Teamwork in clinical genomics

**Teamwork in clinical genomics: A dynamic sociotechnical healthcare setting**

Running title: Teamwork in clinical genomics

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**Introduction**

Clinical genomics, reading a person’s entire genetic material to deliver optimal healthcare benefit, is a complex transformative approach to patient care offering the potential for timely and accurate diagnosis and personalised treatment plans for many patients, particularly those with rare diseases and cancer.\(^1\) Although traditional and established healthcare services are adapting as resources diminish and expectations shift, the demand for rapid change at scale found in the new field of clinical genomics merits attention.\(^2\) The promise of this new technology is to be delivered by novel teams, with the close interaction of health scientists and healthcare practitioners spanning a range of disciplines.\(^3\) Uniting traditional individual ‘silos’ in healthcare is already known to be challenging\(^4\) as healthcare professionals prefer working in homogenous groups, often behind ‘invisible walls’.\(^5\) The necessity for cross-discipline collegiality in clinical genomics due to the emergent work order – that Engeström called “knotworking”\(^6\) – is further challenged by the speed and scale at which the field is evolving,\(^7\) with new discoveries and technological advances threatening to unhinge any delicately emerging team ‘norming’.\(^8\) Understanding how team members work together to cope in this less traditional and more fluid environment is valuable when implementing new complex clinical technologies.

**Clinical Genomics:** Genomic sequencing is the process of generating genetic information ready for interpretation.\(^9\) Initial sequencing of the human genome was undertaken at the turn of the century, costing over US$1 billion and taking over 10 years to complete.\(^10\) Today it is possible to sequence a whole genome in a few days at a markedly reduced cost of less
Teamwork in clinical genomics

than US$1,000.\textsuperscript{11} This shift in cost and timeframe has expedited the use of genomic sequencing into the healthcare environment, particularly for rare diseases and cancers. As our understanding of the genomic determinants of health grows, and the knowledge and skills in interpreting genomic data continually develop, the understanding of which gene variations may be pathogenic (disease causing) and those that are not is continuously changing. Coupled with the production of a median of 4.8 gigabytes of data per patient through genomic sequencing, this state of affairs presents clinicians and scientists with an incessant uphill challenge of remaining up to date. The lengthy process of curating gene variants for each patient, to establish if they are disease-causing, requires extensive interpretation and each sphere of knowledge and skills (clinical and scientific) in isolation is of little use in the clinical genomics setting: only when clinical knowledge of the patient’s features (phenotype) and scientific knowledge about genetic variation (genotype) are brought together can any meaningful clinical interpretation be achieved (figure 1).

Bringing genomic sequencing into the clinical setting obliges clinical and healthcare scientist professionals to actively collaborate, demanding unprecedented levels of interdependency. Once the decision has been made to pursue genomic sequencing, clinicians and scientists need to work together to establish the most appropriate testing and then interpret the findings relevant for each patient (highlighted circle, figure 1). Each profession brings expert knowledge into the decision-making process and testing cannot be completed without multilateral engagement.

\textbf{Insert Figure 1:} The interdependency and evolving nature of clinical and scientific knowledge clinical genomics with a simplified example of steps required for genomic testing
Teamwork in clinical genomics

and potential professions involved. *curation refers to the process of establishing which gene variants should be examined as potentially disease-causing. Source, authors’ representation

**Teamwork:** Teamwork is a well-studied concept, with a commonly used definition of a team as a ‘*distinguishable set of two or more people who interact, dynamically, interdependently, and adaptively toward a common and valued goal/objective/mission*’.\textsuperscript{14, p4}

Many key features contributing to successful teamworking have been identified such as: the need for leadership, communication and joint education\textsuperscript{13}; appropriate skills for the setting\textsuperscript{14}; and organisational factors e.g., positive perceptions of staffing and management support.\textsuperscript{15} Yet, these studies were focused on healthcare environments such as primary care or palliative care, which one could argue have a relatively stable evidence-base and processes. Genomics in contrast is more dynamic and emergent.

Teamwork requires a ‘contingency approach’ rather than existing on a linear hierarchical perspective of bad to good\textsuperscript{23} with a more graded understanding of the team and context, and how the team complements the clinical needs of the local population: in essence, how the team is adaptable to the presenting context. The concept of this ‘adaptive zone’ has been identified in complexity leadership, existing in the overlap between standalone operational and innovation spaces, as a temporary area permitting freedom of movement for information to facilitate the creation of new ideas.\textsuperscript{17} Typically, teams working in a new area will start in the innovation space and transition to the operational space via the adaptive zone.

As the range of highly dynamic areas of health care have grown (e.g., clinical informatics, AI in medicine, emergency medicine, clinical genomics) so too has research interest in this field\textsuperscript{18}, from an organizational and individual perspective.\textsuperscript{19, 20} Several components
Teamwork in clinical genomics

influencing team adaptation have been identified. *Temporal fluidity*: Groups need to form rapidly in some clinical settings, for example in the Emergency Department where the nature of patient presentation can lead to ad-hoc team formation\textsuperscript{19} or during a cardiac arrest call where team membership is driven by proximity.\textsuperscript{21} For clinical genomics, although team members do change, the groups are not formed on an ad-hoc basis. Edmondson\textsuperscript{22} stressed the role of teaming - i.e., rapidly formed groups, working in dynamic settings - in particular where innovation is required. *Speed of decision-making*: the nature of a patient’s presentation will impact the need for team adaptation. For example, paramedic decision-making for prehospital thrombolysis may require rapid decision-making,\textsuperscript{23} while discussing the use of anti-depressants may permit more reflective practice and so an opportunity to broaden team input. With the exception of ultra-rapid genomics e.g. urgent childhood brain cancer, decision-making in clinical genomics does not need to be instant allowing discussion on optimal variant interpretation or clinical management. *Complexity of team composition*: the need for team adaptation arises when professionals are drawn from across organisational boundaries and professional groups\textsuperscript{24,25} as organisational structures and professional expectations vary amongst team members. For example, teams including members from healthcare and social services will have differing views on priorities for patient outcomes as well as organisational matters such as pay scales or key performance indicators.\textsuperscript{13} The broad range of professions engaging with clinical genomics (figure 1) reflects the high complexity of team composition as teams are drawn from laboratories, medical professions and across organisational boundaries.

Our focus in this study has therefore centred on clinical genomic team members, as they negotiate and enact teamworking between different professional perspectives and, significantly, as they continue to renegotiate and enact as the presenting context (e.g., team
Teamwork in clinical genomics

knowledge, expectations, role delineation), continually shifts. In particular, we ask, what are the key factors that influence teamworking in clinical genomics and how can they be applied in practice?

Methods

Study Context and Design: Worldwide, there is substantial government investment in the use of genomics in healthcare with a range of national genomic initiatives funded to accelerate implementation (e.g., Genomics England, China Precision Medicine Initiative, and Australian Genomics).\textsuperscript{1} In Australia, clinical genomics has been supported at a national level through Australian Genomics Health Alliance\textsuperscript{26} and also at a state level e.g., Melbourne Genomics Health Alliance.\textsuperscript{27} These organisations typically support a series of short-term funded clinically focused projects aimed at generating clinical and implementation evidence to support the appropriate use of clinical genomics, while simultaneously upskilling the workforce.

We employed an inductive, phenomenological, qualitative study design using datasets from three sets of semi-structured interviews, taken from a larger national implementation programme of research investigating the translation of genomics into clinical practice (table 1).\textsuperscript{28} Set 1 interviews examined, in depth, clinicians’ and organisational experiences of implementation of clinical genomics; Set 2 interviews explored the perceptions of laboratory staff and genetic clinicians to changes in service delivery due to increasing demand for clinical genomics; and Set 3 interviews focused on staff perceptions and experiences of working in clinical genomics.\textsuperscript{29}

Participants and recruitment: In total 140 people were invited to interview by email (SB/LN) and everyone who responded was interviewed. Interviews examining determinants
Teamwork in clinical genomics

influencing implementation of clinical genomics were undertaken in 2018/19 with laboratory scientists, genetic and other medical specialists (n=77). Interviewees were identified by either an expert resource group (set 1), or operational leads (set 2 and 3).

Insert Table 1 Study details about here

Data collection and procedure: One researcher conducted each set of interviews (Set 1 and 3 SB, Set 2 LN) either face to face (n= 52) or via videoconference (n=25) at their workplace. On average the interviews took between 30 and 60 minutes, were audio recorded with participant consent, fully transcribed and managed using NVivo 12 software. Each transcript was given a unique anonymised identifier, numbered and with NGC denoting non-genetic clinicians, GS, genetic staff, LS, laboratory scientists, PO for project officers and S/P for service or programme leads.

Data analysis: We used the Framework approach to analyse all three datasets to identify themes of integrated teamworking in the evolving sociotechnical healthcare context of clinical genomics. The matrix-based method, Framework, has five iterative steps (with the option to loop back at any stage) that directs data analysis: from the initial step of familiarisation with the data to progressing onto mapping the resultant themes. The Framework approach is well suited to managing multiple datasets with the data used typically in text format. Two co-authors (SB and HB) independently coded 10 interview transcripts before discussing themes and findings. Following this discussion the themes were revised and then coding was completed independently (SB). Weekly meetings (SB and HB) over two months allowed the opportunity to discuss challenging areas of coding, to negotiate either changes in coding structure or how to code sections of the transcripts.

Results
Here we report on the characteristics of participants before sharing themes identified from the data.

**Participant characteristics:** The interviews included a broad representation of professions (table 2) and included participants from all Australian states. The high participation from Victoria may reflect the significant investment in genomics in this state through Melbourne Genomics Health Alliance and as the base for coordination for Australian Genomics Health Alliance. Additionally, not all states took part in all of the three studies e.g. study 2, ‘Perceptions of laboratory staff and genetic clinicians to changes in service delivery’ was based in Melbourne and study 3, ‘Perceptions of staff from one area of clinical genomics’ did not include Western Australia.

Insert Table 2: Participant characteristics across the three interview datasets about here

**Themes:** Four overarching themes were identified: i) **The role of the team in keeping knowledge up to date;** the capacity to cope with the speed of evolving information and developing strategies, and being mindful of future activity (e.g., growing independence of non-genetic clinicians and the need for succession planning), ii) **Professional identity, building relationships and respect,** including the need for trust and the ability to disagree, plus the ability to step up while mindful of boundaries, iii) **Team adaptability,** calling for flexibility within the team and developing an iterative process of learning to work together, and finally iv) **Practical/organisational considerations** such as the necessity of good communication, time management for scheduling meetings and funding for multidisciplinary team (MDT) meetings. We present each of the four themes, along with illustrative quotes.
i) The role of the team in keeping knowledge up to date (Box 1): Working in a team played a vital role in maintaining knowledge as the field of genomics evolves. Keeping up to date with current knowledge was recognised as being challenging and participants described the importance of fellow team members for staying informed. While they reported several strategies for staying up to date they placed emphasis on having collective knowledge building, “shared learning is critical” S/P33. Bigger teams, in larger hospitals, felt it might be easier for them, as maintaining current knowledge over time was dependent on the local team. “I guess you bounce ideas off each other and share information.” S/P33

Central to teamworking was the need to grow and share knowledge which manifested in several ways. For example, one non-genetic clinician reported the importance of including the whole team to be able to share each disciplines’ expertise: “I think having corporate knowledge [was helpful]... They’re looking at, not just this project, but all the other projects as well. So, they’re able to draw on experience from the other diseases.” NGC9. The need to share specialised knowledge unselfishly/generously was essential for the clinical success of the team: one example given was distributing a shared spreadsheet with known patient presentations (phenotypes). These opportunities to share expert knowledge had greater potential to present when there was a bigger team.

Positivity was reported, as team members grew their knowledge and started to become more independent decision makers. This development was accompanied by feelings of nervousness by some experts as their knowledge was taken up by others. For example, one genetic clinician described the feeling as, “setting an adolescent child free and [laughs], watching them go off into the wilderness...” S/P&GS27. Others recognised the importance of succession planning and proactively sharing knowledge to develop a sustainable model of
Teamwork in clinical genomics care, as knowledge evolved. One interviewee noted if, “we all learn, and we all expand our knowledge base...I think sharing knowledge is the critical thing.”NGC23.

**Box 1:** Full text quotes for theme i) The role of the team in keeping knowledge up to date

ii) **Professional identity, building relationships and respect (Box 2):** The importance of understanding one’s own and others’ roles in clinical genomics was a strong theme from the interview data. Participants reported the need to build relationships that depend on trust and ensure the ability to disagree. One genetic clinician described a debate over curating a gene stating, it’s “that dialogue enables you to be more confident GS2 in the final decision that is made.

The interdependency noted amongst team members required participants to ‘step up’ and move out of their comfort zones to facilitate teamworking. While some staff may find the process of broadening their experiences challenging, many people found it strengthened the team, saying it has “been quite unifying from a team perspective”GS76. Despite this need for participants’ roles to evolve to meet the changing needs of clinical genomics there was an awareness of not overstepping boundaries. For example, there was concern that participants did not want to be seen to be ‘taking over’ patients from other clinicians. One nongenetic clinician described how they manage referrals inside and out of a genomics clinic and explained that, “I don’t do that [ongoing patient management] in clinic because that’s not my role in the genetics clinic.”NGC12.

Teamworking was seen to be facilitated by the recognition of and the valuing of others, “it helps having multiple opinions in the room.”GS6, in particular from multiple disciplines. These differences of experiences, skills and opinions held the potential to gain the best
result for the patient. Participants were pleased to note that the need for the multidisciplinary team had been recognised by senior managers with funding for the team to meet, “the big guns who are running the team here that have sat up and said, “Yeah, actually we value this [team structure]” GS66.

Box 2: Full text quotes for theme ii) Professional identity, building relationships and respect

iii) Team Adaptability (Box 3): Benefits of having flexibility within the team were identified. One genetic clinician reported the advantages of having several members of the team who could respond to clinical situations as they arose, especially when they were covering other clinics or wards, “because sometimes, we might be doing something where we couldn’t drop what we were doing” GS67. Participants also appreciated having team members who were happy to discuss cases outside of the standard clinical team meetings. This flexibility was particularly welcomed in acute care (set 3 interviews) where genomic results were ‘turned around’ very quickly, i.e., within five days.

Interviewees also noted that developing adaptability amongst the team did not occur by happenstance. Time and effort needs to be invested to learn the best ways to work together in the evolving scenario of clinical genomics. It takes an iterative approach to become, “a team that’s become very good at working together” LS5. However, there are challenges to developing team adaptability e.g., physical attendance. One area some participants found difficult to adapt to was the combination of physical and online attendance at meetings. Maybe surprisingly for a highly technical speciality, participants reported that is was challenging to communicate when people were not in the same room. With some team
members based in other parts of the country, or different hospitals in the same city, this
interviewee recognised the clash of traditional and current technologies “we have some
clinicians ringing in, it’s really hard for them to have that same quality of interaction as being
physically in the room. It strikes me as a really interesting sort of retrograde, it’s like vinyl in
the era of iTunes, you know?” GS4

**Box 3: Full text quotes for theme iii) Team adaptability**

**iv) Practical/organisational considerations (Box 4):** Good organisation was reported as an
essential component to successful team working, including communication. For example, “I
think that’s really important and everyone’s aware of what’s going on.” GS48. However, it
was recognised that working with a wider team was not always easy and required strategies
for managing different team members’ expectations and ways of working. Priorities varied
amongst the various professional roles. Here, a clinician reported, “I like to build structures
around me that, protect me from that uncertainty and the curve balls that tend to find us in
clinical work” NGC63. In common with many projects, longer term funding was highlighted
as an issue. One participant combined concern about sustainable funding (“it needs to be
properly funded” GS71) with the need for team members to bring passion to see clinical
genomics realised in practice, “it requires so much love from the clinical team to make it
happen” GS71.

**Box 4: Full text quotes for theme iv) Practical/organisational considerations**

**Discussion**

This novel study provides insights to advance our thinking on teamwork in dynamic
sociotechnical settings. The unique ecosystem of clinical genomics presents additional
opportunities for clinicians and scientists, to maximise the clinical benefits from new areas of practice such as this. These contemporary settings create new challenges that do not always fit the traditional ways of working and will require team members, organisational and team leaders to adopt innovative strategies to ensure the diagnostic advances of clinical genomics can be realised and the enthusiasm of staff is retained.

From this study we have observed that multidisciplinary teams working in clinical contexts, where new and innovative technologies are being implemented, and that require knowledge and service delivery to continuously evolve, exist in a prolonged adaptive zone. The emerging scientific and clinical knowledge—and skills required to exploit it—are constantly expanding and being pooled in order to advance clinical practice. In contrast to moving through the adaptive zone\(^\text{17}\) (figure 2i) clinical genomics\(^\text{12}^\text{17}\) lingers in the adaptive zone (figure 2ii) with the ongoing discovery of novel genes and establishing pathogenicity.

\textbf{Insert} Figure 2 Locating clinical genomics in the elongated adaptive context, i adapted from Uhl Bein & Arena\(^\text{24}\); ii author’s representation

Since genomics is so fast-paced, and predicated on new discoveries, we think of it being in an elongated adaptive context, exhibiting longitudinal, elastic properties. Considered alongside other influences on teamworking (figure 3) such as temporal fluidity,\(^\text{19,22}\) speed of decision-making\(^\text{23}\) and complexity of team composition,\(^\text{24}\) the adaptive context provides an additional explanatory factor affecting how teams work.
Teamwork in clinical genomics

This paper set out to identify the key factors influencing teamworking in clinical genomics and how they can be applied in practice. For team members finding their way in a new, disruptive and evolving healthcare discipline the blend of keeping knowledge up to date, professional identity and respect, and team adaptability – in addition to any practical/organisational considerations – are all identified as essential themes for teamworking in the rolling, *elongated adaptive context* of new practices and operationalisation. These themes are required to initiate, maintain and further develop fruitful teamworking that can serve to improve patient care in the context of clinical genomics and potentially in other healthcare settings too. Within these themes we can find Edmondson’s pillars of a teaming culture, to be curious, passionate, and empathic – “it requires so much love from the clinical team to make it happen.”

The findings build on previous studies exploring factors impacting on teamworking found in more stable healthcare settings. Themes such as the influence of leadership, communication and the importance of learning together reinforce earlier studies, and the practical considerations for the organisational factors affecting teamworking. The need for roles to expand and scope of practice to be extended has been identified in clinical practice previously, for example, extended scope physiotherapists (ESPs) in musculoskeletal care (e.g. requesting X-rays) and pharmacists in chronic pain clinics (e.g. prescribing medication). However, our findings also stress the significance of the need for team roles to evolve, at speed due to the rapid shifts in knowledge and technology, as team members ‘step up’ to meet the changing demands placed on the team, reflecting the dynamic nature of clinical genomics. There are benefits to extending roles however, there is also a need to be mindful of concerns such as scope of practice boundaries, challenges of interdisciplinary
leadership as well as adequate training to ensure the capabilities of practitioners are appropriate for the role required.\textsuperscript{35,36}

Due to the complexity of clinical genomics, open knowledge sharing was reported as essential. No single person or profession can hold all the knowledge (tacit or explicit) required to translate clinical findings (phenotype) and laboratory findings (genotype) into improved patient care. Nonaka and Takeuchi's\textsuperscript{37} SECI spiral model for knowledge creation and transfer recognises that knowledge needs Socialisation (tacit knowledge that passes on through practice, observation etc.), Externalization (codification of tacit to explicit knowledge), Combination (explicit knowledge sources are combined to create new knowledge) and, Internalization (as explicit knowledge becomes tacit and common practice). Participants recognised the necessity of teamworking in clinical genomics to both socialise (e.g., “I think having corporate knowledge [was helpful]...they’re able to draw on experience from the other diseases.”NGC9) and externalise knowledge (e.g., “I appreciate the opportunity to toss that [information] around with other people”LS49) knowledge. This need obliges highly skilled, autonomous professionals to work together as both experts in their fields and equals, each contributing essential tacit and explicit elements of the knowledge jigsaw to patient selection, testing, interpretation, diagnosis and clinical care. Rather than a single “spiral” of processes, the constantly changing knowledge base requires repeated, interconnected spirals.

Bringing together disparate professional groups is not easy\textsuperscript{38} and demanding the SECI spiral occurs both within and across each profession is a potentially challenging expectation. In essence, it is a dynamic expression of Engeström’s\textsuperscript{5} knotworking. We know knowledge sharing is dependent on culture and the organisational climate,\textsuperscript{39} however there is limited
Teamwork in clinical genomics

evidence on this area within frontline clinical decision makers, such as in clinical genomics. Our findings underline how crucial relationship building is for teams to meaningfully recognise and value the contribution of each team member. As the team evolves individual team members may change, so the need for respect and valuing others may need to be emphasised more formally e.g., as part of specific role descriptions. Again, this recurring process contributes to the elongated adaptive context.

Despite working within a technology-based healthcare setting, participants reported the importance of face to face time with colleagues. Geographical propinquity is known to support ‘spillover’ benefits of knowledge, however the preference for non-virtual modes of meeting (regardless of the inherent organisational challenges) is perhaps surprising in a geographically disparate country like Australia. The preference for in-person meetings could signal the importance placed on meeting face-to-face to negotiate the significance of genotype/phenotype findings and learn from each other while establishing and adapting models of service delivery. Although meeting in person makes it easier to read people in the room, this approach limits the area of influence the elongated adaptive context that clinical genomics lies in (figure 2ii) and does not facilitate the use of clinical genomics outside the immediate environment. In addition, it is not a sustainable use of resources longer term: while face-to-face working may be part of the early phase of working in clinical genomics there is a need to identify how to move away from this approach to virtual communication methods as relationships, understanding and knowledge matures. Perhaps as a consequence of the predominance of face-to-face time, participants did not directly report challenges with the evolving status quo. Although clinical genomics is constantly moving with the rapid generation and application of new knowledge, the need for processes to change and roles to evolve, participants did not report a feeling of disruption. Whether this
acceptance and flexibility will be present with the roll out of genomics amongst less specialised and non co-located teams is unclear.

**Limitations:** Data for this study were drawn from three datasets centred on implementation in clinical genomics. However, there was consistency in the approach to the interviews as one author led all three studies. The advantage of combining the datasets is the wealth of rich data at our disposal to analyse with 77 interviews to interpret, offering good representation of this new concept. However, the interview schedules were not designed specifically to examine teamworking and so the findings could be limited. Nonetheless, the fact that teamworking emerged strongly from the data is an important finding demonstrating it is of significance to those working in the field of clinical genomics. These studies took place in Australia: all health systems have their own idiosyncrasies and different genomic implementation strategies, so the generalisability of our findings will need consideration. However the use of clinical genomics is developing and our findings arguably reflect the diversity of those in sociotechnical teams.

**Implications for implementation and delivery of clinical genomics:** The findings from this study may be generally applicable to other settings where there are rapid changes in knowledge and understanding of the field, frequent technology upgrades and a need for evolving staff roles. Gaining an appreciation of how knowledge, professional identity and respect, team adaptability and practical/organisation considerations interrelate is essential to facilitate teamworking in novel sociotechnical healthcare fields. Table 3 summarises the key concepts of teamworking in clinical genomics and provides potential practice recommendations. Understanding the significance of teamworking in a dynamic setting is vital for both organisational and team leads looking to promote the use of genomics in
clinical practice. These concepts require input from the organisation and individual teams for example, by demonstrating a commitment for working collaboratively to develop an understanding of the complexity of working in this environment for all team members. Learning to work together takes time and is further challenged in the highly elongated adaptive context, with the rapid evolution of the knowledge base, staff roles and technology. Organisational leads also have a key role to play in providing the time and permission for team members to share knowledge and continue to evolve, even though this may challenge existing ways of working, funding or hierarchical structures. Communicating ideas and developing corporate knowledge is central to the growing understanding of this young clinical speciality. Both team and organisational leaders can foster a motivation to learn by developing a culture of ongoing learning alongside practical support such as time for training and education. The success of the genomic team is reliant on team members’ interdependency which requires the building of trustful relationships and open dialogue. Again, organisational and team leaders have a central role to play here, ensuring conflict is well managed and mentoring team members to ensure the team continues to develop alongside progressions in the evidence base. Participants recognised the need for role delineation and importance of succession planning. These skills lie within the remit of organisational and team leaders who can provide guidance on establishing clear boundaries, set expectations of team members and promoting capacity building in line with each professions’ scope of practice and participants’ values and beliefs41,42.

Insert Table 3: Key concepts to facilitate teamworking in novel sociotechnical healthcare fields and potential related practice recommendations
Teamwork in clinical genomics

Examining how the four themes identified in this study interact over time as knowledge and ways of working continue to progress will provide a rich source of ongoing study, and there are many crucial practice questions to be explored. For example: How do team members adopt new roles and stop doing some activities? How do emergent professions negotiate their roles in a changing clinical landscape, especially as accreditation, training and funding to recognise these new roles are lagging behind? Can this information be used to inform the design of an intervention that can support the fluidity of keeping knowledge up to date, professional identity and respect, team adaptability, and practical considerations, particularly in a more dispersed non co-located team?

**Conclusion:** Delivering care in an *elongated adaptive context* brings additional challenges to teamworking as members strive to stay abreast of current knowledge and technology. The significance of understanding how teams – drawing on professions from across the sociotechnical divide – can work together effectively is gathering pace as technology continues to offer new approaches to healthcare provision. Influencing team behaviour and team member experiences will ultimately impact on patient experiences and health outcomes: the findings from this study suggest that successfully negotiating the interplay of the team role and emerging knowledge, professional identity and respect, team adaptability, and organisational considerations will play a key role in ensuring best quality care is provided in a dynamic emergent clinical field.

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Teamwork in clinical genomics


Teamwork in clinical genomics


Teamwork in clinical genomics


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Data availability statement
Data sharing not applicable - participant consent to share transcripts was not received

Conflict of interest statement
The authors declare no conflicts of interest.
### Box 1: Full text quotes for theme i) The role of the team in keeping knowledge up to date

#### i) The role of the team in keeping knowledge up to date:

- “It’s hard to keep up. I think we’re using each other as a team.” S/P27.
- “A big part of what we do is read the literature and talk to peers and go to conferences and professional meetings – but shared learning is really critical and I think it’s much easier to stay on top of that somewhere like the [large tertiary hospital] where there’s a bigger team and I guess you bounce ideas off each other and share information.” S/P33.
- “I think having corporate knowledge [was helpful] …So, I went to all the meetings when we’re looking at patients...I think having both the neurologist and the clinical geneticist and the bioinformatician and the genetic counsellor, so the multidisciplined nature makes it work...They’re looking at, not just this project, but all the other projects as well. So, they’re able to draw on experience from the other diseases.” NGC9.
- “We have an Excel spreadsheet available to us, courtesy of [project leader] and the leadership team which, gives us the [gene] panels that we would likely use for these particular phenotypic presentations.” NGC23.
- “I feel like the times when I think we’re going in the right direction, it’s things like when I see the renal team running a lot of things without a lot of support...but I know in my heart, as much as all geneticists are control freaks and [we] want to keep everything, that we can’t and in some respects it’s like setting an adolescent child free and [laughs], watching them go off into the wilderness...” S/P&GS27.
- “My aim would be that this is something that any member of my team can be part of. I might do one in three clinics, for example and my colleagues would do the other two of three. Because then we all learn, and we all expand our knowledge base...I think sharing knowledge is the critical thing that I would have to build into the system if it was ongoing.” NGC23.
- “I didn’t have much of a background, um, in genetics before and so I certainly attended a few, courses that, [name] provided but I still – I am still not, in a state that I would be comfortable making that decision independently, but I suppose that is why we have got a team meeting anyway. It’s because people can then put in their ideas” NGC11.
- “This is all a team approach. You know, so it involves everybody” S/P&GS36
- “…you’re a team, your job is to make it, like to make sure that you have the most up to date team, and there’s a lot of resources now that, share, like there’s a lot of effort within the [medical speciality] community to combine all these efforts internationally. And so, you have databases of variance that I use and that are updated with a new study being published, and there’s really something that, not at my level but at a higher level, people really try to combine their effort”. NGC17
- “we’ve got a very close knit team here, so we approached it as a team rather than as one person driving a study” NGC70
**Box 2: Full text quotes for theme ii) Professional identity, building relationships and respect**

**ii) Professional identity, building relationships and respect:**

- “When you have rigour and you’re debating variants and you’ve got the scientist in the room who can say to you “but guys, this variant’s got a terrible quality score and it doesn’t even look real, are you sure you want that curated?” that dialogue enables you to be more confident and go “no, I don’t want that curated” GS2.
- “Lots of members of the team have all stepped up and gone over and above their usual commitments to deliver so I think that’s been really good and that’s been quite unifying from a team perspective” GS76.
- If they [the patient] should have been referred earlier, or they need to have a different medical team involved as well, or they would really be better off now if they start on a certain medication. I don’t do that in clinic because that’s not my role in the genetics clinic.” NGC12.
- “it helps having multiple opinions in the room, at the same time, and having the scientist physically present so, you can ask them to pull up specific information that, for example, if we want to look at, how many homozygotes are in gnomAD, [it can be] sorted through immediately.” GS6.
- “This [team structure] has actually been built into the funding of the project. But I very much think it is actually that the big guns who are running the team here that have sat up and said, “Yeah, actually we value this [team structure].” GS66.
- “if we would know that once per week the genetic team comes around we could actually batch questions to them and then discuss the case, and that may just help to build up that relationship. At the moment it is still there but ad hoc” GS56.
- I still think… this kind of approach – still needs geneticists, absolutely needs counsellors, and it absolutely needs geneticists to work as part of the team and delivering health care to baby. Just like we’ve always needed different types of people for, to deliver health care to a complex baby. LS52
- “each individual clinician can’t know everything about every single gene, so, it helps to have that second clinician in the room, often. So, yeah, I think that was, that’s one of the big advantages of the way we currently run things”. GS4.
- “Oh, I’m just a scientist.” I’m, like, “What do you mean you’re just a scientist, because I keep saying you’re a clinician.” And she’s, like, “Oh, no, I’m just a scientist,” and, “No, you look at real patient samples, giving real interpretation images for the other clinicians in the bigger team to give answers to patients, that means you’re part of this team. A diagnostic, genetic scientists doing reporting they’re just as much as part of the clinical team as anyone else.” S/P35.
- “I thought the multidisciplinary team approach worked really, really well, we seemed to have a lot of – all the NICU staff were on board with the project” GS72.
- “I think it would be important to actually, kind of, as the genomics’ team to learn a little bit of how neonatologists, or how PICU people, or how cardiologists, kind of, see the issue and which patient groups they would find interesting”. GS74.
### Box 3: Full text quotes for theme iii) Team adaptability

#### iii) Team Adaptability

- “I think it was really good to have a team of us and not just have one person that was the go to genetic counsellor...so we could share the workload, particularly when we were needed urgently, because sometimes, we might be doing something where we couldn’t drop what we were doing...I think that team approach was really important.” GS67.
- “I appreciate the opportunity to toss that [information] around with other people” LS49.
- “I think you’re getting a consistent approach with a team that’s become very good at working together” LS5.
- “I think email and even teleconference, when we do our MDT, we have some clinicians ringing in, it’s really hard for them to have that same quality of interaction as being physically in the room. It strikes me as a really interesting sort of retrograde, it’s like vinyl in the era of iTunes, you know? It’s never been more important that you actually take the message one human’s trying to communicate to the other and make sure they’re being received and that there’s a proper discussion about it, which is fascinating.” GS4.
- “Another learning that we had was how to communicate with patients as a team with a neonatal intensive care team or a paediatric intensive care team, and what we found with the neonatal intensive care unit is that they didn’t want a genetic counsellor to come along to the results disclosure. They wanted their departmental social worker there. So, we found a different way of disclosing a result” NGC70.
- “we’re probably much less involved in the curation now because the lab has so developed so much skills set. For most cases they are very autonomous, and they contact us if there’s questions, or we have a quarterly meeting, to go through difficult cases.” NGC12.
- “I know it’s taken a lot of work for lots of other people to get it running that way but it’s been a huge undertaking for the lab people as well as the clinical people and I think the whole process of the Australia-wide leadership team and getting approval and stuff, that’s been incredibly good. They’ve all been really engaged and it’s moved quickly so I’ve been quite impressed with it.” GS76.
Box 4: Full text quotes for theme iv) Practical/organisational considerations

<table>
<thead>
<tr>
<th>iv) Practical/organisational considerations:</th>
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<tbody>
<tr>
<td>• “I think the organisation of the project has been incredible...Communication was wonderful...everyone’s included in the communication because it just helps everyone know where things are at for that patient and I think that’s really important and everyone’s aware of what’s going on.” GS48.</td>
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<td>• “I think there are challenges in time management, and I consider myself a fairly organised person. I like to build structures around me that, kind of, protect me from that uncertainty and the curve balls that tend to find us in clinical work.” NGC63.</td>
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<td>• “It [genomics] needs to go into clinical care and be properly funded and be properly funded at the clinical end. Which I know is on everyone’s radar, but it requires so much love from the clinical team to make it happen.” GS71.</td>
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<td>• “The biggest problem is I think scheduling. So, the downside is to schedule a meeting that everybody can attend and you’ve got enough people to attend.” NGC21.</td>
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<td>• “And the funding for a multi-disciplinary team meeting to do that pre-intake or post-intake information sharing interpretation before the next appointment, is not really funded. And I know, there was little, sort of, approaches that one could utilise the multi-disciplinary team meeting, [with] codes that exist within Medicare. I have concerns that they don’t really meet what I consider is a multi-disciplinary meeting, as interpreted by Medicare.” NGC23.</td>
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<td>• “… effective communication is really important.” GS53.</td>
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Figure 1: The interdependency and evolving nature of clinical and scientific knowledge in clinical genomics with a simplified example of steps required for genomic testing and potential professions involved. *Curation refers to the process of establishing which gene variants should be examined as potentially disease-causing. Source, authors’ representation.
Figure 2: Locating clinical genomics in the elongated adaptive context. i adapted from Uri Bein & Arena; ii authors' representation.
Figure 3: Conceptual model of components influencing teamworking. Source, authors' representation.
Examples of teams:
- Crash team
- Paramedics
- Aged care
- Clinical genomics

SPEED OF DECISION MAKING
- Instant to reflective decision making

ADAPTIVE CONTEXT
- Slow to rapid evolution of knowledge base
- Consistent expectations of roles to evolving roles of staff
- Consistent technology to rapid changes in technology

TEMPORAL FLUIDITY
- Ad hoc group formation to long-standing working

COMPLEXITY OF TEAM COMPOSITION
- Single organisation to crosses organisational boundaries
- Uni professional to multiple professions
- Single staff group (e.g. clinical or non-clinical) to multiple staff groups

Figure 3: Conceptual model of components influencing teamworking. Source, author’s own

JEP_13573_figure 3 for dyn groups BnWFinal.tif
<table>
<thead>
<tr>
<th>Interview set</th>
<th>1. Experiences of clinicians’ and service leads’ implementing clinical genomics</th>
<th>2. Perceptions of laboratory staff and genetic clinicians to changes in service delivery</th>
<th>3. Perceptions of staff from one area of clinical genomics</th>
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<tbody>
<tr>
<td>Interview focus</td>
<td>Barriers and enablers to implementation of genomics</td>
<td>Service improvement in curation of genomes</td>
<td>Learning from implementation of acute care genomics</td>
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<tr>
<td>Geographic focus</td>
<td>Australia wide</td>
<td>Melbourne</td>
<td>Participating states – New South Wales, Queensland, South Australia and Victoria</td>
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<tr>
<td>Date of data collection</td>
<td>2018</td>
<td>2018</td>
<td>2019</td>
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<tr>
<td>Participants (N interviewed/invited)</td>
<td>Non-genetic medical specialists (N=16/27), and service level decision makers (N=21/35)</td>
<td>Healthcare scientists and clinical geneticists (N=8/17)</td>
<td>Healthcare scientists, genetic clinicians, project officers and paediatric intensivists (N=32/61)</td>
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<tr>
<td>Inclusion criteria</td>
<td>Participates as a member or a multidisciplinary team</td>
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<td>Deliverying an Australian or Melbourne Genomics study</td>
<td>Participating in a Victorian Clinical Genetics Service improvement project</td>
<td>Delivering the Australian Genomics acute care genomics project</td>
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<td>Ethical approval</td>
<td>Melbourne Health HREC (HREC/13/MH/326).</td>
<td>Melbourne Health HREC (HREC/13/MH/326).</td>
<td>University of Melbourne HEAG Committee (ID 1646785.9)</td>
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<td>Interview duration (on average)</td>
<td>1 hour</td>
<td>30 mins</td>
<td>30 mins</td>
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Table 2: Participant characteristics across the three interview datasets

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<tr>
<th></th>
<th>Non Genetic Clinicians (NGC)</th>
<th>Genetic Staff (GS)</th>
<th>Laboratory Scientists (LS)</th>
<th>Service/Program leads (S/P)</th>
<th>Project Officers (PO)</th>
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<td>By profession</td>
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<td>21</td>
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<td>7</td>
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<td>By state</td>
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<td>New South Wales (NSW)</td>
<td>8</td>
<td>10</td>
<td>6</td>
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<td>Queensland (QLD)</td>
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<td>South Australia (SA)</td>
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<td>Victoria (VIC)</td>
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<td>Western Australia (WA)</td>
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<td>Key concepts of teamworking in clinical genomics</td>
<td>Examples of potential practice recommendations for organisational and team leaders to promote teamworking</td>
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<tr>
<td>1. Gaining an appreciation of how knowledge, professional identity and respect, team dynamics and practical/organisation considerations interrelate</td>
<td>A commitment to working collaboratively, designing team based job designs</td>
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<td>2. Understanding the significance of teamworking in a dynamic setting</td>
<td>Provision of the time and permission for team members to share knowledge, fostering motivation to learn</td>
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<tr>
<td>3. Learning to work together takes time and is further challenged in the <em>elongated adaptive context</em>, with the rapid evolution of the knowledge base, staff roles and technology.</td>
<td>Conflict management, promoting the value of others and mentoring</td>
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<td>4. Communicating ideas and developing corporate knowledge for healthcare scientists and clinicians</td>
<td>Provision of guidance on establishing clear boundaries and expectations of team members, promoting capacity building</td>
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<td>5. Successful teamworking is reliant on team members’ interdependency which requires the building of trustful relationships and open dialogue.</td>
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<td>6. The need for role delineation and the importance of succession planning.</td>
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Teamwork in clinical genomics: A dynamic sociotechnical healthcare setting

Running title: Teamwork in clinical genomics

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Author Contributions: SB conceptualised and designed the study with NT; SB and LN carried out data collection; SB, HB, ZS, JCL, LN, NT contributed to data analysis; SB lead writing the
manuscript with NT; HB, ZS, JCL, LN, JB contributed by providing critical feedback and helped shape the research, analysis and write up of the manuscript.
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