AUSTRALIAN GENOMICS
WORKFORCE & EDUCATION

Technical Report

Perspectives of Education Providers on Education & Training Needs of Non-Genomic Health Professionals

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Important Information: Use of Data in This Report

Data in this report may not be used without written permission from the authors, who may be contacted at education@australiangenomics.org.au.

Some data in this report are included in the manuscript:

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Context

Thirty-two education providers were interviewed between 2016 and 2017, who convened a variety of genomics-focused education activities ranging from university courses, online learning modules, resources to continuing professional development (CPD) activities.

Education providers were consulted to both map existing educational programs and to describe the future needs of health professionals in genomics. This technical report touches on provider experience, educational practice and expectations of the future genomics workforce.

In this report, genomic specialists are defined as clinical geneticists, genetic counsellors, medical specialists or scientists with specific genetics and/or genomics training or expertise, or clinical bioinformaticians. Non-genomic health professionals are defined as medical specialists and trainees, general practitioners, nurses, midwives or allied health professionals without formal genetics or genomics training.

Key findings

- **Target audiences** of existing genomics-focused educational activities ranged from university undergraduate and graduate students (medical, science and computer science), non-genomic health professionals and genomic specialists. Several education providers noted non-genomic health professionals attended activities that were not targeted towards them.
- **Curriculum:** Education providers felt that it is neither feasible nor necessary for non-genomic health professionals to learn genomics in-depth.
    - These health professionals need to first and foremost accurately understand the capabilities and limitations of genomics and the basic premises of tests. It was more important to have an understanding of clinically-applicable genomics, including being sufficiently proficient in interpreting genomic results to communicate and make decisions about testing and treatment. They should leverage support from genomic specialists and accessible guidelines/resources to select tests and interpret genetic results.
    - Some providers thought learning about genomic data collection, processing and analysis would help health professionals better understand genomics in their practice and gain confidence. However it is not expected that processing genomic data will be a significant part of non-genomic health professionals' roles.
    - Overall, education programs should focus on latest updates in clinical genomics so as to be relevant and time-efficient. However, some providers felt a strong foundation in basic genetics to be more effective for long-term learning, reflecting the usefulness of needs-based approaches where information is layered according to background knowledge of basic genetics.
- **Learner attributes** driving successful implementation
    - ***Confidence:*** Lack of confidence surrounding genomics is a barrier to education and training. Non-genomic health professionals may be less willing to seek out genomics education if they perceive it as too complex.
        - Simply providing exposure to genomics may be enough to enhance confidence.
        - Hands-on experience with genomics was considered particularly useful for confidence.
    - ***Relevance:*** The current landscape of infrequent genomics use in many practices presented a challenge.
        - Non-genomic health professionals may not see the relevance of genomics education and training if they do not use it in their daily practice.
        - For those who do complete genomics education, lack of proximity to genomics practice provides less opportunity to consolidate and apply their learning.
    - **Time:** Education providers noted a lack of time to attend education and training appeared to be a major challenge that affected attendance.
- **Education attributes** driving successful implementation
    - ***Currency:*** Keeping content current was important but challenging given the rapidly changing nature of genomics; one suggestion was to focus on revising basic genetics to provide tools for non-genomic health professionals to keep themselves updated.

- ***Tailored to audience:*** Education content and delivery style should be clinically-relevant and tailored to the audience's knowledge levels and discipline. Health professionals prefer short, face-to-face activities that are easily accessible, potentially leveraged off existing events that health professionals already attend or complete. Peer learning is useful; this is usually informal and opportunities for discussion within education activities are also useful.
- ***Recognition:*** Formal recognition of training (e.g., CPD/CME points) provides incentives.
- ***Funding*** was a challenge that affected the ability of education providers to employ sufficient personnel to develop curricula, run programs and update material.

- **External factors driving successful implementation:** More collaboration between genomic specialists and non-genomic health professionals will help overcome some of the challenges noted above. This will be strengthened by the support of more 'just in time' guidelines, resources and public education.

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Acronyms, abbreviations and terminology

For the purpose of this report, genetic and genomic tests/reports will both be referred to as 'genomic' tests/reports, due to the topics discussed being applicable to both and the fact that genomic testing is being done at an increasing rate for a range of complex, multigene conditions.[1]

For the sake of consistency, the term 'genomic' will also be used to describe specialists in this field, and conversely 'non-genomic' for those who are not specialists in this field (i.e., the target education audience of non-genomic health professionals).

The following acronyms and abbreviations are used in this report.

Acronym	Term	Definition
	Clinical genomics	The study of complete sets of DNA including structure, function, evolution, mapping, and associated technologies, as applied to health care
CPD CME MOPS	Continuing professional development	Any education or training activities designed to be undertaken after and/or outside official qualification or accreditation requirements, that may or may not be officially recognised by the relevant professional body Also includes discipline-specific terms such as Continuing Medical Education (CME) for medical specialists and Maintenance of Professional Standards (MOPS) for genetic counsellors. Programs of this nature must fulfil standard educational program requirements, e.g., identifying needs, clear learning objectives and evaluation included
	Education	Programs where participants receive information, which may or may not include hands-on components such as learning to use specific software programs; this may include CPD/CME/MOPS activities
F2F	Face-to-face	In person activity, as opposed to purely online synchronous or asynchronous learning. Some programs may be blended, i.e., at least some in-person contact plus online learning
	Genetic or genomic health professional	Clinical geneticists, genetic counsellors or medical specialists with specific genetics and genomics training or expertise
	Genomic education	Courses, subjects, activities and/or resources with curricula that cover genomics, including those specific to health contexts such as genomic medicine or clinical bioinformatics
	Genomics	The study of complete sets of DNA including structure, function, evolution, mapping, and associated technologies
	Laboratory genetic specialists	Genetic pathologists and elite medical scientists with advanced training in genetics and genomics
MOOC	Massive Open Online Course	Free course available online to an unlimited number of people, usually with no minimum requirements to enrol, i.e., courses can be completed by both professionals and lay people, with content written for varied audience levels. Some MOOCs embed self-assessment activities and/or offer Certificates of Completion for a small fee

Acronym	Term	Definition
	Medical scientists	Scientists who perform medical laboratory tests to provide information for diagnosing, treating and preventing disease and may also conduct research. May specialise in haematology, cytology, molecular genetics or genomics, for example, variant prioritisation and curation in collaboration and levels accredited by the Royal College of Pathologists of Australasia
MDT	Multidisciplinary team meeting	Clinical meetings where clinical and laboratory staff come together to discuss patients and/or test results. May also include non-genetic health professionals
	Non-genetic or non-genomic health professionals	Health professionals who have not undertaken training in specific knowledge and counselling in genetics/genomics but whose role will be impacted by genomics, such as medical specialists, general practitioners, allied health professionals, nurses and midwives
	Substantive programs	Separate and independent ongoing programs and resources suitable for CPD (workshop, podcast, case study) but not an official education or training activity. This may include a lecture series where a particular topic may or may not be repeated but the program may include other genomics topics in the future
	Training	Any activities required to achieve certification and/or accreditation by the relevant professional body, e.g., the medical colleges' trainee programs Also includes workplace-integrated learning activities, apprenticeships, secondments and placements
	University subjects, courses or programs	Post-graduate subjects or courses provided by universities, usually taken as part of a degree but in one instance could be taken as a stand-alone subject. Undergraduate university subjects or courses are outside the scope of this definition and report

1. Background

Genomics is a field that is becoming increasingly important and present in healthcare. Advances in technology and decreasing costs are enabling genomic medicine to be applied to more clinical situations than ever before.[2]

It is predicted that the rise in genomic medicine will see a changing role for currently non-genomic health professionals such as general practitioners and allied health, who may need to become more involved with genomics in their clinical practice. For this reason, it is important to up-skill these professionals and ensure that they are ready for genomics in their practice.

In order to do this, it is important to first determine what these health professionals currently know, what they are being taught, and what their education needs are likely to be in the future, including whether they are indeed likely to use genomics in their practice.

2. Purpose

The aim of this needs assessment report was to determine what education providers of genomics believe that non-genomic healthcare professionals will need to know and be skilled at in the future for genomics in their practice, and how to best achieve this.

3. Scope

Table 1 specifies the breadth of topics that are and are not covered by this report's 'Findings' section:

Table 1. Scope of this report

In	Out
Explicitly stated needs for future • Needs of non-genomic health professionals[1] • Needs of prospective or current medical students	Needs of genomic specialists
Gaps in current and recent education • Current education of non-genomic specialists • Current education of prospective or current medical students (but not the focus of interviews)	Current education of non-medical students
	Quantitative descriptions of current landscape[1] • Education provider demographics • Current education activities

[1] Provided in this report but results not obtained exclusively from this report.

Certain aspects of education such as useful modes of delivery (e.g., peer learning) were also drawn from education providers whose education activities were not all necessarily targeted to health professionals (e.g., non-medical students, genomic specialists). These education strategies were included in this report if the author judged them to be non-specific and able to be generalised to health professional audiences.

4. Study design

Thirty-two semi-structured interviews were conducted and transcribed with a range of education providers providing various education activities. The Interview Schedule used to conduct the interviews and which provided the focus topics for the needs assessment is provided in Appendix A.

Interviews were qualitatively coded in NVivo 11using a 'constant comparison' approach, and the main findings were derived using thematic analysis.[3]

5. Sample characteristics

5.1 Education providers

The backgrounds and areas of expertise of the interviewed education providers directed the education they administered and provided insight into what they consider important. Demographics were obtained from Project 1 mapping data (refer to report 'Project 1: Mapping Existing Education & Training for the Australian Clinical Genomic Workforce') and confirmed by these interviews. The qualifications of the 32 education providers interviewed are detailed in Table 2 and visualised in Figure 1, with Figure 2 showing the diversity of qualifications and prominent regions of overlap amongst the education providers interviewed.

Table 2. Highest qualification in each discipline of education providers interviewed

Broad category	Highest qualification	Number[1]
Science	PhD (science, social science, bioinformatics)	25
	Masters/Bachelor	6
Clinic	Clinical (genetic counselling, medical specialty/physician, nursing, allied health)	11
Pathology	Pathology	4
Education	Education	4

[1] Includes second/third qualifications for an individual.

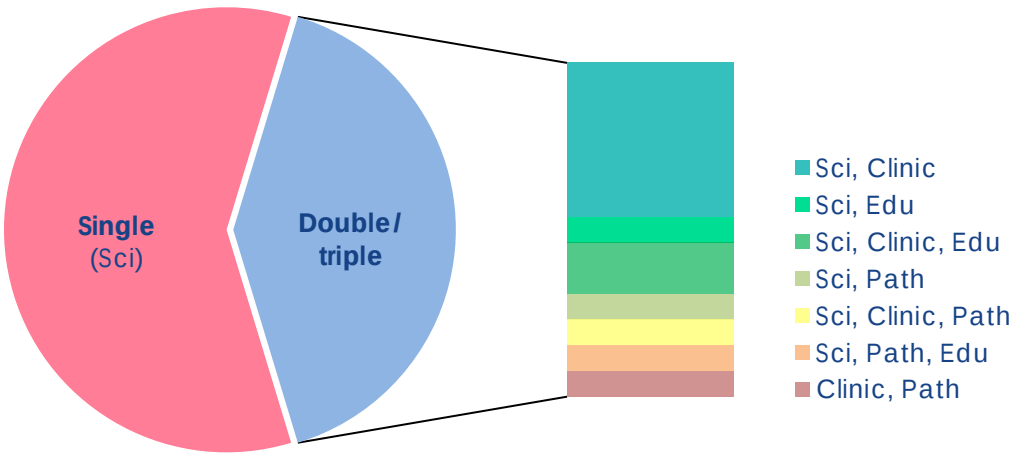

Figure 1. Visual summary of the range in number and combination of qualifications held by the education providers interviewed

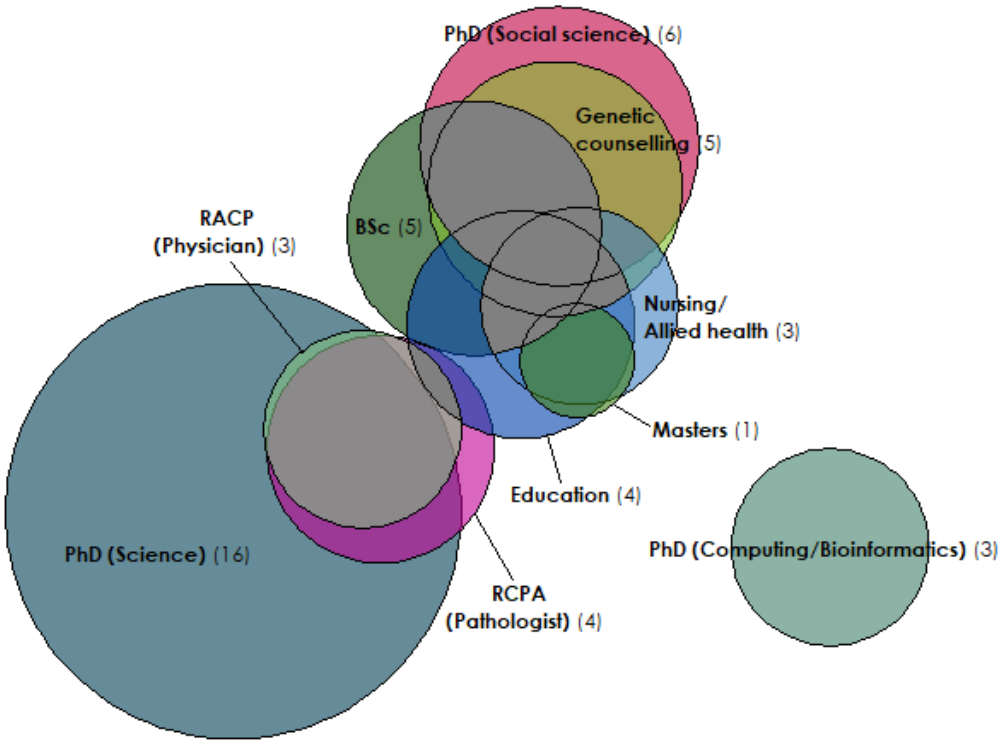

Figure 2. Overlapping qualifications of singly- and multiply-qualified providers

NB: Created with 'VennMaster-0.37.5' software using data from Project 1 Mapping data. Due to the large number of data categories, not all overlapping regions displayed contain individuals with those set of qualifications, but is the result of visualising a complex range of combinations.

- All but one education provider (who was a physician/pathologist) had a science background (PhD, Masters or Bachelor).
- Providers with doctorates in bioinformatics were the only cohort who did not undertake degrees in different disciplines.
- Almost all combinations of double/triple qualifications were unique, with only two providers possessing the same combination of qualifications (PhD in social science with genetic counselling). This reveals a diverse spread of disciplines contributing to these genetics education activities (mentioned in Section 6.5.3).

Most interviewees were not exclusively educators or college representatives; prior/concurrent careers included:

- Academic (Associate Professor or Professor)
- Researcher (e.g., in cancer genomics, chemistry, animal breeding)
- Bioinformatician
- Genetic specialist (genetic counsellor, clinical/medical geneticist, genetic pathologist)
- Health professional/medical specialist (e.g., paediatrician, pathologist, nurse)
- Dietitian.

5.2 Current education activities

Topics that education providers stated as being important were generally consistent with the education they provided. Therefore current education was a useful indicator of what education providers consider important for future needs.

The providers developed and/or ran a wide range of education activities including formal education (e.g., university courses), online courses/resources and continuing professional development (CPD) activities (Table 3). Their target audiences ranged from undergraduate students (e.g., medical, science, bioinformatics), non-genomic health professionals, medical scientists to genomic specialists.

Table 3. Types and numbers of education activities

Education categories	Number of education activities/resources	Stated goals of this category of education
University course/subject	14	Comprehensive coverage of basic genetics/genomics[1]
Ongoing programs/ resources (e.g., CPD)	24	Keeping updated on current trends and new developments in genomics[1]
MOOC	2	Support for other education

[1] Refer to Section 6.5.4 for a comparison of the goals of initial vs ongoing education.

Education strategies

Education providers used a range of sources, incentives and strategies when planning and developing education activities.

- **Needs assessments**, including asking health professionals directly what they require (e.g., 019_EDU, convenor of ongoing program/resource)
- **Their own experience**, expertise, and interests, including observations that
  - genomics is a "game changer" (043_EDU, convenor of ongoing program/resource)
  - accessing genomics data is "too hard" (028_EDU, convenor of university course/subject and ongoing program/resource)
  - there is a need for "free", "high quality education" (041_EDU, convenor of MOOC)
  - biology students do not know enough about computation (053_EDU, convenor of university course/subject)
  - advanced courses are too complex for some audience members (056_EDU, convenor of ongoing program/resource)
- **Other experts**' experiences, knowledge and opinions, including
  - observing other groups undertaking multidisciplinary collaboration and applying it to their discipline (e.g., genetic counselling in the case of 043_EDU, convenor of ongoing program/resource)
  - benchmarking education against others (e.g., finding that most medical genomics is taught at Masters level worldwide by 067_EDU, convenor of university course/subject)
- **Academic literature** (e.g., 051_EDU, convenor of ongoing program/resource).

Education providers described education activities in terms of time-frames, accreditation and delivery styles, commenting on the pros and cons of each type (Table 4).

Table 4. Characteristics of current education activities, and stated pros and cons of each

Characteristic[1]	Pros	Cons
Time-frame		
Short-term (i.e., <1-4 days)	• Accommodates schedule of time-poor professionals	• Insufficient opportunity to reiterate knowledge
Long-term (e.g., 12 weeks during university courses)	• Opportunity to reiterate learning[2] • Able to go further in-depth, spend more time on basics	• Not feasible for health professionals currently practising (insufficient time)
Accreditation		
Accredited	• Valued by and incentivises health professionals	• Costly and complex
Not accredited	• More self-directed learning encouraged • Less costly and complex to deliver	• May not be prioritised by health professionals requiring CPD points
Delivery styles		
Online (incl. videos) either main education or as support	• Accessible (to accommodate schedules of time-poor individuals)	• Less personal • Time differences
Podcast	• Easily accessible	
Face-to-face presentations/talks (e.g., lectures, conferences)	• More personal (than online, for example)	• Less consolidation of learning
Peer learning, group discussions	• More personal and interactive (than online and presentations) • Get feedback	• Less reliable assessment • If informal peer learning replaces official learning, may result in less consistent education
Hands-on, practical (e.g., workshops)	• More consolidation of learning • Increased confidence • Developing skills	• Not effective for all kinds of learning (e.g., understanding concepts, background)
Combined/blended	• Has benefits of multiple delivery styles	• May be more complicated and costly to deliver

[1] Refer to Table B- 1 for representative quotes.
[2] Refer to Section 6.5.4 for more details.

6. Findings

This Technical Report summarises the views expressed by thirty-two Australian genetics education providers between 2016 and 2017 regarding the education and training needs of non-genomic health professionals for genomics in their practice.

Perspectives of health professionals played a role in the topics discussed by education providers, a reminder that stakeholders (target audience) are intertwined with education providers.

6.1 Need clearer defined roles: Where does the non-genomic health professional end and the genomic specialist begin?

Anticipating the potential role changes induced by genomics, it became apparent it is important to clarify and distinguish the roles of non-genomic health professionals and genomic specialists.

6.1.1 Non-genomic health professionals

Health professionals should be aware of their roles in relation to genomics in order to deliver a reliable standard of care (Table 5). Representative quotes are provided in Table B- 7. This knowledge is to be cultivated with the intention of bridging the communication gap with genomic specialists, not to replace them.

Table 5. The main future responsibilities of health professionals, as predicted by education providers

Health professionals' responsibilities regarding genomics	Relevant sections within this report
Know when and who to refer to for genetic conditions	–
Understand the basics of genomic tests, including capabilities and limitations	• Basic genetics/genomics • Capabilities and limitations of genomics
Be more aware of hereditary conditions to increase successful diagnosis rate	–
Provide clinical information to inform genomic test selection and interpret result	–
Select genomic tests[1]	• Selecting the appropriate test • Capabilities and limitations of genomics • More collaboration with genomic specialists
Interpret genomic test reports[1]	• Capabilities and limitations of genomics • Roles of genomic specialists • More collaboration with genomic specialists
Address questions and misconceptions of patients[1]	• Communication • More public education

[1] There were mixed opinions regarding the extent to which these are responsibilities of health professionals and not other stakeholders (genomic specialists).

Do not need to know genomics in detail

The consensus amongst several education providers was that the future would likely bring an increase of genomics usage and changing roles in clinics, but that it is neither feasible nor necessary to expect health professionals to understand all the complexities of genomics.

Stated reasons for health professionals not needing to learn genomics in detail included:

- Insufficient time to learn
- Genomics not currently being used routinely
- Genomics perceived to be too complex for health professionals
- Resistance by genomic specialists to their roles being infringed upon.

> *"Somebody needs to define just how much knowledge and confidence they should have and I don't think there's anything wrong with them leaving quite a lot of that with the clinical geneticist and the genetic pathologists because. . ...they're extremely busy they've got a lot to deal with and they need to be able to confidently refer" (029_EDU, convenor of ongoing program/resource)*

Refer to Section 6.7 and Table 9 for more details and potential strategies to address these impediments.

6.1.2 Genomic specialists

The terms 'Genomic specialists/service providers' include clinical geneticists, genetic counsellors and genetic pathologists. Refer to Table B- 7 for representative quotes regarding their roles.

Education providers expected that the main responsibilities of genomic specialists and service providers now and in the future are to:

- Write more comprehensible genomic reports for clinical readers
- Support health professionals in selecting the most appropriate genomic test
- Assist in the clinical interpretation of genomic tests

These responsibilities were defined in relation to other specialists: it was thought non-genomic health professionals also need to leverage existing genomic specialists to save time and cost by minimising the number of inappropriate tests or incorrect diagnoses.

> *"People writing the report should be writing so that health professionals don't need to interpret really, essentially that means it makes it easier so you've got to teach the health professionals what needs to be ordered and when each thing should be most appropriate" (041_EDU, convenor of MOOC)*

While the roles described above appear to be relatively clear, there was still disagreement about the extent of genomic test selection and interpretation that health professionals ought to be responsible for, revealing room for more clarity. This is indicated by the diversity of opinions on the topic (Table B- 7).

Refer to Section 6.6 for more details of how this multidisciplinary collaboration is envisaged.

6.2 Knowledge: What health professionals need to *know* to fulfil roles

The following section summarises the knowledge that education providers stated as important for health professionals to know in order to use genomics effectively in their practice. These topics are able to be explicitly taught as education content.

Refer to Table B- 2 for representative quotes for this section.

6.2.1 Capabilities and limitations of genomic testing

To make decisions regarding genomic testing and to address patient-initiated questions, many education providers expressed the view that health professionals need to first and foremost accurately understand the capabilities of genomics and the basic premises of tests (Table 6).

Table 6. What health professionals need to know about genomic testing

Knowledge/understanding	Example
What is being tested	Single gene, several exons or entire genome
Capabilities of test	What conclusions can and cannot be drawn from test
Appropriate reliance on test	Extent to which test results can inform prognosis and treatment decisions
Ethical implications of testing	Informed consent, incidental findings
Genomic testing in scientific literature	Find evidence for/against running particular tests

> *"They need to know the scope of how it's going to fit in with health care generally. And for example with the new tests that are being slowly made available to just have an understanding of the scope of what those tests can do but also the limitations" (074_EDU, convenor of university course/subject)*

6.2.2 Varying depths of genomics

There was disagreement between the education providers as to whether health professionals should learn basic genetics, the latest updates in genomics or clinically-applicable genomics.

Basic genetics/genomics

Some education providers held the view that teaching basic principles of genetics/genomics (e.g., Mendelian genetics) would be a longer-lasting, overarching approach to education. This is because technologies change rapidly, whereas basic principles will always be able to aid understanding by being applied to more complex genomics. Basic genetics was particularly important when teaching a group with diverse knowledge levels, and were important to revisit as several education providers identified a genomics education gap in current medical training.

> *"(New approaches) come and go so fast that filling up the course with a lot of technical detail about the actual technologies that are in use this year won't even be of any use to those people in 2 years' time. . ...so while I try and keep moderately up-to-date with it, the focus isn't so much on the actual technologies as all of the stuff that you are going to need to be able to understand what the technologies are telling you, and that ability will help people whether they're undergraduates or medicos will help them all the way through their career" (063_EDU, convenor of university course/subject)*

Some examples of basic concepts included:

- Mendelian genetics
- Manual risk calculations
- Basic knowledge and interpretation of genomic techniques.

Those who expressed the view that teaching basic principles was less important explained that this was partially due to the expert status of the health professionals. Since health professionals are experienced independent learners, it was believed that it would not be necessary to teach them basic genetics that they could learn themselves. Other common reasons including lack of time and perceived need.

Refer to Section 6.7 and Table 9 for more details and potential strategies to address these impediments. A potential strategy to unify these recommendations may be to encourage learning of basic genomics through independent learning (e.g., online courses), while more complex topics could be taught more formally.

Advanced and/or clinical genomics

For the purposes of this report, advanced and clinical genomics topics were distinguished based on the extent to which they can be applied to clinical practice (as opposed to purely research applications, for example); refer to Table B- 2 for representative quotes regarding the importance of these topics.

Most believed that clinically-applicable genomics (e.g., how to interpret genomic tests) was most useful, while keeping updated on more advanced genomics (e.g., microarrays, epigenetics) was also beneficial, as many health professionals are not up to date with current genomics. Topics taught were categorised as either clinical genomics or advanced genomics (Table 7). It is important to note this distinction was not made by education providers but rather is based on the extent to which each topic/technology could be applied to clinical practice.

Table 7. Examples of currently taught advanced and/or clinical genomics topics

Clinical genomics	Advanced genomics
Genetic report interpretation	Bioinformatics/computational genomics • Using databases • Managing big data • Variant curation and analysis
Microarrays	Quantitative (non-Mendelian) genomics
Personalised medicine and predictive genomics	Statistics
Epidemiology (incl. population genetics)	Epigenetics
Pharmacogenetics/genomics	Developmental genetics

Exposure to bioinformatics

As part of recent updates in genomics, education providers had different predictions of the importance of bioinformatics and genomic computing capability for health professionals' future roles. While most implied that personally managing or analysing big data will not be a significant part of health professionals' roles, some expressed the view that biology and medicine are becoming more computational in nature. Thus exposure to the 'black box' of genomic data storage, access and analysis would help health professionals to better understand genetic tests and gain confidence in this area. One provider even foresaw the possibility of health professionals needing to use computation in their practice in the more distant future if personalised medicine and whole genome sequencing (WGS) were to become routine. Hands-on exposure to bioinformatics in particular was mentioned by several individuals as being useful for gaining confidence.

> *"To understand and the delivery in the complexity of interpreting that report. . ...we need to give them an opportunity to have a bit of a look at how you do variant analysis. We are not going to teach that of course but giving them an opportunity to be exposed to that process so that in a way that informs why those results are so complex" (019_EDU, convenor of ongoing program/resource)*

Refer to 'Hands-on experience' and Table 4 for more details on the hands-on style of education. Refer to Table B- 2 for examples of how education providers taught these skills.

6.2.3 Awareness of public understanding

Once health professionals have a strong foundation of genomics-related knowledge, they should be able to communicate with their patients effectively to ensure understanding. For this reason, one education provider highlighted that health professionals should be aware of the average patient's knowledge level on the topic of genomics in order to tailor their communication appropriately.

6.3 Skills: What health professionals need to be able to *do* to fulfil roles

The following section summarises the actions that education providers think health professionals should to be able to do to use genomics effectively in their practice. These skills can be developed as part of education.

Refer to Table B- 3 for representative quotes.

6.3.1 Communication

The ability to communicate effectively and confidently about genetics and genomics with patients was considered important by education providers, and in at least one case had been explicitly requested by health professionals. Genomics requires some communication skills that are beyond many health professionals' current skills and practices.

Health professionals should be able to:

- Appropriately communicate sensitive information around hereditary conditions
- Accurately inform and advise their patients about the capabilities and limitations of genomic testing, including answering questions and addressing misconceptions (refer to Section 6.2.1 for more details).

Accurately informing the public is becoming increasingly important with the rise of online DNA or direct-to-consumer (DTC) genomic testing and media coverage, as this drives public curiosity, misconceptions and patient-initiated discussions.

While some education providers argued that health professionals should not be solely responsible for informing the public about genomics (refer to Section 6.6.3), health professionals are being faced with clinical genomic questions as they are the public's first point of contact, especially in primary care. Therefore, providers believed that it was important to address the current communication gap.

> *"I think that they need to be able to communicate well to the patient so they need an understanding of the technology that's out there. And in simple terms so that then they can provide a better service for their patients in a sense that can relate to them and answer their questions." (050_EDU, convenor of ongoing program/resource)*

6.3.2 Selecting the appropriate test

Education providers highlighted the importance of appropriate decision-making regarding genomics in clinical practice, possibly due to far-reaching implications of genomic conditions for the patient and their families.

Health professionals should be aware of:

- A range of genetic conditions
- The options available for their patients (i.e., tests)
- The ethical issues of each option (including implications for the patient's family)

While providers emphasised the need for genomic specialists to support health professionals in decision-making (refer to Sections 6.1.2 and 6.6.1), as the first point of contact clinicians' decisions can be critical. This would likely become even more important as genomics becomes more common in clinics.

> *"I feel that's quite important to understand when is it relevant to order and or is it relevant to do the old fashioned test?" (041_EDU, convenor of MOOC)*

6.4 Learner attributes driving successful implementation

Education providers described personal attributes they felt were beneficial for health professionals to use genomics effectively in their practice, or variables influencing the success of education that can be classified as being in the control of participants. Attributes cannot be explicitly taught, but rather come indirectly from education as a result of building knowledge and skills.

Refer to Table B- 4, Table B- 5 and Table B- 6 for representative quotes.

6.4.1 Confidence

Confidence was considered an important outcome of genomics education, which would facilitate health professionals' use and communication of genomics in their practice.

> *"I think the education they need is really just that front face when a patient asks that question how they can confidently respond, know who to refer to for further advice. . ...it's the lack of the knowledge causes an issue around confidence." (024_EDU, convenor of MOOC)*

6.4.2 Attitudes

Overall, education providers held the view that it is important for health professionals to have a positive attitude towards genomics in order them to undertake education and successfully learn.

Advantageous attitudes for successful education outcomes include:

- Interest in genomics
- Perceived relevance
- Willingness to accept advice.

Interest and self-directed learning

Perhaps as a result of the currently infrequent use of genomics in clinic, one major driver for health professionals currently undertaking genomics education was their personal interest and attitude towards genomics. These were the early adopters who sought out education proactively.

Education can help health professionals develop the tools to undertake independent learning for genomics. The influence of self-directed learning was demonstrated by some health professionals attending education activities that were not necessarily targeted to them, which came as a surprise to some providers. Self-directed learning was said to have the benefit of allowing health professionals to continue learning independently at their own pace.

Interest was likely to be driven at least in part by how relevant participants perceived genomics to be to their practice.

> *"The GP. . ...module was a good one because they approached us about developing it so the benefit of that is the carrot is better than the stick when someone comes to you, you are able to put in good process." (019_EDU, convenor of ongoing program/resource)*

6.4.3 Perceived relevance to clinic

The perceived need for education stems from how useful it is for current practice. This presents a challenge since many disciplines of health professionals are not usually exposed to genomics in their clinic. For this reason it is important to make education as clinically-relevant as possible (e.g., using case studies) in order to encourage learning of content that may be much more applicable in the future, if not immediately.

6.4.4 Expert status

It was suggested that willingness to accept advice is influenced by the perceived power distance of the education provider and participant. Since health professionals are experts in their respective disciplines, they are less likely to accept education if they perceive it to be coming from a source less credible than themselves or delivered in a condescending manner. Therefore it is important to tailor education to health professionals' expert status by delivering it in a context appropriate to their career level (e.g., hospital location rather than university).

6.4.5 Stimulus for further independent learning

While health professionals are assumed to be familiar with self-directed learning given their expertise, being taught certain skills specific to genomics would enable them to continue learning by knowing where to best access information for genomics.

Advantageous skills for independent learning (obtained through education) include:

- Finding genomics resources
- Using genomic databases
- Critically analysing scientific research

> *"I guess it's more to train (dieticians) to be able to ask the questions that are required to get an understanding of the case. . ...what do I need to consider to be able to critically analyse (a genetics research paper). . ... what I look out for (in a genetic test from a biotechnology company). How should I understand if this is legit?" (024_EDU, convenor of MOOC)*

6.5 Education attributes driving successful implementation

This section describes variables influencing the success of education which can be classified as being in the control of providers of education activities.

For more details of effective timing, duration, incentives and delivery styles of education refer to Table 4, and refer to Table B- 6 for representative quotes.

6.5.1 Tailored to audience

Ensuring that the education is tailored to the learner's attributes was a common requirement mentioned by education providers. In order to achieve this, the first step is to understand the audience demographics. Where possible the content and delivery style of education should be targeted to the audience attributes presented in Table 8.

Table 8. Audience attributes that education content and delivery style should target

Audience attribute	Explanation	Example	Further details within this report
Knowledge levels	-	-	Table 9
Clinician status	Make clinically relevant	Case studies	Section 6.4.3
Medical specialty (if any)	Genomics use is known to differ between disciplines	Oncologists, paediatricians more frequent users	-
Expert status	Make participants feel comfortable	Hospital instead of university location	Section 6.4.4

The appropriate audience can be targeted through clear promotion and leveraging existing discipline-specific events (e.g., conferences) for the setting of the education activity.

It is often a challenge to tailor education to a diverse audience, so to address this it is useful to be willing to adapt or create new content and to encourage self-directed learning as a way for health professionals to cover material which may not be feasible to cover in official education. Refer to Sections 6.4.2 and 6.4.5 for more details on self-directed learning.

> *"The world of genetics is becoming tailored to each of the disciplines" (056_EDU, convenor of ongoing program/resource)*

6.5.2 Currency

Keeping education content updated was highlighted as being important but also challenging given the rapidly changing nature of genomics. One suggestion to address this was to focus on teaching the foundations of genomics rather than trying to keep up with all new genomic technologies. This was predicted to give health professionals sufficient knowledge to then keep themselves updated.

6.5.3 Interdisciplinary providers

Drawing on expertise from a wide range of disciplines (e.g., between education and genomics specialists) contributed to the successful development of several education programs.

6.5.4 Initial education vs ongoing CPD

Similar to the distinction between basic and clinical genomics, a distinction was noted between health professionals' initial medical training and their ongoing CPD. These activities were highlighted as currently having or needing to have different goals from each other. Refer to Table 3 for the number of initial education activities and CPD activities convened by these education providers, respectively.

The prerequisite formal education should have a more comprehensive coverage of genomics than it currently does, while the emphasis of CPD should be on current trends and new developments.

Both were seen as important, but CPD and staying updated was seen as particularly useful given the rapidly changing nature of genomics.

Reiteration

The opportunity to practise and apply learning was highlighted as important to consolidate learning from education. While some reiteration can occur through ongoing education, there is currently insufficient opportunity to apply learning in practice since genomics is not currently used routinely in most clinics (Section 6.7.1). Refer to Table 4 for the context and feasibility of reiteration in education, and to Table 9 for the barriers to achieving reiteration in the current landscape.

6.5.5 Incentives

Accreditation

Formal recognition of the education activities (e.g., CPD points) was one method of incentivising participation, as this was said to be valued by health professionals.

While considered important and useful by many, formal recognition was also said to be costly and/or restrictive by several education providers.

> *"I think professional development courses with credit seem to work well with a variety of doctors and so they will go to things providing they get the credit for actually doing it." (067_EDU, convenor of university course/subject)*

Refer to Table 4 for the benefits and challenges of accrediting education.

6.5.6 Prominent delivery styles

Refer to Table 4 for the benefits and limitations of each mode of delivery mentioned by education providers and Table B- 1 for representative quotes.

Peer learning

Peer learning, both informal and as part of educational discussions, was considered a valuable learning strategy by education providers. Currently, health professionals who know genomic specialists were said to already approach them for advice informally, indicating that peer learning is widespread and familiar to health professionals.

However, some providers noted the inconsistent quality of peer assessment as a limitation. This indicates that while peer discussion is very useful for learning, assessment may be more effective when conducted by education providers rather than peers.

Cross-disciplinary

Several education activities involving group discussions were considered to be even more useful when members were from different disciplines, as they benefited from a wider range of perspectives.

Hands-on experience

Providing practical experience as part of education activities was considered very useful for learning by most education providers. Activities such as interpreting genetic reports, working with sequencing data and observing variant analysis were said to enhance participants' skills and confidence.

> *"We discovered the first year that if you just talk at the student they don't really learn anything and that they definitely learn in this area (bioinformatics). . ...by doing" (044_EDU, convenor of university course/subject)*

At least one provider, however, expressed an alternate view that hands-on learning (such as labwork) is less effective for at least some types of learning, such as when trying to understand concepts. In these cases theory may be more effective for learning.

> *"Doing pracs isn't the most useful part you know you put DNA in a tube and it could be kangaroo DNA or human DNA doesn't make any difference really" (063_EDU, convenor of university course/subject)*

Problem-solving

Problem-solving was mentioned by some to be an integral part of education programs, and a skill that is important for genomics. This is closely linked with and developed through hands-on learning.

6.6 External factors driving successful implementation: More ongoing support

This section describes variables influencing the success of education which can be classified as not being in the control of either participants or providers of specific education activities. Instead, they are part of the entire landscape of clinical genomics education, and are important for wider implementation of genomics education. Refer to Table B- 7 for representative quotes.

6.6.1 More collaboration with genomic specialists

Education providers highlighted a current gap in communication and understanding between health professionals and genomic specialists, which may hinder implementation of clinical genomics if clinicians are not accessing the genomics expertise available. Refer to Section 6.1.2 for more details.

It was predicted that it will become more important for health professionals to collaborate with genomic specialists and for these specialists to in turn take a more active role in supporting clinical practice. Some envisaged this by co-locating health professionals and genomic specialists to facilitate collaboration, such as in a "GP superclinic" (029_EDU, convenor of ongoing program/resource).

Research translation

It was also suggested that increased translation from genomics research to clinic would facilitate health professionals in their roles by providing more evidence upon which to base practices.

6.6.2 More guidelines and resources

In addition to more collaboration with genomic specialists, accessible reference materials were highly recommended for ongoing support of health professionals, which they should be able to readily access to guide practice and aid decision-making.

> *"If they're not going to be able to access geneticists or genetic counsellors then they're going to need to be able to have some way of finding accurate information" (074_EDU, convenor of university course/subject)*

6.6.3 More public education

Some education providers expressed the view that a greater genomics education gap exists between public expectations and reality rather than workforce understanding. They therefore argued that it is more important to target education to the public rather than health professionals in order to address misconceptions about genetics at an earlier stage.

6.7 Challenges

6.7.1 Genomics not used routinely

Lack of perceived need

The current low usage of genomics in most clinical practices means that it was often not considered important or urgent for health professionals to use or learn genomics in detail.

> *"There won't be a lot (of genomics content in resource) because at this point in time how does genomics impact on the GPs you know management of that patient. It doesn't really. Because for many things you'd be expecting a GP to be referring." (058_EDU, convenor of ongoing program/resource)*

While it may not be currently used routinely, as genomics becomes more important in the future this lack of perceived need will be a barrier to pre-emptively educating the workforce. Lack of perceived need could potentially also have a positive reinforcement effect on the low usage rate of genomics; lack of awareness or interest in new practices (such as genomics) may lead individuals to ignore or even avoid using them in favour of more familiar practices (Figure 3).

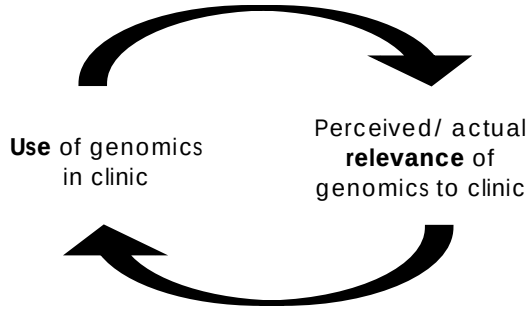

Figure 3. Schematic showing proposed cyclic relationship between current use and perceived versus actual relevance of genomics in clinical practice

Low usage also means that there is less opportunity to reinforce learning in practice, which would make education less effective. Refer to Section 6.5.4 for more details on the role of reiteration.

Some clinical education providers stated that they themselves did not perceive a need for genomics in clinic. This may indicate a potential conflict of interest on the part of education providers if their attitudes are reflected in their education practices.

Refer to Table 9 for this challenge in relation to its effect on the needs of health professionals, as well as strategies suggested to address it.

6.7.2 Perceived complexity

While developing confidence was one of the desired outcomes of education activities (Section 6.4.1), lack of confidence and perceived complexity of genomics was also a barrier to implementing education successfully. This was because health professionals may be less willing to seek out education if they perceive it as too challenging.

While some education providers felt that genomics is indeed more complex than other changes to clinical practice, others believed that for the level of knowledge required for health professionals the challenge was more so the *perceived* difficulty of genomics rather than the actual difficulty.

How to address

It was suggested that simply providing exposure to genomics during training would be sufficient to increase health professionals' confidence surrounding genomics. Giving participants the opportunity to gain hands-on experience in some capacity was found to be particularly effective.

6.7.3 Insufficient time

Limited time, for both organisers and participants of education, was noted as posing a challenge to developing successful education activities. Health professionals' busy schedules were highlighted as a challenge which affects the likelihood of both attendance and learning.

Refer to Table B- 8 for representative quotes about these challenges.

Table 9. Current challenges associated with implementing genomics into healthcare practice and facilitators/strategies to address

Challenge (current landscape)	Problem created by challenge (how affects needs)	Education strategy to address challenge			External strategy to address challenge (not through education)
		Topics	Delivery style	Other	
Genomics not used routinely in clinic	• Lack of perceived relevance, interest and incentive for learning • Few opportunities to apply learning	• Focus on clinically-applicable topics (e.g., genomic tests) • Tailor education topics to specialty	• Present topics in clinically-applicable way (e.g., case-studies)	• Provide incentives for participation (e.g., accreditation)	• More collaboration with genomic specialists to gain exposure to genomics • Increased translation
Perceived complexity	• Lowers confidence surrounding genomics	• Provide exposure to bioinformatics and processes of reporting	• Hands-on style of learning		• More collaboration and support from genomic specialists
Diverse knowledge levels	• Decreases extent that participants can learn if education is not targeted to needs • Lowers confidence of participants if education is too advanced	• Tailor topics to audience knowledge levels and specialty • Basic genetics/ genomics	• Encourage independent learning to cover broader range of content	-	• More public education
Rapidly changing field	• Difficult and costly to keep education updated	• Latest updates in genomics • (alternatively) basic genetics/ genomics	-		• Ensure sufficient resources to keep education updated

Challenge (current landscape)	Problem created by challenge (how affects needs)	Education strategy to address challenge			External strategy to address challenge (not through education)
		Topics	Delivery style	Other	
Insufficient time (for both participants and providers)	• Limits breadth and depth of coverage possible for topics • Limits how often education/ resources can be updated	• Focus should be on clinically-relevant genomics (most important)	• Convenient, accessible location (e.g., online) • Short, face-to-face education activities	• Provide incentives for participation (e.g., accreditation)	• Leverage existing events (e.g., conferences) • Support from genomic specialists, to help manage role and workload of health professionals surrounding certain aspects of genomics
Limited funding (esp. for education provided free of charge)	• Difficult to employ sufficient personnel to keep education/ resources updated • Unstable future	-	-	-	-
Unsystematic resources (incl. research)	• Makes education development time-consuming (and costly)	-	-	-	• Unify genomics education resources
Informal external learning (e.g., peer learning)	• Although better than no education, information may be inaccurate if used instead of official education	-	-	• Supplement with official genomics education	• More support from genomic specialists for accurate advice • More public education

NB: Some challenges, but not all, appear as separate headings in different sections. Some strategies address multiple challenges.

Future directions

The needs assessment for health professional genomics education will continue with further quantitative and qualitative data collection. Other stakeholders of interest include medical specialists, general practitioners, pharmacists, allied health practitioners, and the multidisciplinary team involved in providing genomic testing in an intensive care setting: intensivists, clinical geneticists, genetic counsellors and medical scientists.

References

1. Brittain, H.K., R. Scott, and E. Thomas, The rise of the genome and personalised medicine. *Clinical Medicine*, 2017;**17**(6):545-551.
2. Birney, E., J. Vamathevan, and P. Goodhand, *Genomics in Healthcare: GA4GH looks to 2022.* 2017. bioRxiv 203554; doi:10.1101/203554
3. Corbin, J. and A. Strauss, *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory.* 2008, SAGE Publications: Thousand Oaks, California.

Appendix A: Interview Schedule

The following interview schedule was used as a guide for these semi-structured interviews. The coding for this needs assessment was focused on the answers to the highlighted questions. The first of these 'Why did you offer/develop the program?' was used to determine past and current needs. This often overlapped with and informed future needs, as there may have been ongoing needs which had not been resolved at that stage.

Table A- 1. Interview schedule: Representatives of professional Colleges or education providers

Broad topic	**Questions** (Representatives / education providers)
Introduction	What is your title and background?
	Please describe your current role
	What sort of educational activities have you offered your members / developed?
Description of past/current educational activities	Who was the program for?
	Why did you offer / develop the program?
	Who delivered the program?
	When was it held?
	Where was it held?
	What was the delivery mode?
Approach to evaluation	How was the program evaluated?
	Were you/your members / audience satisfied?
	Did the program meet your/your members' / audience's needs?
Needs assessment	What genomics education activities do you feel are needed in the future?
	What are some barriers and facilitators to developing genomics educational activities?

Appendix B: Representative Quotes

B.1 Current education characteristics

Highlighted = cited in-text

Table B- 1. Opinions on different education modes of delivery

	Representative quotes
Time-frames	
Short-term (<1–4 days)	*. . ...are (medical specialists) going to come for a whole day, probably not. Are they going to attend for a couple of hours, at a stretch? So there is more for medical specialists. (019_EDU, convenor of ongoing program/resource)* *It's just presentation. So it could be a half an hour it could be 10 minutes. It could be an hour. It just depends on the need for the group that I'm presenting to (050_EDU, convenor of ongoing program/resource)* *Health professionals are not generally very happy to do an extra thing online on their own outside of their hours. Most of the time I've found they prefer to see people and they like to do it in a short way so they want to do it as an intensive (067_EDU, convenor of university course/subject)* *I think making the easiest possible access is obviously best. It needs to be short and concise and to the point. (010_EDU, convenor of ongoing program/resource)*
Accreditation	
Accredited	*So the certificate signature track I think for that kind of thing is really important because if you want to have. . ...you need to know that person's doing it. The money doesn't go pretty much because the government is going to track if you're going to have something monitoring whether it really is that person monitoring and the image that they provide and all that sort of thing it just has infrastructure costs associated with it and person costs as well. I think for those sorts of things it's pretty important but there are kind of fancier versions for other courses where you can pay a huge amount more money (041_EDU, convenor of MOOC)* *So I think professional development courses with credit seem to work well with a variety of doctors and so they will go to things providing they get the credit for actually doing it. They can be things that are run at conferences, workshops or individual sessions and I've been involved in some of those and some of them are well attended and are quite good, we could be doing a lot more of those, it just takes time and organisation and people to get into it. (067_EDU, convenor of university course/subject)* *I mentioned online modules, they weren't particularly enthusiastic about that- a couple were, but I must admit some of the ones. . ...say they don't have time, especially the younger guys, they are working really long hours and they said: 'you know it takes too much self-discipline to sit down and go through something in your spare time' if there were CPD points attached to it, that is certainly an incentive (014_EDU, convenor of ongoing program/resource)*
Not accredited	*I haven't gone into (CPD points) because the audience is going to be varied. Obviously career scientists don't give a damn about that and usually when you're applying for those CPD points you have to jump through hoops. And yeah it does restrict your freedoms somewhat. So you know for my professional development in Australia we don't need to have accredited points. (042_EDU, convenor of ongoing program/resource)* *we provided them with a certificate of attendance so they could put it towards their CPD. So the way it works is that the only full specific point generation you know getting exact numbers of points and things like that. The only- To my knowledge the only people in our sector that need quite specific numbers are GPs. So you get. . ...accreditation from the college for you know category specific categories of points and a certain number attached to it. So but in other fields among other specializations you can really just add to your list of you know whether you went to a seminar or whether you went to a conference, or whether you went to a workshop like this. (023_EDU, convenor of ongoing program/resource)*

	Representative quotes
Delivery styles	
Online (incl. videos)	*So we did a needs assessment analysis with GPs and we also piloted the original version with GPs and they wanted an online version as well as some sort of way of helping them, you know, a tool so they could look at. . ... I think an online module and so forth isn't sufficient to change attitude. It's a good tool for updating knowledge and a good tool to some extent for enabling people to reflect on communication but it's not adequate to change attitude (019_EDU, convenor of ongoing program/resource)* *And the whole strategy has been not just to develop the (online) resource but the idea was to support it with other activities right. It was never intended to be an online standalone resource. It was always meant to be there to support GPs. (058_EDU, convenor of ongoing program/resource)*
Podcast	*It seems like the podcast is the easiest thing for people to engage with. They don't have to be sitting in front of a computer. ....it's kind of perhaps more interesting to listen to a few different voices than to just read some materials. But out of all those formats. Yeah the podcast probably gets 10 times more traffic. (068_EDU, convenor of ongoing program/resource)*
Face-to-face presentations/talks	*Most of the time I've found (health professionals) prefer to see people and they like to do it in a short way so they want to do it as an intensive (067_EDU, convenor of university course/subject)* *In terms of continuing professional development, I think a face to face format, where you can engage and talk about the issues would be more beneficial to (health professionals). . ...It's easier to shift the discussion in the face to face format than it is to shift it in the online one (009_EDU, convenor of university course/subject)* *You know we discovered the first year that if you just talk at the student they don't really learn anything and that they definitely learn in this area they learn by doing so basically we try to keep the lectures to a minimum. It's mostly just telling people where they can get online help and where they can find out more about it. (044_EDU, convenor of university course/subject)* *I guess for many people they like the idea of face to face- it is more accessible, it makes them do it, but in the long term, obviously we're not going to reach as many people and it is not sustainable so we are exploring avenues for developing online modules (014_EDU, convenor of ongoing program/resource)*
Peer learning, group discussions	*there are discussion forums they're really essential I think to how the course was run so that's really designed for peer-based learning while they get feedback (041_EDU, convenor of MOOC)* *So at the Centenary there's a molecular genetics group. ....And they do a lot of genetic testing in-house. And then they sit down and they talk about their families and they talk about the variants that they found. . ...and they classify the variants basically and they do it in a really multidisciplinary way. . ...we just thought that other people in our profession need to be exposed to that and need to start thinking about what skill sets genetic counsellors are going to need to have moving forward. (043_EDU, convenor of ongoing program/resource)*
• Not peer assessment	*The one thing I didn't like with the Coursera was that it was all, I mean, peer marking has its good points as well. But I think sometimes it depends on whose marking and what their level of literacy is difficult for them to mark others. (064_EDU, convenor of MOOC)*
Problem solving	*You know we discovered the first year that if you just talk at the student they don't really learn anything and that they definitely learn in this area they learn by doing so basically we try to keep the lectures to a minimum. . ... And then we go through a series of problems I guess problem solving in the lab and then once we've done that, we give them a project. So all of the students get grouped into threes or fours and then each little group gets a separate project basically a heap of sequence data that we ask them to go and analyse. (044_EDU, convenor of university course/subject)* *it's lectures and 2 hour problem-solving tutorial every week. So it's always had a strong emphasis on problem-solving skills genetic analytical skills because that's*

	Representative quotes
	what makes human genetics different, it's not the fooling around with the DNA it's actually thinking about stuff (063_EDU, convenor of university course/subject) *Problem based learning. PBLs. So we do it for every unit of study, except the research. . ...Well for the coursework units of study related to clinical practice. Not so much the counselling ones because they're interactive. But for all of the. . ...science and the clinically related science we do PBLs student led facilitated. (016_EDU, convenor of university course/subject)*
Hands-on, practicals developing skills (e.g., workshops)	*we wanted some of it to be really practical We didn't want it we didn't want people sitting there listening to lectures. It's the kind of stuff that you need to sort of do hands on and you get some data and start playing out of having a look at the databases yourself and navigating them. (043_EDU, convenor of ongoing program/resource)* *To understand and the delivery in the complexity of interpreting that report I feel pretty strongly and so does [other education provider] that we need to give them an opportunity to have a bit of a look at how you do variant analysis. We are not going to teach that of course but giving them an opportunity to be exposed to that process so that in a way that informs why those results are so complex (019_EDU, convenor of ongoing program/resource)* *I think that you really need hands on experience, you have to have a mixture of didactic lectures, case examples, and hands on experience, people rotating through workshops. That Practical Genomics Workshop, the feedback we got that. . ...half and hour per rotation was too quick. Wasn't enough time. You really do need some time for hands on stuff. (007_EDU, convenor of ongoing program/resource)* *You know we discovered the first year that if you just talk at the student they don't really learn anything and that they definitely learn in this area (bioinformatics) they learn by doing so basically we try to keep the lectures to a minimum. . ... And then we go through a series of problems I guess problem solving in the lab and then once we've done that, we give them a project. So all of the students get grouped into threes or fours and then each little group gets a separate project basically a heap of sequence data that we ask them to go and analyse. (044_EDU, convenor of university course/subject)*
• Not labwork	*there are no pracs we don't do pracs. Doing pracs isn't the most useful part you know you put DNA in a tube and it could be kangaroo DNA or human DNA doesn't make any difference really. . ...(the course has) always had a strong emphasis on problem-solving skills genetic analytical skills because that's what makes human genetics different, it's not the fooling around with the DNA it's actually thinking about stuff.* *(063_EDU, convenor of university course/subject)*
Combined/ blended	*I think you've got to you know there is evidence that a single approach does not work so one resource, it is just a resource that is what it is but to educate you really need multiple approaches. And those sorts of activities and case-based scenarios are critical I think. (058_EDU, convenor of ongoing program/resource)* *we haven't quite got the balance but we are thinking that (the education activity) needs to be longer we are trying to make a blended learning model so that it would be face to face or online which is also what was asked in that (019_EDU, convenor of ongoing program/resource)* *So what we are going to do is we'll have module formats for that information and we'll also have some face-to-face possibilities and networks and things like that there'll be a range of different flexible learning approaches. (067_EDU, convenor of university course/subject)*

B.2 Knowledge

Table B- 2. Topics needed to be understood by health professionals

Topic	Representative quotes
Capabilities and limitations of	*I think it's hard for GP to know exactly. . ...where things really are at. I think we could probably do with you know this is a forum that we would probably consider doing is genomics hype or reality. You know what genomics in cancer what where*

Topic	*Representative quotes*
genomics (incl. genetic tests)	*are we at. And that might be quite a good GP training offering. (023_EDU, convenor of ongoing program/resource)* *An overview of the platforms and what we can do with them what we cannot do and understand their possibilities and limitations. Where we are at now. And then a bit of how to deal with the practical side of what we do once we have results of all these tests. (031_EDU, convenor of university course/subject)* *what I feel the health professionals need to know the difference between what is being measured and what isn't, e.g., if you send off for variant sequencing what does that truly give you is it quality data and low coverage can you say for sure that you haven't got something or that you have got something else but also can you look at a deletion what can you analyse what can you measure with that technology and what are the caveats? And I guess that's a reasonably high level of understanding about what's being offered but there is nothing that's necessary in reporting it back to patients (041_EDU, convenor of MOOC)* *Well I guess they need to know the scope of how it's going to fit in with health care generally. And for example with the new tests that are being slowly made available to just have an understanding of the scope of what those tests can do but also the limitations and I think that often people feel that it's going to give them very definitive answers and in some cases it can do but it can also obviously raise a whole lot of other things and a lot of uncertainties. And I think that's quite hard for people to get their head around, (074_EDU, convenor of university course/subject)*
Latest updates/ advanced genomics and clinical genomics	*I think I think we've probably pretty much covered it in terms of you know just basically being that that need- an awareness even among specialists who are actually working in the field you know and researchers who are working in the field that awareness that the opportunities are there but they're not quite sure exactly how and when and if it's going to be possible to apply those genomics and what they actually are. What does it mean for their practice. (023_EDU, convenor of ongoing program/resource)* *(the course covers) sort of the latest cutting edge ways in which things are done. Yeah I can imagine a lot of these like metabolomics and proteomics and these sorts of approaches and genetics- They are more and more increasingly going to be used in the medical diagnostic labs. And particularly I mean mass spectrometry is used now. So I guess an understanding of how those techniques work. It's critical for doctors, nurses and medical professionals to make decisions about how relevant and how reliable the testing is that's being done and background information. (018_EDU, convenor of university course/subject)* *I'm speculating here maybe it could be a training consideration of how previously we have been trained in as you see in that real Mendelian, causal type way. . ...Whereas now you know the gene-environment interaction it's sort of a term or concept that I'm not sure is a very strong one. So yes you've got this variation therefore it must do something, without the understanding of how is it linked with the environment. You know the environment is still a major player. If so maybe this variation doesn't mean anything. Even though from a biochemical perspective. You can see it in the biochemical pathways. Look there is where it is. That's what it looks like it does the what's that translation into health- how does actually- what do we see. . ...Yes we all have variations. I think it's that concept that it's very new to a lot of people. Getting that out. (024_EDU, convenor of MOOC)* *I don't think we need to take basic steps for medical specialists through genomics they don't seem to need to know that and even if they want to know it they will learn it. So it is actually the pointy end of interpreting that report that's the challenge and so I think we need to be very creative in how we enable medical specialists to understand the complexity which then will direct them out to understanding the importance of consent and if you like considering communication and delivering results. (019_EDU, convenor of ongoing program/ resource)* *Given the feedback and working with the students, definitely the beginning is just an awareness of what's out there. . ...There's a lot that are not aware of what's out there, and when you do talk about the different emerging technologies that people can access in a variety of ways- either in a clinical or non-clinical setting,*

Topic	*Representative quotes*
	they're quite surprised by what is available out there. So the first I would say would be an awareness. (009_EDU, convenor of university course/subject)
	From a clinical sense it's more relevant for them to know what this can lead to and what it can do to mitigate it or manage it. I don't think they are so interested in the nitty gritty of genes and genetic interactions and biochemistry from the practitioner side.. . ...they will get a bit of (population genetics, genomic prediction) in their introductory genetics. Their basic knowledge and genetics. Yes I'm sure that all is sorted out. So the next step is understanding it is more quantitative genetics and that's why actually it's quantitative not Mendelian. (031_EDU, convenor of university course/subject)
	I think that would be a bit of an easier way to setup because they will have all the background and you can put it within a quantitative framework. Anything, especially quantitative science, what is genetics from a non-Mendelian perspective. If they know the Mendelian it should not be too much of a stretch for them to understand that side of things. (031_EDU, convenor of university course/subject)
• Exposure to bioinformatics	*I don't think they need to know so much about how to analyse the data from scratch. But more how to understand just the steps in them, what are the implications of that. (031_EDU, convenor of university course/subject)*
	(bioinformatics training is) designed for people to be able to use large amounts of data. So in most cases probably health professionals won't be faced with the sorts of volumes of information that we're feeding the students. It would be more I guess somebody at a higher level running research or epidemiology studies or anything where somebody is dealing with large amounts of data across say multiple patients. . ...But maybe somebody just dealing with single patient records, probably not. Until we get to the stage of personal genome sequencing when that starts becoming standard then there's no then even data on a single person starts becoming pretty much untreatable except by computational analysis. (044_EDU, convenor of university course/subject)
	for that kind of (clinical genomics) background "computational genomics" is the subject that covers that because as I said it sort of teaches you what you can do with sequencing data. And it does that because sequencing is the Swiss Army knife of genomics. . ... And so with that it teaches all the clinically relevant analysis that you can do such as variant calling, structural variants, copy number variants, RNA analysis, etc. That A) gives students an idea of what you can do in genomics. And B) to give the students an idea if they have somebody coming in what the relevant assays may be to get at the pathogenicity of what's going on (053_EDU, convenor of university course/subject)
• Variant analysis and curation	*[Another education provider] can probably tell you more about this that she went the ear to the ground is very much probably the variant curation is very much moving more into the medical specialty realm (022_EDU, convenor of ongoing program/resource)*
	To understand and the delivery in the complexity of interpreting that report I feel pretty strongly and so does [other education provider] that we need to give them an opportunity to have a bit of a look at how you do variant analysis. We are not going to teach that of course but giving them an opportunity to be exposed to that process so that in a way that informs why those results are so complex (019_EDU, convenor of ongoing program/resource)
Basic genetics/ genomics	*(GPs need to know) Fundamentals. In talking to a lot of our bioinformaticians who collaborate with health professionals, often when they're dealing with GPs or people, like for example, nurses, from what they've said, they don't even have a basic understanding of what bioinformatics is, and some of them even need an updating course on genomics because it is such a new field. (011_EDU, convenor of ongoing program/resource)*
	we do everything in the course from first principles and also we're using this technique in the lab we want that to be in the course, my view is yes there is a certain amount of the new approaches but they come and go so fast that filling up the course with a lot of technical detail about the actual technologies that are in use this year won't even be of any use to those people in 2 years' time when MLPA is seen as a bit old fashioned and we are using another approach or

Topic	Representative quotes
	whatever so while I try and keep moderately up-to-date with it, the focus isn't so much on the actual technologies as all of the stuff that you are going to need to be able to understand what the technologies are telling you, and that ability will help people whether they're undergraduates or medicos will help them all the way through their career (063_EDU, convenor of university course/subject)
	We run this course. What I find is that so for the first like two hours almost I have to give an introduction to just basic genomics or genetics even, because yeah we get a range of people doing the course and yet some have no background in their genetics. And so you know you type so I guess it should be an elective for people who don't have the background they need to do a couple of hours of primer on it. (028_EDU, convenor of university course/subject and ongoing program/resource)
	many healthcare professionals not traditionally involved in genetic testing or that being trained clinically in genetics seem to have I guess not very good- their basic genetics 101- whether they learned it at uni or not is not very strong you know that probably haven't used it for a very long time. The genetic potential that they learned you know 10, 20 years ago is you know was very much the classical style of genetics rather than you know what we know now from when a human genome project was finished. And so it is creating a lot of confusion in the media. It's creating a lot of confusion in the public health space and in practice as a healthcare professional. (024_EDU, convenor of MOOC)

B.3 Skills

Table B- 3. Future skills required of health professionals

Skill	Representative quotes
Communication	*So we did a needs assessment analysis with GPs and we also piloted the original version with GPs and they wanted an online version as well as some sort of way of helping them, you know, a tool so they could look at. What they asked us was 'can you tell us how to communicate, what to say to patients'. So we decided that we would do an online module with the content that we trialled with them which is very successful and part of that module which is answering questions that you work through. (019_EDU, convenor of ongoing program/resource)*
	(GPs) might know about the gene but they might not know how to communicate that very well to people or how to deal with talking to other family members. I think you know genetic counsellors are very good with all family communication. But I don't think specialists and GPs really know how to use that information when talking about families and things. (015_EDU, convenor of university course/subject and ongoing program/resource)
	I think that they need to be able to communicate well to the patient so they need an understanding of the technology that's out there. And in simple terms so that then they can provide a better service for their patients in a sense that can relate to them and answer their questions. 050_EDU, convenor of ongoing program/ resource)
Decision making	*they're ordering the test so they need to know what will it really measure or am I better off not doing genomics because sometimes you are better off not doing genomics, sometimes the old fashioned techniques are better for what you want to know. So I feel that's quite important to understand when is it relevant to order and or is it relevant to do the old fashioned test? (041_EDU, convenor of MOOC)*
	But so yeah like the topics I kind of looked at it in the podcast was well you know which tests do I need to do a whole genome test? And is that the only way to do it. And if so is that going to drag in all sorts of other problems. Or is there a simpler cheaper way to do to test for this particular disease and that'll kind of cut out a lot of the anxiety. So to be honest I don't know if that's already common knowledge. (068_EDU, convenor of ongoing program/resource)

B.4 Secondary outcomes

Table B- 4. Secondary outcomes beneficial to health professionals

Outcome	*Representative quotes*
Confidence	*I think the education they need is really just that front face when a patient asks that question how they can confidently respond, know who to refer to for further advice. . ... it's the lack of the knowledge causes an issue around confidence. So I think if you're a practitioner and you're not confident in speaking about it there's that danger that the advice is maybe not wrong but the patient might not be quite getting exactly what they should be getting or need to get to help them and get the right advice. So it's really addressing those confidence levels. (024_EDU, convenor of MOOC)* *I mean GPs are confronted now with a lot of questions from their patients particularly about things that are new and you know unfortunately things like to direct to consumer genetic testing has increased the burden for GPs in that respect. So the word confident is probably right because they just need to know what they don't know and be able to confidently say to someone- either you know that testing isn't appropriate and not accurate and you shouldn't have you know you don't need to worry about it or you should be referred to a genetic counsellor because you might need further investigation, etc. (029_EDU, convenor of ongoing program/resource)*
Independent learning • Finding resources • Using databases • Analysing research	*So yeah right at this point obviously learning how to use that database would be quite an important thing for I would imagine any clinical genetic pathologists and I'm sure a lot of them who knows about it would be using it already to help them interpret the variants. So that's kind of a specific thing. And that will change. I mean I'm sure there will be newer versions of out in years to come. So then I guess in the end it's more about how do you get into a mindset of finding out what the best resources to use and then how to use that. . ...it's hard but that's what I think would be useful. So it's something to teach them. It's still good to have an idea of what data is available. But you know it's more how to use it properly. (028_EDU, convenor of university course/subject and ongoing program/resource)* *So I guess it's more to train (dieticians) to be able to ask the questions that are required to get an understanding of the case. So I'm looking at a research paper that you know is steeped in genetics what do I need to consider to be able to critically analyse this. I have got a test from a biotechnology company in front of me you know what I look out for. How should I understand if this is legit or if it's you know the potential if the accuracy is going to be good you know things like that. Can I use really any of this information or not. (024_EDU, convenor of MOOC)*

B.5 Internal factors driving success

B.5.1 Learner attributes

Table B- 5. Audience attributes leading to successful genomics education

Attribute	*Representative quotes*
Perceived need, interest and attitudes	*the GP [name] module was a good one because they approached us about developing it so the benefit of that is the carrot is better than the stick when someone comes to you, you are able to put in good process. (019_EDU, convenor of ongoing program/resource)* *I think nursing is a good illustration of a group that are avid for knowledge. They are essentially aware that there are new ways of approaching treatment. There are new emerging new treatments. There's genomics which may be determining influencing what types of treatment that you get and that you know they they'd like to know more around this. They'll sign up for anything that's going basically if they could. They are given a certain amount of time that they can go and do extra training. But to my way of thinking there's nothing that's really coordinated to their needs. And so they're just kind of grasping at anything that's sort of going. (023_EDU, convenor of ongoing program/resource)*

Attribute	*Representative quotes*
	so we actually we did see an increase in knowledge and attitude and skills I mean not a massive increase. The evidence is that you never see major changes even with an intervention. Yes that's the way it is. These were probably also fairly early adopters who were interested already. (058_EDU, convenor of ongoing program/resource)
	the introductory (short course) clearly there is enormous appetite and we clearly have to do it every year. (056_EDU, convenor of ongoing program/resource)
	there's definitely a need and a lot of interest from a lot of people to get some upskilling in genomics and curation so that's the primary driver of those (workshops). . ...I think as time has gone on there's actually been more interest, there's been slowly increasing interest from other specialists. So renal physicians, cardiologists, they've actually been coming, and neurology. It hasn't been limited strictly to genetics people, it's now been opened up. (007_EDU, convenor of ongoing program/resource)
	the limitation in a sense is getting them to go to these things. So that they've realized that it is important to be aware of these things. (050_EDU, convenor of ongoing program/resource)
Self-directed learning	*And so that's a lot of self-directed learning that has to happen. We can't offer all the training. So we you know we set the curriculum we periodically update the curriculum and we run assessments essentially off those curricula. And so the knowledge base and the practical skills are all defined in those training handbooks and our assessments the exam you know anything that is listed is fair game right. We don't run tailored training for them. They have to do it themselves. That's the same in all of the medical colleges. It's the only real way you can do it. (056_EDU, convenor of ongoing program/resource)*
	the thing is about health professionals particularly the specialists, they're very smart so they pick things up pretty quick. So not really too worried about them. They've obviously shown that they can educate themselves. They've been educating themselves their whole life. (068_EDU, convenor of ongoing program/ resource)

B.5.2 Education attributes

Table B- 6. Education activity attributes leading to successful genomics education

Attribute	*Representative quotes*
Tailored to audience	*The only thing I would say for the melanoma and skin cancers is they're sort of quite- the specialists in that area are fairly varied. So you have oncologists you know immune-oncologists and surgeons, plastic surgeons who may not know a lot about genomics you have dermatologists who are probably the key group who probably need to know more some more about genomics and so probably the dermatologist and the oncologists. But there is a big difference split there. (023_EDU, convenor of ongoing program/resource)*
	I talk to a lot of people in my role and this goes all the way from genetic counsellors to clinical geneticists, medical specialists, and it's very interesting to see where they're at, and also the information they require I find would really differs depending on what field they're in. Cardiologists for example, differ quite a lot from nephrologists and some people require broader genetic testing whereas others are looking at really doing single gene tests or very small panels or something. So the different fields and different specialists are at very different stages and requirements at genetic testing and I think developing material, I don't know whether it be webinars or things for specific areas. . ...So in the renal space for example, genomics and genetic testing hasn't hit them in a big way, you know whereas a cardiologist is much more aware of genetic testing and the benefits and limitations and all of that in their field. So if we developed information specific to renal genetic testing and what is offered and the benefits and would include everything from what tests are available, how to order a test, advantages of testing, counselling patients. It's also dependent on whether you want to open it up for a nephrologist to order a test if you want to maintain

Attribute	*Representative quotes*
	testing to the clinics, so I think it really depends on your target audience and who you want to educate. (010_EDU, convenor of ongoing program/resource)
	the world of genetics is becoming tailored to each of the disciplines. Our world traditionally being mostly working towards the need- setting the needs of doctors involved with either paediatrics or pregnancy. . ...But now cancer predominates. So you know what I'd expect the average paediatrician to know would be a bit different to the average foetal medicine specialist or obstetrician who isn't a foetal medicine specialist or dermatologist- they are kind of different worlds of patients with different problems. So. . ...to my mind there is three classes of basic classes. . ...You've got the undifferentiated doctors just come out of medical school. . ...So we assume that the starting level was. . ...the lowest denominator of all the medical graduates coming out of the Australian medical schools. And that way we would not leave anybody behind. So we assumed the registrars were at that level. . ... I wouldn't assume the GPs to be at that level. In fact I regard the GP as a specialist but in general practice. And so paediatricians the specialist in child health, cardiologist, etc., and pathologists would be specialists in a particular laboratory domain but everyone has graduate at different points in history. . ...The Anatomical Pathologist who graduated 30 years ago is going to be one hell of a lot lower than that but they are specialists so you need to be aware of that difference. (056_EDU, convenor of ongoing program/resource)
	So we do sort of run these (information sessions) but in terms of bridge the gap I think it is more at the hospital level for the doctors they need to be educated on their level in the hospital rather than they come to university that probably wouldn't go down as well (071_EDU, convenor of university course/subject)
• Clinically-relevant (e.g., case studies)	*when I'm giving a lecture I try to put a bit more of my human spin on it. . ...Basically I try to give some examples of relevance because people like some things more than others. I mean you can do a prediction of human disease exactly the same way as you predict breeding value in an animal, but if you are interested in humans you don't really care about how well you can select an animal. (031_EDU, convenor of university course/subject)*
	so the videos themselves are case scenarios and what you can see is the GP talking to a patient in a particular scenario and there are a couple of communication skill techniques that are in those. We wrote the scenarios, the patient is actually an actor as is the doctor to achieve that. . ...we ask the GPs to view it and then we ask them to follow the scenarios through looking at a number of the different techniques or looking at each scenario in a different way and then to highlight a couple of things that they take away. . ...It's been very, very successful and we've had excellent evaluations from it and people have reflected later in that it has given them an extraordinary opportunity to reflect on their own practice and make some changes. (019_EDU, convenor of ongoing program/resource)
• Expert status	*someone's got to talk to the clinicians. The clinicians who will take seriously. Otherwise a lot of the people out there actually are sadly quite rudely dismissive. You have to somehow in the conversation convince them of your bona fides . . ...You can usually do it you know just briefly because you know their world. . ...If you don't know their world then they start to you know they kind of think like "where are you coming from." (056_EDU, convenor of ongoing program/ resource)*
Up-to-date	*we're in an era of rapid technology change and a lot of people including many clinical geneticists actually don't really quite have the insight it's really needed these days sadly. (056_EDU, convenor of ongoing program/resource)*
	My main motivation is that things have changed a lot from when I was a student. And nowadays we need to make use of computers and the data has really become very, very large so none of our traditional ways of teaching how to do things really transport to modern datasets (031_EDU, convenor of university course/subject)
Interdisciplinary providers	*(for bioplatforms) you need staff you need developers you need content experts to be able to come together and make sure that actually what you're saying is good. (022_EDU, convenor of ongoing program/resource)*

Attribute	*Representative quotes*
	(To develop education material) So with [university] working alongside a number of members in the department, a number of education specialists, a number of genetic molecular biology specialists. And then dietitians to get more the healthcare side of it you know what are we seeing what's happening in this space and then yet put it putting that together. (024_EDU, convenor of MOOC)

B.6 External factors driving success

Table B- 7. External needs to support health professionals with future genomics

Need	*Representative quotes*
Clearer defined roles	
• Who to refer to	*That was kind of one of the gists of the podcast was not necessarily that you know you've got to know all of this yourself but these are the places where you get information. These are the people you refer to for the more complicated things. I think that's important. (068_EDU, convenor of ongoing program/resource)* *I don't offer testing in my practice- but I still get a lot of people calling up asking for testing. It's like didn't really matter what they say- the first thing is you should speak to a genetic counsellor about that or even GPs. It's a complex one. I sort of suggest clinical geneticists, genetic counsellor to have a conversation first. . ...But a lot of people haven't heard of them or know what they do. So I think a lot it can be sometimes hard to see one as well especially from a self-referral. So It's those people that are seeking out their own answers and trying to get them to the right people I think can be hard. (024_EDU, convenor of MOOC)*
• Interpreting genetic reports	*So it is actually the pointy end of interpreting that report that's the challenge and so I think we need to be very creative in how we enable medical specialists to understand the complexity which then will direct them out to understanding the importance of consent and if you like considering communication and delivering results. (019_EDU, convenor of ongoing program/resource)* *So I guess anyone that is taking samples for testing or perhaps even more so communicating the results of test back to patients if those tests are genomic based. So really needs to know what's going on through testing and what the interpretation of the results might be. (044_EDU, convenor of university course/subject)* *I think probably the specialists who are in the public system who get exposed to more things might be might be across (genomics) a little bit better there might be people who are working privately who are less up to speed and they get a report and either over or under call the content of the report. (043_EDU, convenor of ongoing program/resource)*
• Do not need to know details of genomics	*I mean at the moment they don't need to know anything because it's just it's too hard to in general to access it. Physicians are probably the most important interest group. Personally I think as a physician it is too hard to expect people to get the average exome report coming back and getting them to make sense of it unless they have a special interest in the subject. I think in terms of picking you know known mutations you take a number of genetic diseases many of which are going to present in childhood. I think that if they can get a report that says this person has Duchennes Muscular Dystrophy then I think that's very useful. If it says you've got a loss of function mutation in this gene which is heterozygous and of uncertain significance that's not going to be of use. So at this stage I think they need to know the concepts of and screening of clear genetic diseases when the diagnosis is not obvious. But in terms of the nitty gritty of interpreting the exome report, I think that is way out of left you know way out of contention in terms of what a general doctor is going to be able to take on. (042_EDU, convenor of ongoing program/resource)* *I mean we're having enough trouble maintaining the competence and confidence of our non-genetic pathologists in genomics and genetics molecular pathology et cetera. . ...it's a bit like expecting a GP to know something about the latest in neurosurgery. And have confidence or competence in that area in managing their patients and I guess we here at the college are probably would like to provide some of that guidance. We certainly have fact sheets on our*

Need	*Representative quotes*
	website. . ... But somebody needs to define just how much knowledge and confidence they should have and I don't think there's anything wrong with them leaving quite a lot of that with the clinical geneticist and the genetic pathologists because. . ...they're extremely busy they've got a lot to deal with and they need to be able to confidently refer I suppose and confidently not mess up the interpretation of results that they shouldn't feel like they need to be competent in genomics (029_EDU, convenor of ongoing program/resource)
More collaboration with and support from genomic specialists	*Yeah, they may ask me how to interpret a particular result or what the best way of investigating something is what the most appropriate investigations may be. You know they may have a diagnosis that they're suspecting and may want to know how do I confirm that in the best possible way or the most efficient way how do I get access to this- all sorts of things. What does this result mean. I mean that's what a pathologist does. They advise about tests and the best ways to use them and how to interpret the results. (051_EDU, convenor of ongoing program/resource) (Genetic pathologist)* *I think it needs to be a dialogue between the two groups (health professionals and bioinformaticians), as you were asking me these questions, what I am realising more and more is I don't actually know very many medical people and I don't have much engagement with them on a daily basis. Most of the people I work with are either other bioinformaticians or biologists, and the biologists aren't necessarily medical biologists in the sense that they might be more. . ...scientists (012_EDU, convenor of university course/subject) (Bioinformatician)* *people writing the report should be writing so that health professionals don't need to interpret really, essentially that means it makes it easier so you've got to teach the health professionals what needs to be order and when each thing should be most appropriate when the report is delivered back it is actually much easier genetic lab because their reports genomics labs should deliver their reports in a particular way as well to mean you actually don't depending on the interpretation the interpreting is done by the genomics. But I guess that is hard because the genomics facility probably don't want to have that responsibility either (041_EDU, convenor of MOOC)* *I guess it's been talked about for a while that you know a good model for a big enough GP superclinic would be to have a genetic counsellor either full time or part time. And I guess you know realistically it's going to be very hard for GPs is to become familiar with things unless they are sitting in with a genetics expert be that a genetic counsellor or a clinical geneticist or genetic pathologist to really understand interpretation of results. (029_EDU, convenor of ongoing program/ resource)*
More guidelines and resources	*And so for non-genetic medical specialists I think we certainly need resources- online resources- to assist when they run into issues (029_EDU, convenor of ongoing program/resource)* *if they're not going to be able to access geneticists or genetic counsellors then they're going to need to be able to have some way of finding accurate information (074_EDU, convenor of university course/subject)* *when you look at a lot of genetic tests you know the education around the terminology is not there. So yeah C677T to them is like a different language. I don't even know what that means. So to have that resource to kind of explain a case. This is the result I get on my test. This is the interpretation in two lines. But okay you know potentially no effect. OK. No supplementation or no change in folate required or whatever the result might be. That is such a good resource for them. (024_EDU, convenor of MOOC)* *health care professionals I think are screaming out for practice guidelines. And more information around what they should be doing. . ...That MTHFR factsheet is something that as soon as you tell you know I share that quite a lot with dieticians when they're looking for advice around MTHFR. It's like oh my god it's something. . ...there's nothing else out there. They are looking for an evidence base. And this is one reason why we had thought about this idea of the systematic reviews is because- Otherwise as a sole dietician to then sort of think oh I've got this question on MTHFR what should I do. You have to go and collate all the information yourself from all the different studies. (024_EDU, convenor of MOOC)*

Need	*Representative quotes*
	There's a lot of questions that patients do come up with that might not be that straightforward. So if there was an education or just a pamphlet, or reading material that a doctor could hand to a patient that covers all those common questions and if the patient wants to find out more then there would be a hotline, or a genetic counsellor that would support specialists for example. (010_EDU, convenor of ongoing program/resource)
More public education (incl. media)	*There is enough misinformation amongst patients that does an enormous amount of damage where it is interpreted in the wrong context. I don't think you can expect every medical practitioner especially a general practitioner or otherwise to have a specialty knowledge of genomics so you need to have a gateway. (042_EDU, convenor of ongoing program/resource)* *In the last 5 or 6 years in particular there have been more and more articles in the newspapers and things talking about findings that are found in the scientific literature, and these findings they are making are relevant to what people eat, what they worry about in terms of their exposure to the environment and what they might have inherited from their parents but the issue is the public is not very well educated in epigenetics. It is often the vast majority of the people wouldn't know what the term means so then when you are reading the newspaper articles you've got no capacity to assess what is just propaganda and what's real and so what I wanted to do was to provide some level of education that was out there and the course is really for the advanced undergraduate not like for your general lay community there are aspects that can be covered that can be relevant but in general I wanted to provide some education out there in this really topical area for people to be able to access if they wanted to and that's what happened (041_EDU, convenor of MOOC)* *Well I think one of the things that worries me is that there is a lot of talk in the media and there is a lot of advertising from companies to provide information to people about genetics and genomics. Ancestry.com is reasonable and that makes sense it's not really looking at genetics it's just people interested in their pedigrees and backgrounds. 23 and Me is a bit different that's out there and some people know about that and then there are various other companies that say that they can provide information on this and that or whatever for you. I really think this is an area that's a real problem that there's a lot of information out there and people without the background have no idea what's legit and what's not legit, and this is why there's a need to upskill people. . ...I think a lot of the media and these are people I would also like to see learning more, a lot of media journalists who write some things, don't have the background to understand what they're writing about a lot of the time. I'm not saying they beat it up but they don't actually know what they are saying too, so if they don't put their factual information that people read, people don't actually understand it that way too. Science journalists I think there should be a hell of a lot more of them, there's not many of them around it would be nice to have the people with the training (067_EDU, convenor of university course/subject)* *If you have a workforce generally that is unknowledgeable about genomic testing and you have a population who's been fed a story by media that you know genomic testing is here and you know personalized medicine and this is the future and stuff. They will feel as if they're not getting the right care if they don't have a GP who can explain to them what genomic testing is and or a specialist who can tell them you know yes you can have this genomic testing or a nurse who can help to interpret for them when they're you know having their care. Why am I being given this drug? What does this mean? I-you know- have I been- had my genome of my tumour tested for example. So I think the problem is that you know there's a public expectation which is running ahead of what what's actually happening and what's actually available. (023_EDU, convenor of ongoing program/resource)*

B.7 Challenges

Table B- 8. Challenges which impede health professionals successfully using genomics

Challenge	*Representative quotes*
Genomics not used routinely	*But there won't be a lot (of genomics content in resource) because at this point in time how does genomics impact on the GPs you know management of that patient. It doesn't really. Because for many things you'd be expecting a GP to be referring. (058_EDU, convenor of ongoing program/resource)* *I think genetics and genomics is a kind of a new field and there's a lot of stuff coming in which is rapidly changing. And I think that does take a little while to filter through to a normal practice. You know it's not part of routine practice for many specialties although it has you know it's been part of routine practice for paediatrics. . ...So because it's in such a state of flux I don't think that everybody is at the same level of knowledge or can they be until things kind of you know stabilize if you like. . ...I think some specialists and some specialties where there isn't potentially a lot of application to their specialty it may pass them by. But I think for some others they will get on board. I mean you know I mean a good example is you know obstetrics and NIPT for example where this has kind of swept through and they really understand it now. (051_EDU, convenor of ongoing program/resource)* *One of the things that's happening is because of the cost of sequencing tumours it's not done routinely in pathology obviously. They're not you know because of the moving target of mutations in tumours. It's not something that's considered to be a very you know a very useful. . ... in some areas is starting to be a bit prognostic but it's not something that is done as a routine diagnostic thing now (023_EDU, convenor of ongoing program/resource)* *the limitation in a sense is getting them to go to these things. So that they've realised that it is important to be aware of these things. (050_EDU, convenor of ongoing program/resource)*
• Lack of (perceived) need	*And it didn't raise the questions that we know that were raised by the genomics for genetic counsellors thing a couple of years ago which was why are genetic counsellors learning this stuff. They have a particular role. So there were a number of people that we knew weren't allowed. . ...to go to that or certainly went through some very significant questioning from their workplaces about what value this professional development was. (022_EDU, convenor of ongoing program/resource)* *I wouldn't personally think it's realistic to educate most health professionals to understand you know really when a whole exome or a whole genome is an appropriate test. And you know you wouldn't- They may I'm sure many would be interested in being able to order specific single gene tests you know potentially even things like fragile X syndrome or clotting factor disorders or the NIPT sort of things. I mean you know you're obviously getting upskilling within certain groups of neurologists and cardiologists and obstetricians in genetics. But yes. In terms of referrers there's very different levels of you know what in my view should be ordered by non-specialists. (029_EDU, convenor of ongoing program/ resource)*
Perceived complexity	*it's another extremely complex pure science like immunology. Look I am flat out- I get a lot of referrals from GPs in the field of immunology and their understanding basic immunological disease is I think quite poor. But they know enough to say I think you need to see an immunologist. And if you add on that that they should know how to interpret a genetics report well it's not going to happen. (041_EDU, convenor of MOOC)* *So I think if you're a practitioner and you're not confident in speaking about it there's that danger that the advice is maybe not wrong but the patient might not be quite getting exactly what they should be getting or need to get to help them and get the right advice. So it's really addressing those confidence levels. There's some basic information for them. I think just the first step. (024_EDU, convenor of MOOC)* *genetics lends itself to being a continuum of learning because it is so complex, it's good to take it in stages I think. (013_EDU, convenor of ongoing program/ resource)*

Challenge	*Representative quotes*
	You know they will sort of throw around ideas and one of them one at one of the things is that genomics is a hot topic. Some you know a lot of people don't know a lot about and some physicians are intimidated by it (068_EDU, convenor of ongoing program/resource)
Diverse knowledge levels	*I guess the most difficult thing that we face is trying to approach things at a level because there's so much variation between how much exposure people have had to the different approaches and techniques before they get to the course (018_EDU, convenor of university course/subject)* *I definitely think there are different needs in that group, and I think it's essentially a spectrum- you have people who need very, very basic understanding, they need foundational material I should say, and then you also have people at the other end of the spectrum who need to understand how to read reports, interpret the reports and also the pipelines as well I suppose, so I definitely think that there is a continuum. I don't think there is necessarily one workshop or one training solution for all. (011_EDU, convenor of ongoing program/resource)* *It varies a lot. So some students coming through with almost no previous encounters with computational analysis and they can really struggle. So some students find it really hard. Others if they have some of them come through with a computer science degree then it's trivially easy. So that's a problem for us to solve in the future I think is to try and find a way of teaching all the students whatever the background they have. (044_EDU, convenor of university course/ subject)* *There is broader interest. So the ones- the courses have been aimed at senior genetic people initially who were a bit startled to find that were getting people enrolling from other disciplines. So there were anatomical pathologists, haematologists, so more lab scientist folk, or lab pathologists tending to enrol. We had the odd physician and just occasionally you'd have possibly a paediatrician or a physician who has got some kind of interest who enrolled as well as they were in advanced programs and quite early on we realized that it was actually not helpful to them. So we were discouraging those people. . ...it went straight over their heads and they were getting very irritated because it was going straight over their heads they were not our target audience and we were unashamed about that. . ...after the first course we realized there were a few people who you know we made that very explicit that they hadn't read the instructions. And then when they arrived to realize that they weren't the target audience and they weren't comprehending much of it. Well most them kind of left. Sadly, not sadly, it was just unfortunate. (056_EDU, convenor of ongoing program/resource)*
Rapidly changing field	*I mean it's quite tricky. The field is moving so quickly you know like even for the teacher it is difficult. Every year I do basically-update a lot of things because it simply changed a lot. (028_EDU, convenor of university course/subject and ongoing program/resource)* *but you know it really is so complex and so rapidly changing that it's almost better to say to people don't rely on direct to consumer testing. But if you are interested or you do have a family history you know here are some of the referral pathways. (029_EDU, convenor of ongoing program/resource)*
Insufficient time • Health professionals	*so what that lends itself to though unfortunately is time and so you need time to do an introduction to all the issues so that they can do that. So in the Master's program students have a day really an afternoon then they have another day so it's virtually a whole day that program of which we could do with medical specialists but I'd be unsure if they'd take the time to do that..... the medical specialist who's just part of here might say I really do need to probably order that genome test. . ...Now that person doesn't want to go and do their PhD but they just wondered if they got that result what would it look like (019_EDU, convenor of ongoing program/resource)* *we did actually try to hold information sessions for example not for doctors though more for lab managers on how to be able to convey the message across accurately to the doctors. But that initiative wasn't very successful a lot of these lab supervisors are very very busy always on shifts and you know so it wasn't really*

Challenge	*Representative quotes*
• Education providers	*I would say the most effective way to try to mediate that gap, but then it's really hard doctors are generally always very busy and different hours and things like that. (071_EDU, convenor of university course/subject)* *Competition for brains. That's the challenge. GPs and Other groups are also busy with things so actually having them have sufficient interests to devote significant time to it's a challenge unless unless they're confronting it in their practice and finding it frustrating. (029_EDU, convenor of ongoing program/resource)* *to get (the course) up and going we just need a person to put significant time in to doing it and I'm afraid I can't walk away from my 1200 person institute and spend my entire life doing it (067_EDU, convenor of university course/subject)*
Limited funding • Challenge for keeping updated	*Yeah I guess it's very difficult because (MOOCs are) free. You have to find some sort of source to continually fund it you know especially with personalized medicine. There's only so long you can keep the material before you need to update. (064_EDU, convenor of MOOC)* *Well so again the conversation. . ...would be trying to figure out what could we do- and with bioplatforms- what could we do with what is there. But the thing is online stuff costs. . ...a lot. So it would have to be first off made, second off futureproofed, thirdly maintained. (022_EDU, convenor of ongoing program/ resource)* *We are limited by our budget, so we can't do too many videos, for example, we don't have the funds to employ actors to do scenarios in that sense, and so I think that that's going to be up to [the institute], to fit within the budget, that we've given them to use the best way, whether it's an animation, whether it's text and then questions, I am not sure exactly. (013_EDU, convenor of ongoing program/resource)*
Unsystematic resources (incl. research)	*So one of the issues that I find is that there's actually a lot of fragmentation in genetics and genomics education around the world. And so it's at this point that I really wanted to just make sure that. . ...we were using what was already available. And that's what I think needs to happen. (022_EDU, convenor of ongoing program/resource)* *I guess sometimes the lack of the way that research can be carried out isn't standard you know. So for example we just finished a systematic review looking at zinc and. . ...our genes you know looking at basically what's out what's in it doesn't matter what SNPs or any sort of health background and zinc. . ...what was very hard to do was put all that information together because different SNPs were used in regards to different health conditions and then zinc status that was measured was different across the board so each study is difficult to compare (024_EDU, convenor of MOOC)*
Informal external learning	*a paediatrician or an immunologist or somebody who did not learn this in their curriculum in their training relying on recently acquired knowledge that they probably pursue themselves rather than being part of a structured education program. (029_EDU, convenor of ongoing program/resource)* *Well most labs have no educational training. Training is more like learning the techniques on-site but it doesn't actually provide the content or the background or the knowledge of how does this method work, why would you use this method as against another method or what are the basic skills and things you need to know about not just the technology but the analysis of the results you get about the databases you should compare things to, about the statistics and probability... (067_EDU, convenor of university course/subject)*