, P3)

Some facilitators recommended that stronger buy-in from the trainee workplace would have supported better engagement of participants. If participants were being actively supported and encouraged by their workplace, they would have been given the opportunity to attend in person, or a better environment, and more time to dedicate to the workshop and associated education.

*"It was obvious that some of the participants had not really had much support from their site to engage in the session."* (FG2, P3)

Clear and detailed communication about the workshop's format, expectations, and the level of participation required from both facilitators and participants could help set the right tone and prepare everyone involved for a more productive session.

*"Making it very explicit... you are going to be expected to have cameras on and be engaging"* (FG1, P2)

Some facilitators noted the benefit of peer learning and support, where participants helped each other understand the materials.

Encouraging this peer interaction was seen as beneficial, especially in overcoming challenges related to difficult content.

*“Participants often helped each other understand difficult concepts, so I tried to encourage peer interaction as much as possible.”* (FG2, P4)

Facilitators noted a preference for face-to-face sessions due to better engagement and interaction. Balancing the delivery of online and face-to-face workshops, or even prioritizing face-to-face sessions where possible, could improve the overall effectiveness of the workshop.

*“I would love to try and do it again in a face-to-face setting. I can imagine you get a different experience as a participant and as a facilitator. Given the level of interactivity, this is really appropriate for in-person sessions.”* (FG1, P2)

#### Theme 4: facilitator approach to workshop content and facilitation

Facilitators highlighted the need for flexibility in their facilitation style to adapt to the varying levels of participant engagement and understanding. This included being able to switch between different methods of delivery and interaction based on the group's needs.

*“I had to switch between different methods to keep the participants engaged. So, at times I was quite ‘teachy’ and then I would try to draw them into discussions by posing questions and ‘what if’ type scenarios.”* (FG2, P3)

Facilitators found the initial setup and introduction phase was deemed crucial for setting the tone of the workshop. Facilitators who used icebreakers or initial informal chats found it helped in making participants more comfortable and willing to engage.

*“Using icebreakers made participants more comfortable and willing to engage”* (FG2, P3)

There was a discussion around the balance between structured activities (like specific tasks and role plays) and unstructured time for discussion. Facilitators noted that too much unstructured time could lead to disengagement, whereas well-structured activities helped maintain focus and progress.

*“Well-structured activities helped maintain focus, as too much unstructured time led to disengagement.”* (FG2, P4)

Facilitators stressed the importance of being able to link the workshop content to real-world professional practice. They felt that participants were more engaged when they could see the practical application of the concepts being taught.

*“Participants were definitely more interested when they saw practical applications”* (FG3, P4)

Previous experience in facilitation and teaching, whether online or face-to-face, was beneficial. Facilitators who had such experience found it easier to manage the dynamics of the workshop and engage participants effectively.

*“Previous experience in online education helped. I was familiar with how to work the tech and getting people to engage.”* (FG2, P5)

## Discussion

The key findings of this study show that a facilitated PGx workshop, supported with pre-workshop activities, can improve trainee pharmacist knowledge, confidence, and application of PGx to simulated cases. Participants self-reported increased confidence in their PGx knowledge and desire for further development to increase their confidence in applying this knowledge to clinical practice. Participants demonstrated some improved knowledge and application of knowledge in a pre-/post-workshop questionnaire, but results evidenced the need for further education and training.

Overall, feedback from participants was largely positive, highlighting the interactive format and relevant case-based learning. However, some participants found the content complex and experienced challenges with time, navigating new resources and technical issues with online delivery. Suggestions for improvement included more cases, extended sessions, and access to more supporting educational resources. Participants had mixed views on whether the sessions were engaging that appeared to be influenced by online or in-person delivery. This range of views was also reflected in the facilitator FGs.

Furthermore, this study identified that workshop facilitators experienced challenges with managing online delivery and tackling material that some felt was outside of their expertise, which could be addressed with additional preparatory materials and technical support.

## Strengths and limitations

This study is supported by its mixed method approach to understand impact and perceptions of this workshop on participants and facilitators. The study could be further strengthened through more in-depth investigation of participant experience and feedback through one-to-one interviews or FGs, however the questionnaire was valuable to collect a sizeable amount of data across many aspects of impact and experience. The study is limited by conducting an evaluation of knowledge, confidence, and application immediately after the educational intervention. Future studies should incorporate an evaluation several months after the educational intervention to assess longer-term knowledge retention. This would provide valuable insight into the sustained impact of PGx education and application of knowledge in real-world settings. Moreover, as this study is based on an educational intervention piloted across North England, future research is needed across a broader geographical area to evaluate scalability and transferability of the intervention to other localities and settings.

## Context

Our findings are similar to those reported by Formea *et al.* [24], who also observed knowledge improvements following participation in a case-based PGx continuing professional development program but noted low overall retention among pharmacists. This suggests that a single educational intervention is insufficient to meet the knowledge and confidence needs of pharmacists in this topic area, and a series or module of education and training will likely be most appropriate. More broadly, a spiral educational approach to PGx education is needed, where key concepts and basic application are taught at undergraduate level, and then revisited and expanded upon in postgraduate education and the

workplace, where they can be integrated with pharmacist workflows [14, 25].

Overall, it is clear from the participant feedback and facilitator interviews that participants did not generally engage as well online as they did in person. This may have increased the demand and pressure on the teaching presence to nurture and support learning. Experienced facilitators, or those with expert knowledge, were better equipped to manage this demand, drawing upon their skills to enhance interaction with and between participants, e.g. ice breakers, discussion exercises, and/or offer didactic learning to the group. Similarly, establishing a peer group outside of the learning environment, either in a virtual or real-life capacity, could have better supported a social presence to drive the cognitive presence and bring the teaching presence into balance.

Literature suggests that there are many factors that influence whether online education will succeed or fail, and facilitator factors form part of this. A recent systematic review found that key barriers to medical educators' development and implementation of online learning were lack of skills, resources, institutional strategies and support, and attitude to online learning [26]. Our facilitators in this study referred to the value of facilitator skills, sufficient preparatory and supportive resources, and dynamic approach to facilitation. Similarly, another study exploring the satisfaction of staff and students with online learning found a combination of SWEET (study-load (for students), workload, enhancing engagement, and technical issues) themes influenced satisfaction [27].

Facilitators in the professional development environment have been identified as critical to support adult learning and development [28]. Facilitation in online environments has been classified as requiring a balance of three elements of interaction that occur between facilitators and learners online, through which learning can occur [29]:

- Cognitive presence: where participants' understanding, or content, is constructed through interactions with one another.
- Social presence: or the extent to which each participant contributes their personality, considered crucial to support cognitive presence; and
- Teaching presence: or facilitation, which involves the design and presentation of the content.

Facilitators would have valued a more thorough briefing and supportive facilitator materials and acknowledged that previous experience as a facilitator was helpful to remain dynamic and proactive within the workshop. There were some recommendations for potentially more planning around the workshop participants (e.g. establishing a peer working group before the workshop) and establishing ground rules for online engagement.

## Implications for policy, practice, and future research

This study highlights the importance of a sustained and well-supported educational offer in the topic area of PGx for pharmacists. Interventions to support educators should also be supported, especially if they lack subject matter expertise and feel deficient to support the teaching presence. These insights are valuable to healthcare leaders planning the implementation of PGx services as they highlight the need for investment in structured educational support, rather than relying on isolated training events.

Recommendations for future PGx workshop delivery include a more supportive package of education around this topic area, through structured pre-workshop activities, more opportunities for synchronous learning, and application of knowledge to more case studies. A post-workshop resource pack may also be useful to support and signpost to future learning and opportunities to apply knowledge in the workplace.

## Conclusions

PGx is a complex topic and an evolving area of contemporary practice. This study shows that a facilitated PGx workshop, supported with pre-workshop activities, improves trainee pharmacists' knowledge and confidence of PGx. There was also an increased ability of participants to apply this knowledge to simulated patient cases. However, deficiencies in knowledge, confidence, and application were still prevalent after this workshop. Access to more supportive materials and iterative workshop sessions that include clinical application could be helpful. Facilitators experienced challenges in directing these workshops related to technical issues, managing participant engagement, and lack of subject-specific knowledge, which should be addressed in future delivery. Moreover, as this study is based on an educational intervention piloted across the North of England, future research is needed across a broader geographical area to evaluate scalability and transferability of the intervention to other localities.

Overall, these findings highlight the importance of developing a robust PGx educational offer for pharmacists as PGx testing is increasingly integrated into routine practice, and to prepare pharmacists to interpret PGx results, advise the multidisciplinary team, and support patients.

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## Author contributions

Emma Groves (Conceptualization, Methodology, Writing—original draft, Writing—review & editing), Jessica Keen (Conceptualization, Methodology, Writing—original draft, Writing—review & editing), Samantha L. McLean (Conceptualization, Methodology, Writing—review & editing), Matthew E. L. Hardy (Conceptualization, Methodology, Writing—review & editing), Hamde Nazar (Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Writing—original draft, Writing—review & editing).

## Supplementary data

Supplementary data is available at *Journal of Pharmacy Practice* online.

## Conflict of interest

The authors declare that there are no conflicts of interest.

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## Data availability

Hamde Nazar had complete access to data as an independent evaluator.

## Data access statement

The materials supporting the findings of this study are available from the authors at reasonable request.

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