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Evaluation of the Master's in Genomic Medicine framework: A national, multiprofessional program to educate health care professionals in NHS England

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ABSTRACT

Purpose: Genomic medicine is revolutionizing health care but requires health care professionals to update their understanding of genomics and its application to clinical practice for successful implementation. To meet this need, Health Education England developed the Master's in Genomic Medicine, a national multiprofessional program to increase genomic literacy in the National Health Service workforce. This study summarizes an evaluation of the program, which will inform its future development.

Methods: Underpinned by Moore's evaluation framework, a mixed methods approach was used to characterize (1) learner demographics, (2) perceptions of the program, (3) knowledge and/or qualifications achieved, and (4) the outcome(s) for practice in the workplace.

Results: Learners were a diverse cohort of health care professionals, including doctors, health care scientists, nurses and midwives. Participant satisfaction was high for all elements of the program, including the curriculum, learning environment(s), and multiprofessional cohort(s), despite the challenges of engaging working professionals in part-time learning. Both learners and their managers reported enhanced genomic practice after completion of their studies.

Conclusion: The Master's in Genomic Medicine program is an effective approach to professional education in genomic medicine. This broad multiprofessional learning complements training aimed at specific groups of health care professionals.

Introduction

The need for a Master's program

New genomic technologies, including genome sequencing, are being integrated across health care, in which they are used for diagnostics and personalized treatment.[1,2] However, the adoption of genomic medicine requires substantive changes in health care practice, including increased multidisciplinary team working, integrating systems for the analysis and storage of genomic data into patient care, and developing policies to address the clinical and ethical issues that arise.[3-8] Of critical importance is the challenge of how to address the diverse training needs that arise in disparate health care systems.[9] A key aspect of this is increasing the genomic literacy of patient-facing professionals, who often lack up-to-date knowledge of genomics and/or confidence in applying this in clinical practice.[10,11] Surveys of the training need(s) of health care professionals highlight that genetics/genomics is not well developed in many professional degrees and that many feel their knowledge needs updating.[12-15]

Although updating professionals' genomic literacy is often addressed via continuous professional development (CPD) for doctors and nurses, education for other health care professionals may be less developed.[16-19] Furthermore, many updating programs focus on defined aspects of genomic practice (eg, oncogenetics), typically in the form of short workshops.[10,20-22] These are necessarily limited in scope and cannot update participants on broad areas of knowledge, allow in-depth engagement with ongoing research, or encourage reflection on how this can inform future practice.

The Master's program: Design, delivery, and advertising to learners

To meet this need for genomic literacy, National Health Service (NHS) England's Genomics Education Programme (previously part of Health Education England, HEE) developed the Master's in Genomic Medicine framework, a nationwide program of genomic education for NHS health care professionals that aims to (1) enhance learners' knowledge of genomic medicine and their ability to embed its application in practice and (2) encourage the formation of communities of practice to share knowledge and experience.[23-25] A particular consideration was that this broad-based genomics education should accommodate a wide range of health care professionals, given that multiprofessional working, where health care professionals belonging to different disciplines work together, is central to effective genomics-based care.[3,4] This approach has precedents, as multiprofessional training in clinical contexts where this form of working is established (eg, in chronic disease[26]; obstetrics[27]), is associated with improved patient care.

Table 1 Modules

Mandatory modules (Three modules and a research project are required for MSc qualification)
• Fundamentals in human genetics and genomics
• Omics techniques and technologies
• Bioinformatics, interpretation, and data quality assurance
• Research Project (30 Credits or 60 Credits)
Elective modules[a] (Minimum of 3 required for MSc qualification)
• Genomics of common and rare inherited diseases
• Molecular pathology of cancer and application in cancer diagnosis, treatment, and monitoring
• Pharmacogenomics and stratified health care
• Application of genomics in infectious disease
• Ethical, legal, and social issues in applied genomics
• Introduction to counselling skills used in genomic medicine
• Health economic evaluation in genomics

Learners have a choice of modules, some of which are required for a MSc qualification (Mandatory modules), but others can be tailored to learners' interests (Elective modules).

[a]Not all elective modules are delivered by all HEIs because these reflect the expertise within the institution. Learners may take 8 modules and a 60-credit research project or 10 modules and a 30-credit research project.

A detailed description of the program is available online.[28] The program is modular, allowing learners flexibility to enroll in modules as CPD, and subsequently commit to further study and a postgraduate qualification (Supplemental Table 1). Module topics cover broad themes in genomics (Table 1). Initially the curricula was developed as a collaboration between the Genomics Education Programme and a core group of 20 stakeholders, including clinical geneticists, health care scientists working in genomics, bioinformaticians, genetic counselors, and representatives from NHS England.

The revised curriculum also included input from educators who were delivering the curriculum at each of the higher education institutions (HEIs) listed in Table 2. These are located across England including the North of England, the Midlands, the South and 4 in London. Modules were designed to be completed within 4 to 6 weeks of part-time study and were accredited as postgraduate stand-alone courses that required 150 hours of learning. These were typically delivered using a blended learning approach, consisting of face-to-face teaching and online learning activities supported by digital learning resources. The program was initially delivered by 10 partner HEIs, later reduced to 7 (Table 2), which are directly funded by HEE (now NHS England).

Participation in program modules, up to and including obtaining a postgraduate qualification was free for eligible NHS employees who (1) had an appropriate undergraduate degree, (2) had capacity to undertake part-time study, and (3) were using or had the prospect of using genetics/genomics in their future professional practice. The full Master's program was also open to self-funding students who were not eligible for NHS scholarships. These students were typically recent graduates from a broad range of

Table 2 Learners' choice of educational institution (2015-2021)

Higher Education Institution	Student Enrollment	Proportion (%)
University of Newcastle[a]	68	4.4
University of Sheffield[a]	79	5.1
University of Southampton[a]	109	7.0
University of Manchester	144	9.2
Queen Mary, University of London	153	9.8
St George's/Kings College. University of London	163	10.5
University of Cambridge	187	12.0
Imperial College, University of London	201	12.9
University of Exeter	210	13.4
University of Birmingham	242	15.5
Total	1557	100

Learners were able to choose from HEIs across England. The table shows the number and percentage of learners registered at individual HEIs, including those institutions indicated [a] that were involved in delivery only in the first 3 years of the program (Universities of Newcastle, Sheffield, and Southampton; 2015-2018).

undergraduate programs in the biosciences, and although they made up to ~30% of the cohort at most HEIs, this article will focus on the NHS learner cohort (Learners).

The program was advertised to potential learners by a variety of routes. Although any member of the NHS workforce (estimated at 1.3 million people) was eligible for the program, advertisement concentrated on the clinical workforce (circa 600,000 people), with a focus on doctors, nurses, midwives, and health care scientists because these were the individuals most likely to be using genomics in current and future practice. The marketing campaign focused on communications through existing professional groups and societies (eg, Royal College of Physicians), internal hospital communications (eg, hospital newsletters), and through HEE communication routes (eg, website bulletins). HEE also commissioned a paid social media campaign at the start of the program to raise awareness among the target audience. In addition, individual HEIs conducted their own advertisement campaigns. Once the program was established, word of mouth became a key component of the advertising campaign through recommendations by line managers or those involved in CPD. Learners were not paid to enroll in the program.

Study aims

Now in its ninth year (2015-2024) the Master's in Genomic Medicine program has educated over 1500 learners. The primary aim of this study was to evaluate whether it has achieved its stated purpose; to develop learners' knowledge of genomic medicine and their ability to embed this in their professional practice. We also sought to identify aspects of the program that contributed to or acted as barriers to achieving these outcomes to inform its subsequent development.

Materials and Methods

The study received ethical approval from the University of Birmingham Science, Technology, Engineering & Mathematics Ethics Committee (ERN_21-1180). The study had 3 sources of data: (1) demographic data collected as part of administering the program, (2) survey data from learners and line managers, and (3) interview and focus group data from learners, line managers and program managers at the HEIs. These data were gathered in 3 strands focusing on different participant groups (Figure 1) and handled and stored in compliance with General Data Protection Regulation and the University Code of Practice for research.

Learner demographic data

NHS England routinely collates data to monitor the uptake and outcomes of the program. We analyzed data from the period 2015 to 2021, including (1) the number, geographical distribution and professional background of learners, (2) their chosen HEI provider(s), and (3) the modules completed and/or qualification(s) achieved. Learner data were anonymized and nonidentifiable. Although other demographic data, such as gender and ethnicity, may be collected by NHS England for other purposes, this information was not available for analysis.

Surveys

Survey questions were informed by frameworks used for evaluating training programs initially developed by Kirkpatrick and subsequently developed by Moore for training in health care contexts.[29,30] Using the key aims of the program as a starting point and their previous experience in developing surveys to evaluate genomic and nongenomic health care professional education programs, M.B. and S.B. drafted the survey questions. Initially, questions covered many aspects, including self-perceived changes in knowledge and confidence, as well as impact in practice. Through an iterative process, these questions were refined and reduced by M.B., S.B., and S.S. This process involved mapping against the program's aims and Moore's framework, to ensure that the program's aims would be measured in a structured manner. The survey was then circulated to other members of the HEE team to assess face validity. In addition, face validity was assessed with a small group ($n = 5$) of the target audience. This group also commented on comprehension and readability of the survey questions. Questions in the final survey focused on participants' satisfaction with the program based on their a priori expectations and whether it influenced their practice in the workplace, rather than the more subjective perception of knowledge and skill capabilities or confidence. Separate surveys were designed for learners and the NHS line managers who approved learners' applications to the program (Supplemental Survey 1). The 2 surveys had a similar set of questions with one notable
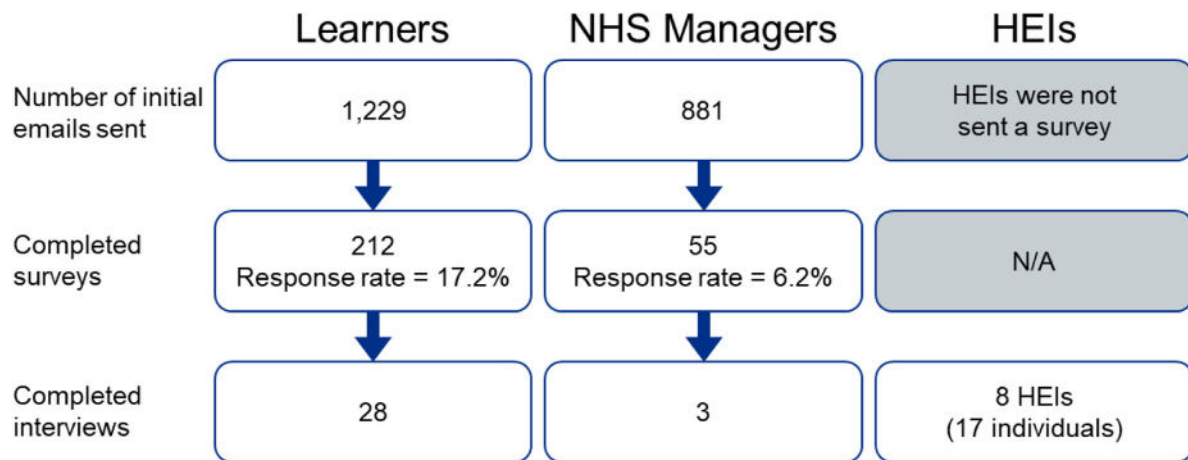
Figure 1   Overview of participant numbers at each stage of the study. Recruitment emails were sent to all HEE-funded learners on the program in which HEE had current contact details ($n = 1229$), of whom 212 completed the Learners online survey. Separate emails were also sent to NHS managers who approved learners' funding ($n = 881$), of whom 55 completed a Managers survey. All respondents that completed a survey were asked if they were willing to participate in interviews, and all those that agreed were contacted. Focus groups were also held with those involved in program management at all current HEIs and 1 involved in delivery at the onset of the program. Response rates were calculated using the number of learners' or managers' contact emails available as the denominator.

difference: the questions in the learners' survey focused on the learner's experience, whereas the manager's survey focused on the manager's perceptions of the impact of the program on their colleague(s) and the wider team. To keep the surveys concise and minimize respondent fatigue, demographic questions were limited to data around professional role and clinical specialty of practice. Surveys were delivered online, used a mixture of question formats, and respondents were asked to review an overview of the study aims and consent to the use of their data before starting. Pilot studies indicated that they took on average 7 minutes to complete.

Data collection took place over a 5-month period (November 2021-March 2022). Study participants were invited to complete a survey via emails to (1) all learners funded by HEE during 2015 to 2022 (for example, those registered for both individual modules for CPD and post-graduate qualifications during this period) and (2) NHS line managers who had approved learner applications. We requested completion of the online survey and subsequently invited respondents who indicated their willingness through the survey to participate in an online interview. Data responses were analyzed using SPSS. Descriptive statistics are presented with data analyzed for significance using χ^2 analysis, with an a priori level of significance set at $P < .05$, where appropriate.

Interviews and focus groups

Learners and line managers that completed the online survey were invited to provide their email address if they were willing to be interviewed on their perception(s) of the

program. All those that indicated their willingness were contacted for interviews. Interviewees were provided with a £10 voucher to thank them for participation. Similarly, the academic teams involved in delivering the program at HEIs were invited to contribute to focus groups, 1 for each HEI. Interviews and focus groups took place virtually during November 2021 and March 2022 (Interview schedules, Supplemental Survey 2), after most survey responses had been received. Questions focused on similar topics to the survey, although areas in which survey respondents had reported difficulties/barriers to learning were explored in more detail. Discussions were recorded and automated captions edited to generate a transcript. Inductive content analysis[31] was performed independently by 2 researchers and focused on (1) learner recruitment, (2) program design (eg, curricula, multiprofessional learning), (3) barriers to learning, (4) impact in the workplace, and (5) overall satisfaction. This was analyzed by NVivo for emergent themes within each category.

Results

This section presents our study findings in line with the evaluative frameworks of Moore et al[29] and Kirkpatrick et al,[30] addressing key reporting item standards (RISE2[32]) where appropriate, to facilitate the comparison of training approaches. We focus on the key findings of the evaluation (for a full report of survey findings see Nightingale et al[33]) and highlight and/or illustrate critical themes using representative excerpts from interviews and focus groups with learners, NHS managers, and academic program leads from HEIs.

Table 3 Learners' professional background(s) (2015-2020)

Professional Background	Number	Proportion (%)
Doctors	632	40.6
Health care scientists	468	30.1
Nurses and midwives	185	11.9
Researchers	127	8.2
Other	145	9.3
Total	1557	100

The number and the proportion of learners recruited from specific professional backgrounds and/or role(s).

Learner demographics

Geographical distribution

The Master's in Genomic Medicine was designed as a national program delivered by HEIs, which are distributed to serve all the English regions. Data for the period 2015 to 2020 confirmed that learners (eg, funded by HEE for individual modules or postgraduate qualifications) had a broad geographical distribution (data not shown), with enrollment at HEIs reflecting this (Table 2).

Learner professional background(s)

An aim of the program was to recruit learners from a range of professions reflecting workplace training need(s).[13] Learners, indeed, came from a variety of clinical and technical roles, including doctors, health care scientists, nurses, midwives, pharmacists, dentists, psychologists, and those involved in health informatics, public health or health care management. More than 80% of learners were doctors, health care scientists, or nurses and midwives, and a further ~8% were researchers (Table 3). The remaining learners, which encompassed small number of individuals from a very diverse roles within the NHS, were combined into a single Other category.

Survey and interview response rates

Participant numbers and response rates for each of the study strands are summarized in Figure 1. Response rates (17.2% of learners and 6.2% of managers) were lower than some post-training surveys on genomics education (eg, ~25%[20] and 57%,[22]) but compared well with large-scale surveys focusing on health care professionals both in the United Kingdom and internationally (eg, dentists: ~14%,[34] health care professionals: ~8%,[35] physicians: 1.2%[36]).

Learners' reasons for studying and perceptions of barriers to learning

Interviews with learners explored the factors that encouraged them to apply to the program. These included an interest in genomic medicine, being keen to develop research in the area, and recognizing the increased role that genomics plays in clinical delivery.

Physician in training (Neurology): "Genomics is just shooting up exponentially in terms of knowledge. All the research is growing at such a fast pace, the NHS workforce needs to keep up with it."

Others, notably health care scientists, anticipated that a postgraduate qualification could lead to progression within their current role or facilitate a career change into the field of genomics. Importantly, many participants stated that they applied because there was funding available and would not have if the program were self-funded.

However, these discussions also revealed learners faced a number of challenges when applying to the program, many of which focused on balancing professional workloads and study. Interviews with learners and managers revealed a widespread perception that there was insufficient study leave for learners from their professional role(s), with some managers suggesting that this reflected institutional constraints and/or pressures. It is unclear whether this acted as a barrier to potential learners.

Health care scientist: "When I spoke to my manager about it, she was very much 'This is going to be very difficult for you - you know it's going to be a lot of time.'"

Nurse (Research matron): "My issue really is that my workload was increasingly stressful."

NHS Manager: "I feel that the amount of study leave that is offered at the moment is not sufficient for working a full-time role."

Learners' and managers' satisfaction with the program

An initial element of the evaluation framework aimed to assess learner's and manager's satisfaction with the program. This encompassed satisfaction with elements of the curriculum and learning environment(s), as well as with the program overall.

A high proportion of stakeholders were satisfied with the program

Stakeholders' appeared satisfied with the program because a high proportion of learners (all learners: 86%, health care scientists: 96%, doctors: 86%, and nurses and midwives, 83%), as well as NHS managers (85%) indicated that they would recommend the program to colleagues.

Doctor (Consultant): "I've been a massive advocate for the MSc and the modules ever since I did them, because I think they're really good. I'd recommend lots of people to go and do it and I'm very, very positive about it."

NHS manager: "We advertised it internally and promoted it internally, because we felt it would be hugely valuable for our staff."
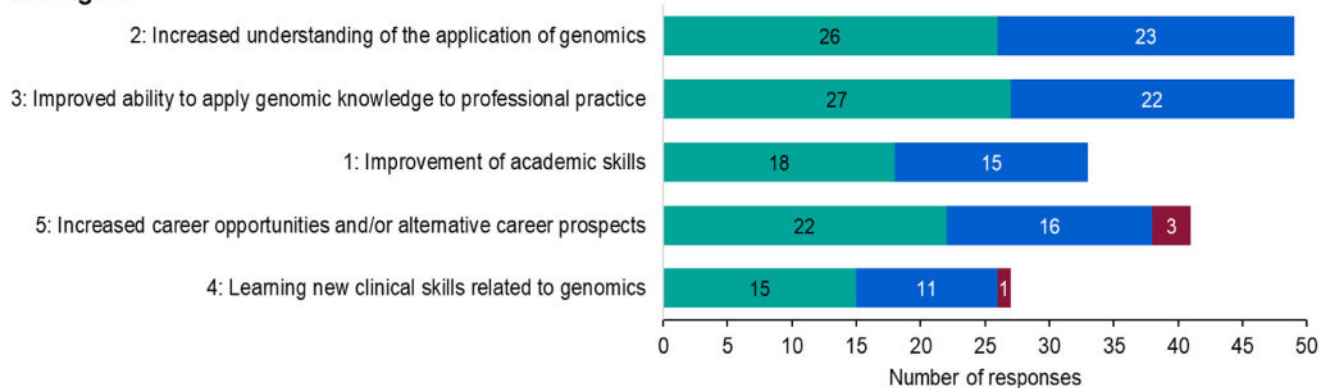
Learners' and managers' expectations of the program were met

A subsequent survey question asked learners and line managers to identify their expectations of the program and the extent these were met. This offered a range of anticipated outcomes (Figure 2), but interestingly, responses

Learners
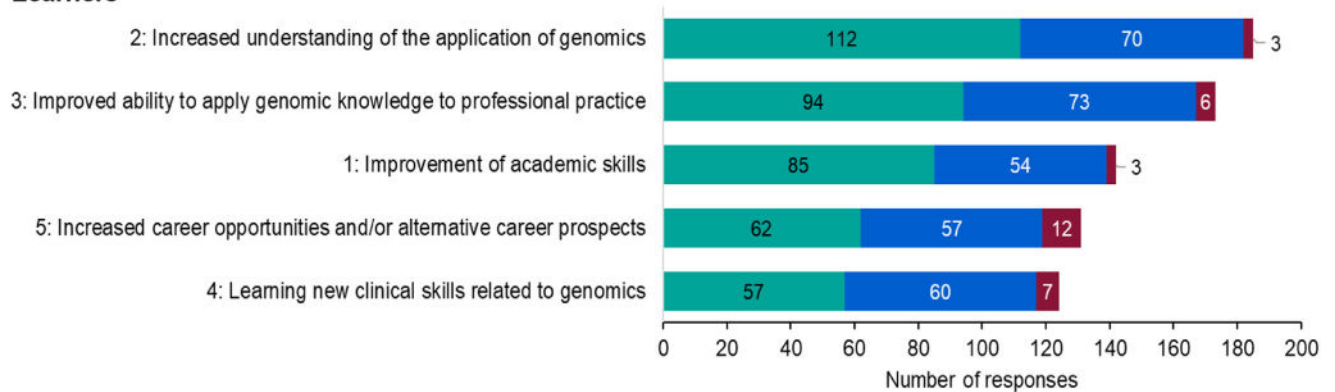
Managers

Figure 2   Learner's and manager's expectations and the extent these were met. Respondents were asked to identify one or more outcomes they anticipated from the program (expectations 1-5), and the extent these were met, Completely (green), Somewhat (blue), or Not at all (red). (Learners, *n* = 212; NHS managers, *n* = 55).

focused on the *application* of genomics, in either broader health care contexts ("Increased understanding of the application of genomics to general healthcare provision."), or professional practice ("Improved ability to apply genomic knowledge to professional practice."). A smaller number focused on developing academic ("Improvement of academic skills.") or clinical skills ("Learning new clinical skills related to genomics.") or increased career opportunities ("Increased career opportunities and/or alternative career prospects."). Most learners (>90%, Figure 2) confirmed that their expectations were met, although 9% reported that this was not the case for their career-related expectations. Reassuringly, we received a similar pattern of managers' responses ("What did you expect your colleague(s) to achieve from participating in the programme?"), suggesting that learners' and managers' expectations of learners' knowledge and skill development on the program were broadly in line.

Learners' satisfaction with the curriculum

A core element of the evaluation was to focus on the program's design, notably whether the curriculum engaged the diverse learner cohort. Overall, responses to the question "Did the topics in the programme provide an

appropriate balance between the science, ethical and practical applications needed in the NHS?" were positive, but differed by learners' professional background, with higher levels of satisfaction in health care scientists (Completely satisfied: 67%), than in those from patient-facing professionals (eg, Completely satisfied. Doctors: 52%; Nurses and midwives: 49%). This disparity was also evident in interviews and suggested that some modules were more challenging or less relevant for learners from some professions.

Health care scientist: "I think it does do a good job of doing all those things [science, ethics, practical application] - having real people, real scientists, real clinicians, counsellors who are bringing cases that are current."

Pharmacist (consultant, genomics): "I wouldn't say it's easy because I did have to work hard on it, and I mean it is complex, but I enjoyed the complexity of it."

Nurse: "I was in a cohort with a lot of biomedical scientists, they were just breezing through - it was all easy to them. I think it was more pitched to them than it was to a nurse."

These differences in satisfaction appeared to reflect learners' familiarity with the science underpinning curricula, and how applicable the material taught was to workplace

practice. This was exemplified by feedback on the bioinformatics module:

Medical technical officer: "I absolutely loved bioinformatics from start to finish, I thought it was brilliant."

Nurse: "Bioinformatics was a really tough one. Sometimes we really felt like we had no idea what was going on."

NHS manager: "I don't think they [the learners] expected them to be quite so 'sciencey' and technical. The courses were very academic in nature, and in some ways not always directly applicable to someone doing genomics in their clinical practice."

Learners were satisfied with the learning environment(s) used

Another key element of the evaluation was to assess whether the blended learning approach(es) used to deliver modules were appropriate given the learners were working professionals. Program managers at the HEIs found that learners' diverse work schedules created difficulties in developing a universally accepted approach, but discussions suggested that the model used, comprising face-to-face teaching followed by online learning activities, was appropriate. Learners valued several aspects of this blended approach, suggesting that the in-person teaching facilitated learning because it created a distinct environment separate from professional duties, and in-person approaches encouraged staff-student and peer group interaction(s). However, learners also valued the flexibility of online learning resources, particularly if they needed more support, consistent with these materials contributing to a more inclusive curriculum.[32,37]

Program lead (HEI): "Some modules were Monday to Friday. Some modules were one day a week for five consecutive weeks. Whatever we did, we always had some students that liked one way over another way, so we can never please everybody all the time."

Doctor (Consultant, Genetics): "I like the fact that the modules were definite one-week blocks, where you could go away. It was actually really important to be able to stop clinical work at the end of one week, go to [the HEI] for a whole week, stay there, and just focus totally on the module."

Midwife (Screening midwife): "I find it easier to interrupt a lecture and just put up my hand and say, 'Oh excuse me, can you just re-explain that?' …. I found it hard to ask questions when I was doing the online training."

Program lead (HEI): "It is absolutely essential we do have some days on campus because of the tremendous peer-to-peer learning. I would be a bit worried about doing a fully distance-based course."

Data analyst: "Having the ability to watch lectures, watch them back if I've missed something or not understood something, because I am dyspraxic so sometimes it takes me a while as I have problems with my working memory. So being able to go back and re-watch a section or a lecture is really useful."
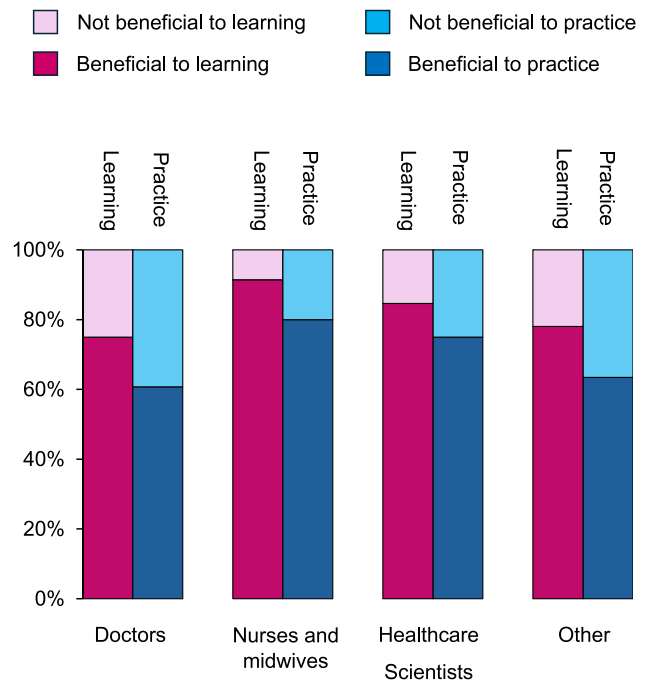
Figure 3 **Survey responses to learners' perceptions of multiprofessional learning and whether it was beneficial to their learning (left-hand columns) or professional practice (right-hand columns).** Responses are presented by professional group, for which lower sections indicate Yes and upper sections indicate No. The professional groups are: Doctors, $n = 84$; Nurses and midwives, $n = 35$; Health care scientists, $n = 52$, and Other professions, $n = 41$, where Other includes a large number of professional groups, including pharmacists, public health, dental team, health care support workers, allied health professionals, medical associate professions, health informatics, psychological professions, and management. A χ^2 test showed no significant differences between the responses of (1) doctors, (2) nurses and midwives, and (3) health care scientists (Beneficial to learning $P = .085$, Beneficial to practice $P = .062$).

Learners were positive about the multiprofessional learning approach

Finally, in addition to surveying stakeholders' views of the curriculum and learning environment(s), we also evaluated learners' perceptions of the multiprofessional cohort. Participants who took part in the evaluation were highly positive about learning with other professionals (Figure 3: "Was learning with peers from different professional backgrounds during the programme beneficial to your learning?"), with many valuing the rich discussion(s) this encouraged. Some learners and teaching faculty observed that the differences in learners' expertise and clinical experience could also create barriers to participation. Importantly, however, a majority of learners, including both clinicians (eg, doctors: 75%; nurses and midwives: ~85%) and health care scientists (~92%), felt the multiprofessional cohort and the ability to network and share professional perspectives benefitted their subsequent practice (Figure 3: "Was learning with peers from different professional backgrounds during the programme beneficial

Table 4 Educational outcomes

Modules/Qualification Completed	Learner Number	Proportion (%)
Individual modules / CPD	515	33
PGCert	340	22
PGDip	40	4
MSc	642	41
Total	1537	100

Summary of the educational outcomes of the program (2015-2022), including the number and proportion of HEE-funded learners studying individual modules for CPD or for postgraduate qualifications.

CPD, continuous professional development.

to implementing this understanding into your professional practice?"). Reassuringly, we found no significant differences in responses between different professional groups (Figure 3), suggesting that multiprofessional learning was equally valued by clinical and nonclinical learners.

Specialist pharmacist for genomics (consultant): [on multi-professional learning] "It is one of the best bits about this course …. because you are problem-solving with people that you will be problem-solving with if you're working in a service."

Nurse (Cardiac genetics): "It was good because we got to experience and see how other people use genomics in their practice, and their perspective and what is their take on it."

Health care scientist: "I've encouraged other people to do the Master's and I've said 'You'll meet doctors, you'll meet people from these departments and you won't realise how useful it is to know them until you do it.'"

Program lead (HEI): "We've heard from some students … they find it quite intimidating when there's people with a lot of clinical expertise contributing to the discussion when others are real beginners."

Participants' training completed/qualifications gained

As an accredited postgraduate Master's program, participants completed different combinations of modules, each of which required ~150 hours of study, including 1 or more assessments. These mapped onto Master's-level learning outcomes, requiring a detailed understanding of genomics and an ability to critically evaluate research in the field. Interviews indicated that this was challenging for learners without prior exposure to genetics/genomics but highlighted the advantage of a program in which learners could enroll on individual modules and build up to the full Master's as they gained confidence.

Doctor in training (clinical genetics): "I started it with the thought that I'll do some modules and see how it goes, and see if I can get a certificate and if it goes ok, I'll do a Diploma."

Data for 2015 to 2022 showed that ~33% of learners completed individual modules as CPD activity, whereas a

majority achieved a postgraduate qualification (including ~40% completing the full MSc; Table 4). This varied by profession, with ~48% of health care scientists and ~41% of doctors completing the full MSc compared with lower proportions of nurses and midwives (~28%). Interviews suggested that this reflected differences in the value of a MSc qualification for career progression in different professions.

The impact of the program

Increased confidence in using genomics in the workplace

Our survey(s) did not explicitly include questions on whether the program increased learners' confidence in using genomics in the workplace, but instead focused on changes in behavior. However, this frequently emerged in interviews with both learners and managers, suggesting that learners' behavior changes were directly linked to confidence, especially when discussing genetic information with colleagues and patients.

Nurse (cardiac genetics): "I think just building up my confidence to discuss genetic concepts with my patients and being able to provide more in-depth advice."

NHS manager: "They have greater confidence and competence [in their] ability to answer patient's questions if they have that sort of science knowledge."

Other impacts on learners' professional practice

Several survey questions focused on whether the knowledge and/or skills developed during the program influenced learners' professional practice. This was initially assessed when surveying participants' expectations of the program (Figure 2), in which a majority of learners reported increased understanding of the knowledge or clinical skills required to apply genomics in the workplace (eg, expectation 3: "Improved ability to apply genomic knowledge to professional practice." or expectation 4: "Learning new clinical skills related to genomics that could be used in professional practice.").

Two subsequent questions focused on whether this increased understanding resulted in a perceived change in practice and the scope of its impact (e.g. "Has participating in the programme enhanced any aspect of your individual practice?" and "Has participating in the programme enhanced any aspect of genomics practice in your department or organisation?"). This showed that, although 86% of learners reported enhanced practice as an individual, 64% also reported impact(s) in departmental practice. Health care scientists were particularly positive (98% reported enhanced practice), but this was also reported by patient-facing professionals (eg, 81% of doctors and 86% of nurses and midwives agreed). Importantly, a majority of managers also observed improved professional practice in individual learners ("Has participating in the programme enhanced any aspect of your colleague's individual practice?": 68% agreed), or at the departmental level ("Has your colleague

participating in the programme enhanced any aspect of genomics practice in your department or organisation?": 58% agreed).

This was reinforced in interviews. Learners reported their increased understanding of genomics helped explaining genomic concepts to patients and made interacting with colleagues more effective. In a broader context, learners reported acting as a source of departmental expertise and (re)engaging with research and/or lifelong learning.

NHS manager: "I think it improves the quality of our MDT meetings, our multi-disciplinary team meetings that we had."

Health care scientist: "I think the ways it exceeded my expectations is the networking with other clinical colleagues and how useful that's been in my job."

Specialty doctor (clinical fellow): [on genetic testing] "When the rest of my colleagues struggled with the interpretation, then I was the resource person to explain that."

Doctor (consultant): "I was surprised how useful it was for me, it opened my eyes to a whole load of … the way the technology works now. The other thing I suppose I should say – a load of our pathology journals actually now make sense again."

Nurse: "It's benefited me phenomenally in my background knowledge of genomics which I now teach to other people."

Discussion

This study summarizes an evaluation of the Master's in Genomic Medicine program, a national response to support the integration of advances in genomics into the NHS. The purpose of the program, to support NHS health care professionals in developing their knowledge of genomic medicine and its application in clinical practice, informed the framework(s) used for the evaluation, which included established models, including one specific to health care education.[29,30]

We found that the program was effective by several key measures. Recruitment was appropriate for a national program, in that learners were drawn from across the NHS and included a wide range of laboratory, patient-facing, and management professionals. Furthermore, our findings show the majority of learners (>65%) chose to extend their learning and complete a postgraduate qualification, which is notable. Given the time commitment required (for instance a PGcert requires 4 150-hour modules; Supplemental Table A), this suggests that learner retention over the program is in line with that seen on shorter focused training programs for health care professionals (eg, completion rate for multicomponent genomic training: ~84%[20]). Learners reported their increased understanding of genomics, and both learners and NHS managers confirmed that this benefitted practice, allowing more informed discussions with patients, and increased contribution(s) to teamworking and/or decision making.

Benefits at departmental and strategic management level(s) included training of colleagues who had not attended the program or contributing to research. Importantly, the proportion of learners' reporting enhanced practice (64%) is comparable to that seen after genomic training elsewhere, although this depends on learners' context(s) (eg, 10% to 18% report increases in different elements of genetic consultations[20]; 68% report more referrals to genetic services[22]). The study also highlighted the benefits of learning in a multi-professional cohort. Learners found that this enriched learning and noted how peer-support networks from the program evolved into workplace communities of practice. This is consistent with other Master's-level programs,[25] but we can speculate that learners found interactions with other professions were particularly valuable in a rapidly evolving area such as genomics.

Our findings suggest that there are several critical aspects to the program. Its broad-based, modular curriculum and use of a blended learning approach maximizes learner engagement. However, the decision(s) to (1), offer an extended, Master's-level program that exceeds what is required for ensuring genomic literacy and (2) target a multiprofessional cohort (ie, patient-facing, laboratory, and management staff studying together) is an innovative approach within the NHS. This has resulted in a community of professionals that bring a research-informed ethos to their practice, which may future proof health care for ongoing change in genomics. As such, the program complements the more widely used approach of using short training courses aimed at specific groups of professionals (eg, Chen et al[20] and Houwink et al[22]).

However, this approach will not be appropriate for all contexts. We found that multiprofessional learning encourages interprofessional working and community formation, but the 'one-size-fits-all' approach reduces how tailored curricula can be for specific groups of professionals. This places additional emphasis on ensuring that there is a supportive learning environment and a wide range of supplemental learning materials for learners at all levels of expertise. Likewise, a Master's-level approach requires more investment, both in funding (eg, cost per learner) and the time required for study. Although we can only speculate on what the learner demographics would look like if this program were not funded by HEE—it would likely not include as many learners from lower paying professions. Many learners commented that they would not have been able to undertake this study without the funding.

Areas requiring further development

The evaluation identified a number of areas requiring review, notably in modifying curricula to (1) accommodate learners with less exposure to genomics/genetics and (2) put greater emphasis on clinical application(s), to reinforce the program's relevance to practice. This evaluation is feeding into an ongoing curriculum review to address these areas. However, other issues require a longer-term strategy

because they center on learner recruitment and the study leave awarded to learners. The current recruitment approach results in learners who are largely self-selected who may not be optimal candidates and/or may result in some specialties or departments with insufficient genomic expertise. It may not also be equitable for learners with less available time or funds, which are issues that plague higher education in general.[38] Further research, notably on NHS workplace training needs and/or the time required for study on the program should guide the development of a more strategic approach to recruitment and appropriate guidelines for the extent of study leave.

The limitations of this study

This evaluation has a number of limitations. The study coincided with the initial phase of the COVID-19 pandemic in the United Kingdom, which is likely to have reduced responses from health care workers, many of whom were under extreme workload pressure. As such, the response rate to our survey (17.2% of learners and 6.2% of managers) was lower than other studies conducting a postcourse/event evaluation of genomic education[20,22] but compares well with many large assessment surveys of health care professionals (eg, ~1%-14%[34-36]). Although the professional backgrounds of respondents were broadly representative of the learners on the program, we found that those who had completed the full MSc degree were more likely to respond, indicating a response bias toward those who had committed more to the program.[33] Likewise, although interviews were held with a broad spectrum of learners and were sufficient to identify consistent themes, this was not the case for NHS managers for whom our sample size was small and likely to be biased toward those with more interest in the program.

Other limitations arise from the data sets we were able to collect and reflect the nature of the program. For example, although we were able to assess learning outcomes (eg, modules completed and qualifications gained), the number of modules available and/or variation between the HEI providers made assessing learners' knowledge gain impractical (for example, by comparing pre- and post-module tests).[39] Similarly, the diversity in learners' professional backgrounds meant that we could not define specific metrics to assess impact in the workplace.[29,40,41] This is a frequent limitation when evaluating genomic education and reflects the diverse impact(s) of genomic medicine across health care systems.

Finally, we were largely reliant on self-reporting to assess changes in learners' behavior (although we did survey managers to address this). Other programs with more homogenous groups of learners have been able to evaluate specific clinical outcomes (eg, GP's referral of patients to clinical genetics centers[22]), and this approach could be explored with subsets of learners in future evaluations.

Despite the limitations of our study and the areas identified for improvement, overall, the program is held in high regard by learners and their managers alike. It also appears to be positively affecting genomic practice within the NHS.

Data Availability

The authors will supply anonymized survey data and/or interview transcript data upon request. Contact the corresponding author.

Author Contributions

Conceptualization: S.B., M.B., K.P.N.; Data Acquisition, Curation, Analysis, and/or Presentation: N.A., L.F., S.S.; Resources: L.F.; Supervision: S.B., K.P.N.; Writing-original draft: K.P.N.; Writing-review and editing: K.P.N., M.B., L.F., S.S., K.T.-B.

Ethics Declaration

The study received ethical approval from the University of Birmingham Science, Technology, Engineering & Mathematics Ethics Committee (Ref. ERN_21-1180). Learner demographic data, survey, and/or individual transcript data were gathered with participants' informed consent. Identifiable data were deidentified before analysis and was handled and stored in compliance with General Data Protection Regulation.

Conflict of Interest

The authors declare no conflicts of interest.

Additional Information

The online version of this article (https://doi.org/10.1016/j.gim.2024.101277) contains supplemental material, which is available to authorized users.

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