Health Education England

The Future of Clinical Bioinformaticians in the NHS:

An Assessment Report and Recommendations to Build and Boost the Future Workforce

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CONTENTS

1. Executive Summary

Health Education England's (HEE) Digital Readiness Programme has commissioned a project to evaluate the current situation and shape the future of the clinical bioinformatics workforce in the NHS. Clinical bioinformatics is the application of bioinformatics in clinical settings to improve the delivery of patient care. Clinical bioinformaticians are already an important workforce in the NHS and with the proliferation of digital technologies, their importance is set to increase. This two-phase project aims to assess the retention and utilization of clinical bioinformaticians in the NHS trusts, as well as to develop and implement necessary strategies for improvement.

The first phase of the project is focused on building a comprehensive understanding of the factors related to the commissioning, training, and employment of clinical bioinformaticians in the NHS. This phase also includes developing recommendations for keeping more clinical bioinformaticians within the ecosystem of the NHS and utilizing them in better ways.

The second phase of the project will focus on transforming the recommendations from phase 1 into actions and following up those actions to ensure that the changes in commissioning and employer models create a positive impact on the clinical bioinformatician workforce.

The project will seek to develop collaboration between organisations and individuals both within and outside of the NHS to increase the value created by clinical bioinformatics. The first step of such collaborative efforts will be the formation of an advisory group that consists of a wide range of stakeholders, to oversee the second phase of this project.

This report is one of the main outputs of phase 1 of the project. This phase comprises an extensive stakeholder engagement, including a workshop and over 40 interviews. From the data collected during this engagement, several themes were extracted and combined with supporting data provided by HEE Digital Readiness Programme and the National School of Healthcare Science (NSHCS). The primary and secondary data collected over the course of the first phase of the project was analysed to deep dive into the current situation for clinical bioinformatics in the NHS, which resulted in the identification of retention factors based on a detailed interpretation of the prominent themes, as well as a series of recommendations. These findings will form the foundation of the second phase of the project.

From more than 20 identified themes, 5 major factors affecting the retention and utilization of clinical bioinformaticians in the NHS were revealed:

- Altruism and benevolence are common traits for NHS clinical bioinformaticians that promote retention.
- The Scientist Training Programme (STP) trainees want to stay in their training trusts, but this is often not possible, leading to a decision to leave the NHS in some cases.
- The nature of the work in the NHS is a big pull factor, however, having to continuously deal with undemanding and conventional tasks is pushing some people out.
- A perceived lack of promotion opportunities may be causing relatively experienced staff to leave the NHS.
- Low awareness of the capabilities of bioinformaticians is reducing the value they generate for the NHS.

Considering these factors along with examples of best practice and expert inputs, 10 recommendations were developed to improve the future of clinical bioinformatics as a profession in the NHS. These recommendations fall into 3 categories, namely, *training and commissioning, stakeholder engagement,* and *infrastructure and support*.

Training and Commissioning

1. ***Survey NHS trusts and integrated care systems (ICS) to identify additional departments where clinical bioinformatics training could be provided***

There are NHS staff with skillsets similar to that of clinical bioinformaticians, whose trusts have not considered them as trainees for the clinical bioinformatics STP. Bringing these people and their departments into the STP will improve training opportunities and outcomes.

2. ***Set out a proposed model of how to involve external partners in the commissioning and training of clinical bioinformaticians by looking at research departments, especially those in universities with existing links to NHS trusts***

Creating partnerships with organisations outside of the NHS is an important goal of phase 2 of the project. Developing a model for involving external partners can start with research departments in universities that are already associated with NHS trusts. In a special partnership programme, the parties can together create plans on how to jointly add value to the training process and improve post-graduate employment prospects for the trainees.

3. ***Develop a strategy to provide timely information about post-graduation employment opportunities to STP trainees***

A major issue expressed by STP trainees and alumni is the lack of clarity from trusts about available positions for their employment after graduation. Improving communication on this matter will help STP trainees find work inside the NHS, and reduce the number of people that look for employment opportunities elsewhere due to uncertainty.

4. ***Proactively encourage the use of elective units for trainees to visit other NHS trusts during the STP***

The electives of the STP is a currently underutilized way for trainees to experience different work environments and expand their employment prospects. Creating a forum with the aim of promoting trainees to use their electives in different trusts should improve retention by better aligning the trainees with the trusts that need them most.

5. ***Explore the option to develop alternative programmes that will complement the Higher Specialist Scientist Training (HSST), commissioned by HEE***

The HSST programme is an important component of HEE's long-term strategy for clinical bioinformatics in the NHS. However, there is an appetite among in-post qualified clinical bioinformaticians for complementary programmes to facilitate upskilling. Developing and promoting continuing professional development modules, especially for those that already hold doctoral degrees, would provide formalised personal growth pathways as well as improving clinical bioinformaticians' perception of promotion opportunities in the NHS.

6. *Plan for medium- to long-term increases in funding for the clinical bioinformatics STP*

Currently, there does not appear to be a shortage of STP positions, however, given the results of HEE Digital Readiness Programme's recent workforce review and the opinions of stakeholders from this study, the demand for clinical bioinformaticians will increase in the future. Potential medium and long-term demand for STP funding should be planned in advance, so that the programme can be scaled to train more bioinformaticians and prevent a workforce gap in this field.

Stakeholder Engagement

7. Ensure that an extensive and inclusive selection of stakeholders are fully engaged for phase 2 of the project via the HEE Clinical Bioinformatics Advisory Group (HEE-CBIAG)

The success of this project depends on bringing together a wide range of stakeholders and making them aware of the roadmap for the future of the clinical bioinformatics profession. The advisory group (HEE-CBIAG) should be the primary entity for this purpose, which will serve both as an arms-length body to independently assess the effectiveness of relevant initiatives, and provide expertise throughout phase 2 of the project. The communication strategy to reach these stakeholders is laid out in this report.

8. Develop alternative promotion activities to raise awareness of clinical bioinformatics, especially within the trusts and integrated care systems (ICS)

The general awareness of clinical bioinformatics is low in many NHS trusts, and especially at relatively senior administrative levels. Conveying information about the role and benefits of clinical bioinformatics to various types of staff in the NHS will be crucial in phase 2 of the project and beyond. Thus, alternative promotion activities should be developed and implemented, which will improve the utilization and recognition of clinical bioinformaticians through raising the awareness of the profession.

Infrastructure and Support

9. Create a portal to facilitate communication of clinical bioinformaticians with each other and with other clinical scientists and managers in the NHS

Evidence from the interviews suggests that informal networks have been beneficial both during and after the STP programme. The development of a portal that promotes communication and networking will help improve the utilization of clinical bioinformaticians and keep more of this critical workforce inside the trusts and ICS. Such a portal should not only connect bioinformaticians with each other for supporting professional and training activities, but also with other NHS staff that may benefit from their capabilities.

10. Define and promote the best practices for work-from-home in the post-pandemic world.

During the Covid-19 pandemic, clinical bioinformaticians quickly adapted to remote working due to the strong computational component of their profession, and the interviewed bioinformaticians were universally positive about partially working from home as a factor that could help alleviate

challenges related to relocating after graduation. HEE should encourage workplace flexibility and support the definition and promotion of best practices in remote working for clinical bioinformaticians to continue work-from-home where and when appropriate.

This report outlines the structure of the HEE Clinical Bioinformatics Advisory Group (HEE-CBIAG) to be formed as part of this project, and a prospective communication strategy to reach the relevant stakeholders. HEE-CBIAG will have an important role in translating the above mentioned recommendations into actions in phase 2 of the project. In addition, a framework has been created to facilitate the evaluation of retention and utilization issues by HEE-CBIAG through the next phase of the project and beyond.

The outputs of this report are designed to serve as a foundation for designing and implementing changes to the commissioning and training processes over the coming years. The following 5 immediate activities are proposed as the next steps:

1. Form HEE-CBIAG;
2. Have this report reviewed by key stakeholders including HEE-CBIAG;
3. Publish this report and collect further feedback from other interested parties;
4. Refine the scope and requirements for phase 2 of the project; and
5. Engage the required partners to start phase 2 of the project.

2. Introduction

2.1. Project Background

Bioinformatics is a multidisciplinary field that involves the discovery, development, and implementation of computational algorithms and software tools, which are used for handling and interpreting biological, medical, healthcare, and behavioural data. Thus, bioinformatics contributes to the use of a wide range of complex data sets for various purposes. The activities of bioinformaticians include but are not limited to data collection, data mining, database searches, modelling, and analysis.

Clinical bioinformatics is the application of bioinformatics in clinical settings to improve the delivery of patient care. Combining unique skills and expertise from different disciplines, clinical bioinformatics has an important role in the creation of knowledge from the data generated in clinical environments. Although clinical bioinformatics is a relatively new discipline in the NHS, clinical bioinformaticians have already proved themselves to be a critical workforce in the delivery of the genomic medicine service, as well as other clinical services, such as medical imaging.

The National School of Healthcare Science (NSHCS) supports the clinical training of bioinformatics through the Scientist Training Programme (STP). The academic component of the clinical bioinformatics STP is delivered by Manchester Academy for Healthcare Scientist Education (MAHSE). The work-based component of the programme is provided by various NSHCS accredited training departments in the NHS trusts and affiliated organisations.

Clinical bioinformatics STP is an academic career pathway for clinical bioinformaticians in the NHS. The programme has 3 distinct streams to support the range of services where clinical bioinformaticians contribute, namely genomics, health informatics, and physical sciences. The NSHCS also provides additional training opportunities for qualified clinical bioinformaticians through the Higher Specialist Scientist Training (HSST) programme. This 5-year programme is designed to prepare clinical bioinformaticians to apply to become consultant clinical scientists in the NHS.

There are other pathways towards becoming a clinical bioinformatician in the NHS through apprenticeships in the NHS trusts or training by non-NHS organizations. Apart from the STP, the Academy for Healthcare Science (AHCS), a joint initiative of the UK governmental health departments and professional bodies, provides an equivalence route for existing NHS staff to acquire the title of clinical bioinformatician.

Clinical bioinformaticians are becoming an increasingly important component of the NHS workforce, however, recent evidence suggests that they are not sufficiently retained in the NHS. Clinical bioinformatics in the NHS was investigated as part of a previous HEE report titled “Data Driven Healthcare in 2030: Transformation Requirements of the NHS Digital Technology and Health Informatics Workforce”[1]. According to this report, the electronic staff record (ESR) indicated that only 2 clinical bioinformaticians remained in-post in March 2020 out of 7 qualified healthcare scientists with the bioinformatician code (U*K). During the collection of data for the Data Driven Healthcare in 2030 study, Manchester University, education commissioners, and

[1] https://www.hee.nhs.uk/our-work/building-our-future-digital-workforce/data-driven-healthcare-2030

Academic Health Science Networks (AHSN) provided anecdotal feedback, which suggested that clinical bioinformaticians in the NHS trusts felt they were not fully utilized. It was reported that the roles and responsibilities of clinical bioinformaticians were not sufficiently understood in the trusts.

To further investigate and address the retention and utilization issues, HEE's Digital Readiness Programme has commissioned a project titled "The Future of Clinical Bioinformaticians in the NHS". The goal of this project is to develop strategies to keep more clinical bioinformaticians within the ecosystem of the NHS, while also improving their utilization in the NHS trusts. This includes investigating the recruitment processes and the factors affecting retention of clinical bioinformaticians through a comprehensive stakeholder engagement, as well as collecting and analysing primary data. The outputs of this exercise will be used to develop and implement revised commissioning and employer models. In addition, an advisory group will be formed to provide support throughout the project.

The Future of Clinical Bioinformaticians in the NHS project is comprised of 2 phases:

Phase 1

The first phase of the project focuses on building a comprehensive understanding of the factors related to the retention, commissioning, and utilization of clinical bioinformaticians in the NHS. This includes a current situation assessment with a special focus on the identification of challenges and their root causes. The findings and recommendations based on this assessment are presented in this study as part of phase 1 of the project.

Furthermore, in this phase of the project, an advisory group that includes the representatives of various key stakeholders is to be formed. This advisory group will provide inputs for developing solutions to improve retention and utilization of clinical bioinformaticians and raising awareness for clinical bioinformatics.

Phase 2

This phase of the project will start with the evaluation of the report created during phase 1. After the acceptance of the recommendations in this report, the project will move on to transforming the recommendations into actions and following up on those actions to understand whether retention and utilization of clinical bioinformaticians are improving. For this purpose, the commissioning and employer models will be evaluated considering the findings of phase 1 and then re-defined as needed. Partnerships and collaborations will be developed to improve the training and wider utilization of clinical bioinformaticians. A communication campaign to raise awareness of clinical bioinformatics and the NHS's clinical bioinformatician workforce will also be designed and implemented.

The advisory group formed in phase 1 of the project will provide support and expertise during phase 2. They will be responsible for the review cycle which will aim to understand whether the changes and communication strategies undertaken by HEE have been effective.

2.2. Scope of this Study

In this retention study, the available information on clinical bioinformatics in the NHS and the wider literature on the topic were reviewed. As part of this review, the relevant documentation concerning the current HEE commissioning process, the STP, and the AHCS equivalence route

were studied. This study was supported by a literature review focused on the current and future roles of bioinformaticians in clinical settings.

Furthermore, a stakeholder mapping exercise was undertaken to identify the relevant stakeholders. An extensive and inclusive group of stakeholders were invited to participate in a workshop to both collect data and aid in the creation of a framework for interviews. The potential interviewees were determined, and data collection tools were developed. The key stakeholders that were interviewed include STP trainees and alumni, as well as those involved in the commissioning, training, and employment of clinical bioinformaticians.

The current situation was assessed by combining secondary research with analysis of data gathered through interviews and the workshop. The factors affecting the retention of clinical bioinformaticians in the NHS were investigated by focusing on the commissioning process, training programme, and working lives of clinical bioinformaticians both inside and outside the NHS ecosystem. The results of this assessment were compiled in this report. This document aims to explain all the factors influencing the retention of clinical bioinformaticians in the NHS. In addition, the report includes recommendations on:

- Actionable changes that are with the scope of HEE, such as changes to the commissioning and training processes,
- Whether there is a requirement for additional funding from HEE,
- Communication strategies to reach the required stakeholders for phase 2 of the project, and
- A review cycle for future monitoring and assessment of the impact of actions that will be undertaken in phase 2 of the project.

3. Methodology

The available information from previous work was assessed prior to the development of the methodological approach used in this study. We mainly used two sources for this purpose, namely, literature review and information from HEE. The literature review focused on knowledge regarding bioinformatics, current and future roles of bioinformaticians in clinical settings, and frameworks for retention. On the other hand, the information provided from HEE included the following:

- Comments from the NSHCS and other bodies concerning clinical bioinformatics;
- Official documentation related to the STP and HSST for clinical bioinformatics;
- HEE Digital Readiness Programme workforce planning reports; and
- Documentation concerning HEE advisory groups.

After assessing the available information, an overarching analytical framework was developed for this study. This framework was used both to develop interview guides and extract themes from the interviews. In addition, it was also used to investigate themes from the workshop with key stakeholders. The themes were then used, in combination with additional information and case-specific details, to synthesize conclusions about the retention and utilization of clinical bioinformaticians in the NHS. Themes extracted from the interviews that did not relate to retention or utilization were not reported in this study.

The conclusions based on the interpretation of themes were then used to create a section of recommendations. The scope of the recommendations were limited to areas where HEE can act or areas where they would be able to influence other decision-makers.

In parallel to the development of this retention study, the necessary groundwork was prepared for the creation of the advisory group which will be needed for phase 2 of the project. Based on the information collected during the workshop and the interviews, a shortlist of suggested representatives was prepared, and a communication strategy was developed to contact potential members.

Finally, building on the experience of data collection in this project, a review cycle framework was designed. This framework outlines how and when data should be collected to investigate the retention and utilization of clinical bioinformaticians. Also, it suggests various additional qualitative and quantitative information that can be collected to help build an understanding of how effective changes have been at improving the retention and utilization of clinical bioinformaticians in the NHS.

3.1. Analytical Framework

Building on similar retention studies in the literature (Hasbollah et al., 2016) [2], we used an analytical framework in this project, which suggests that there are 4 distinct areas important for understanding staff retention, namely, *people*, *processes*, *programme*, and *funding/rewards*. In this project, these 4 areas of investigation were used as starting points to build a thorough understanding of the factors affecting the retention of clinical bioinformaticians in the NHS.

People

This area of investigation focuses on the opinions and perceptions of the clinical bioinformaticians who have been or will be working in the NHS trusts. It looks at the motivations and expectations of those who choose to follow a career in clinical bioinformatics. It also seeks to understand why people choose the enrol in the STP (or AHSC pathway), and how their experiences in the programme and/or workplace have shaped their plans for the future.

Processes

This area focuses on the operational features and workflows existing in an organization that can potentially affect retention. While investigating processes, we took into account all departments of NHS trusts that may impact the experiences of clinical bioinformaticians, as well as the commissioning process before the trainings start. This investigation area also compares the NHS trusts to other organisations, where former NHS clinical bioinformaticians are now working, to understand how organisational and/or operational parameters may have contributed to their choice of leaving the NHS.

Programme

In this area, we delved into the extent to which the training programmes, specifically the STP, has been shaping the long-term career goals of both trainees and graduates. This investigation area does not seek to investigate specific technical components of the training programme, but rather understand the trainees' experiences of it. This area looks at both the educational content and pastoral care components of the trainees' experiences, including how they have interacted with the university educators, NHS training officers, and the NSHSC.

Funding/Rewards

Finally, the availability of funding and rewards at both personal and departmental levels were studied. This includes both financial and non-financial rewards. In addition, the perceived adequacy of operational budgets was investigated.

[2] Hasbollah, H. R., Abd Aziz, N. A., Yaziz, N. A. M., Nasir, M. F. M., & Rosdi, S. N. M. (2016). Conceptual framework in retaining staff for nursing homes in Malaysia: Content analysis based on expert interviews. *International Journal of Innovation, Management and Technology*, *7*(3), 120.

3.2. Equity Sensitivity Perspective Approach

When studying staff retention, the perspectives of the workforce being investigated are of primary importance. To facilitate building an understanding of how people's opinions and experiences are affecting their decision-making processes, an equity sensitivity perspective (ESP)[3] approach is used in this study, which is a sub-type of equity theory.

Equity theory[4] is based on the premise that the employees in an organization respond to the perceived fairness of their relationship with their employer(s). Specifically, if an employee perceives an inequity between the set of inputs, he/she provides for the organization (e.g., skills, work performance, education, experience, etc.) and the outcomes that he/she receives (e.g., benefit package, recognition, relationship between colleagues/superiors, promotion opportunities, etc.), the employee will feel distressed. In order to understand whether they are in an equitable relationship, employees not only compare their inputs with the outcomes that they reach in their organisation, but also consider the input and outcomes of their peers in different settings. When faced with a perceived inequity, employees may decrease their inputs, for instance by reducing how much effort they put into work, or more likely they may look for employment elsewhere.

Equity sensitivity perspective takes this approach one step further and considers different thresholds for the perception of inequity across different types of employees. Building on the premises of the equity theory, it takes into consideration that different employees can be content or discontent under similar input-outcome balances. To this end, equity sensitivity theory categorizes employees under 3 types based on their threshold of inequity: Benevolents, Equity Sensitives, and Entitleds.

Benevolents are content to have lower perceived outcomes compared to their inputs.

Equity Sensitives feel that their outcomes and inputs should be balanced.

Entitleds feel that outcomes should be relatively greater than their inputs.

3.3. Equity Factor Categories

Many different factors may contribute to an employee's perceived equity balance. To facilitate the collection and analysis of information, we grouped these into 5 equity factor categories. Each category focuses on employees' perceived outcomes in specific areas of their work lives. These 5 equity factor categories are:

1. **Nature of the Work** – whether the work is interesting and/or challenging, work-life-balance, and the sufficiency of resources to complete their work

[3] Huseman, Richard C., John D. Hatfield, and Edward W. Miles. "A new perspective on equity theory: The equity sensitivity construct." *Academy of management Review* 12.2 (1987): 222-234.

[4] Adams, J. Stacy. "Inequity in social exchange." *Advances in experimental social psychology*. Vol. 2. Academic Press, 1965. 267-299.

2. **Recognition and Accomplishment –** whether their superiors and colleagues recognize the value they create, as well as the relative importance to them of external recognition versus their own sense of accomplishment
3. **Growth and Promotion** – both short- and long-term career pathways, and whether their work gives them the opportunity to continually up-skill and develop
4. **Income and Benefits** – salary, pension, and leave allowances, as well as how strong motivator higher pay is to them
5. **Relationships** – how they are supported and respected in their workplace

In addition to these 5 equity factor categories, we also looked at off-the-job factors. These are any elements that may affect the decision to stay in an organization while not being directly related to the work or workplace itself. Examples of off-the-job factors include being close to family or friends, quality of public transport, access to particular social activities, etc.

3.4. Data Collection

In line with the objectives of this study, the major sources of primary data were identified as STP trainees, bioinformaticians currently working in the NHS, and bioinformaticians who left the NHS. A mixed-methods strategy was employed for the data collection process, which consisted of semi-structured interviews and online surveys. While the former provided primary data regarding the opinions and experiences of various groups of interviewees related to retention factors, the latter aimed to identify equity sensitivity profiles of the respondents. Additional data was collected from key stakeholders via a workshop, which was held before the beginning of the interviews.

Semi-structured In-depth Interviews

In-depth interview guides were designed and used over the course of the data collection stage to facilitate the flow of the interviews and render the questions as standardized and unbiased as possible. The semi-structured nature of the interviews also allowed the interviewers to have the flexibility to cover the areas that were not included in the guides but were later discovered to be conducive to extracting additional insights. Since there were different groups of people amongst the respondents, interview guides were tailored to explore the themes that were most relevant to each respondent group. For this purpose, separate in-depth interview guides were designed and used for STP trainees, current and former NHS clinical bioinformaticians, line managers, and trainers[5].

For the STP trainees and current/former NHS clinical bioinformaticians, the questions were centered around understanding the retention factors from the perspectives of the interviewees. In other words, the main goal of these interviews was to understand the perception of the interviewees about the areas that have made the NHS an appealing place to work in, as well as the factors that may have caused them to look for employment elsewhere. In addition to the focus

[5] For those who serve both as a line manager and trainer, the interview guide for line managers was used.

on retention factors, these interviews also aimed to develop an understanding of the more ancillary issues that the respondents faced, which were likely to impact the utility clinical bioinformaticians could provide to the NHS.

Interview guides for the STP trainees and current/former NHS clinical bioinformaticians had 4 main sections. Firstly, general career-related questions were asked for building rapport with the interviewees and structuring the rest of the conversation. In the second section, more specific questions were asked about interviewees' general experiences and opinions about working in the NHS and/or attending the training programme. By asking questions about the aspects they were content or discontent about their work and/or training, this section aimed to capture the interviewees' thoughts about relevant benefits and challenges. In the third section, the questions covering several equity factor categories were asked, including *nature of work, recognition and accomplishment, growth and promotion opportunities, income and benefits*, and *relationships*. The aim in this section was to understand the extent to which the interviewees felt in an equitable position with regards to these specific areas of investigation. In the final section, open-ended questions were asked to encourage interviewees to talk about any additional issues that were relevant to them.

For line managers and trainers, the in-depth interview guides focused on different areas. These interviews were designed to shed light on the factors that have been driving clinical bioinformaticians to stay, as well as the factors that have been pushing or pulling them away from the NHS. The interview guides for the line managers and trainers focused more on the managerial issues that were related to retention and utilization, such as the commissioning process, funding, collaboration with universities, etc.

A total of 41 in-depth interviews were conducted between 22 April, 2021 and 14 May, 2021. Except for a single interviewee, all the interviewees gave consent for the recording of their interview. All the recorded interviews were transcribed before the analysis.

Equity Sensitivity Perspective Survey

The equity sensitivity profiles of the trainees and current/former NHS clinical bioinformaticians were evaluated using an equity sensitivity survey instrument. As a standardized tool, this survey was comprised of a series of statements about equity thresholds regarding certain themes. The interviewees were asked to respond with their level of agreement on a 5-point Likert scale from strongly disagree to strongly agree. The survey instrument was sent to the interviewees one day after the interview via e-mail, and the respondents were asked to rate their agreement with the statements on an online survey platform.

Communication Approach

All primary communications for participation in the workshop and interviews were handled by HEE. For the workshop, personal invitations were sent to stakeholders inside HEE and external stakeholders already known to the HEE team. In addition, invitations to participate in the workshop were circulated through HEE's online and social media platforms.

To avoid any bias for data collection during the interviews, no personal invitations were made. Instead, a two-pronged approach was employed to reach as many participants as possible. HEE contacted local leads involved in the training, commissioning, and employment of clinical bioinformaticians. These individuals were asked to circulate invitations to prospective interviewees that were thought to be relevant to the study. In parallel, an open call was made through HEE's online and social media platforms for trainees, current and former NHS clinical bioinformaticians, line managers, and trainers to participate in the interview phase of this project.

All participants that put their names forward were contacted for an interview.

3.5. Data Extraction and Identification of Themes

Interviewee Metrics

In order to describe the data collected, basic information was extracted from interview transcripts to understand what type of interviewee the respondents were (trainee, current NHS clinical bioinformatician, line manager, etc.) and how they qualified as clinical bioinformaticians (via STP or AHCS). Furthermore, the metrics were categorized in terms of the educational background, field of work, future work, and workplace of the respondents.

Equity Sensitivity Perspective Survey Results

For each respondent, a score was calculated for his/her ESP profile based on the answers to the Likert scale statements. These scores were tabulated with the interviewee metrics for comparison. ANOVA and student t-tests were used to test for significant differences between sub-groups of the interviewees at a 5% confidence level.

Themes from the Workshop and Interviews

During the workshop and interviews, recordings were made, and notes were taken. After the transcripts were assessed, using the analytical framework of this study, comments and observations were extracted according to the 4 pre-defined thematic areas, namely, *people, processes, programme,* and *funding/rewards*. The themes that were not related to either retention or utilization were removed from the analysis.

Quotes extracted from the interviews to support the thematic analysis were edited to remove any identifying information.

3.6. Interpretation of Themes

To synthesize conclusions from the collected data, the themes that appeared most strongly associated with retention and/or utilization were identified. Then, connections between themes

were explored and their links with the outcomes of the secondary research, equity sensitivity perspective survey results, and interview metrics were investigated. The extensive list of themes was reduced to a list of conclusions that aimed to bring together the most salient observations. To be as unbiased and neutral as possible in the crafting of the conclusions, factors positively or negatively affecting retention and utilization were considered equal.

The recommendations in this report build on the conclusions from the thematic analysis. These recommendations focus on activities that lay within the remit of HEE or in areas where HEE can be expected to have influence. The recommendations are a starting point for the creation of policies and actions for phase 2 of the project and beyond.

4. Data and Thematic Analysis

4.1. Interviewee Metrics

56 people responded to the publicly available invitation to participate in interviews for this study, and all of them were contacted with a personal invitation for an interview. A total of 41 interviews could be arranged during the 3 weeks assigned for data collection in this project.

Out of the 41 people interviewed, 16 were current trainees in the STP. The remaining 25 were current or former NHS clinical bioinformaticians, which included current line managers and trainers in the NHS trusts. None of the interviewees were currently in the AHSC pathway to become qualified clinical bioinformaticians.

Table 1: The distribution of interviewees

Interviewee Type	Number of Interviewees
STP trainees	16
STP alumni	18
Current and former NHS clinical bioinformatics staff who had not qualified through the STP	7
Total	**41**

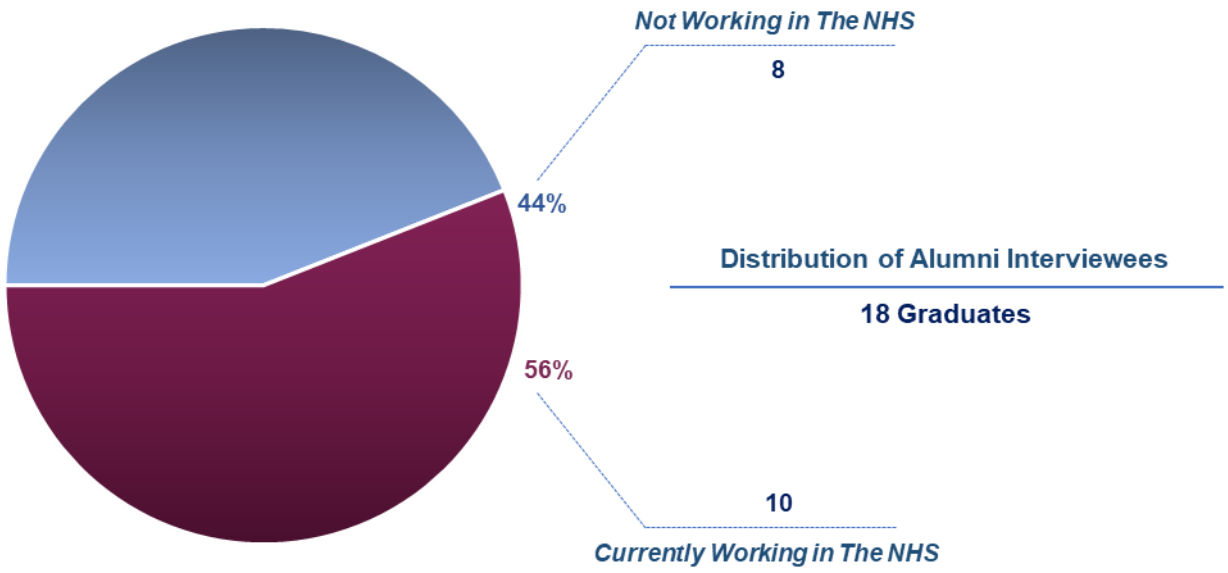

Figure 1 – The distribution of the STP alumni, by employment status

Excluding the 16 STP trainees, 16 interviewees were working in the NHS trusts or affiliated organisations. All these interviewees were involved in providing clinical bioinformatics services at the time of data collection. 9 of them were also training officers, while 4 of them were line managers in their departments.

Table 2: The distribution of bioinformaticians working in the NHS

Additional Roles of Interviewees Working in the NHS Trusts	Number of Interviewees
Both a line manager and training officer	3
Line manager only	1
Training officer only	6
Neither line manager nor training officer	6
Total	**16**

Other than the line managers and trainers, interviewees were asked about their academic background. 19 had doctoral degrees and 12 had either bachelor's or master's degrees before entering the STP (or AHCS pathway). Most of the interviewed current trainees (81%) had doctoral degrees.

Table 3: Distribution of clinical bioinformaticians, by their educational background

	Bachelor's / Master's Degree	Doctoral Degree
Trainees	3	13
Current NHS clinical bioinformaticians	5	1
Former NHS clinical bioinformaticians	4	5
Total	**12**	**19**

The interviewees were also asked which STP stream they participated in. The distribution of different types of interviewed clinical bioinformaticians were similar to the total trainees since 2013. This suggested that there was no bias in the selection of interviewees based on STP streams.

Table 4: Distribution of clinical bioinformaticians, STP stream/field of work

	Genomics	Health Informatics	Physical Sciences
Trainees	8	4	4
Current NHS clinical bioinformaticians	5	0	3
Former NHS clinical bioinformaticians	7	0	1
Total (from interviews)	**20**	**4**	**8**
Total trainees since 2013	**96**	**29**	**36**

Trainee interviewees were asked about their plans after graduation, as well as their long-term career plans. A large proportion of these interviewees wanted to stay in the NHS trusts where they were currently training (69%). Out of those that wanted to stay in their trust, more than 90% had long-term plans to work in the NHS as clinical bioinformaticians. Amongst those who did not want to remain in their training trust, 60% still planned to work long-term in the NHS. 13% of the trainees interviewed did not want to work in their training trust or the NHS long-term.

Table 5: Distribution of STP trainees, by future plans

	Plan to work long-term in the NHS	Do not plan to work long-term in the NHS
Want to remain in the same trust that they are training in	10	1
Do not want to remain in the same trust that they are training in	3	2
Total	**13**	**3**

The current and former NHS clinical bioinformaticians were asked whether they worked in the same trust they trained in after graduating. Of those who stayed in their training trusts after the STP, 38% were currently working in the NHS. Whereas those who did not continue in their training trust, 63% were currently working in the NHS.

In addition, when asked about their future, 100% of those current NHS clinical bioinformaticians who changed trusts after graduation were planning to continue in the NHS, but only 66% of those current NHS clinical bioinformaticians who stayed in their training trust planned to stay in the NHS.

4.2. Equity Sensitivity Perspective Survey Results

All the interviewees, except for line managers and trainers, were sent an equity sensitivity perspective questionnaire. Out of 31 questionnaires sent, 21 responses were received. Each respondent was given a score from 1 to 5 based on his/her answers to the Likert scale statements. A higher score indicates that the person is more *benevolent.* A lower score indicates that the person is more *entitled*. A score of around 3 indicates that the person is *equity sensitive*.

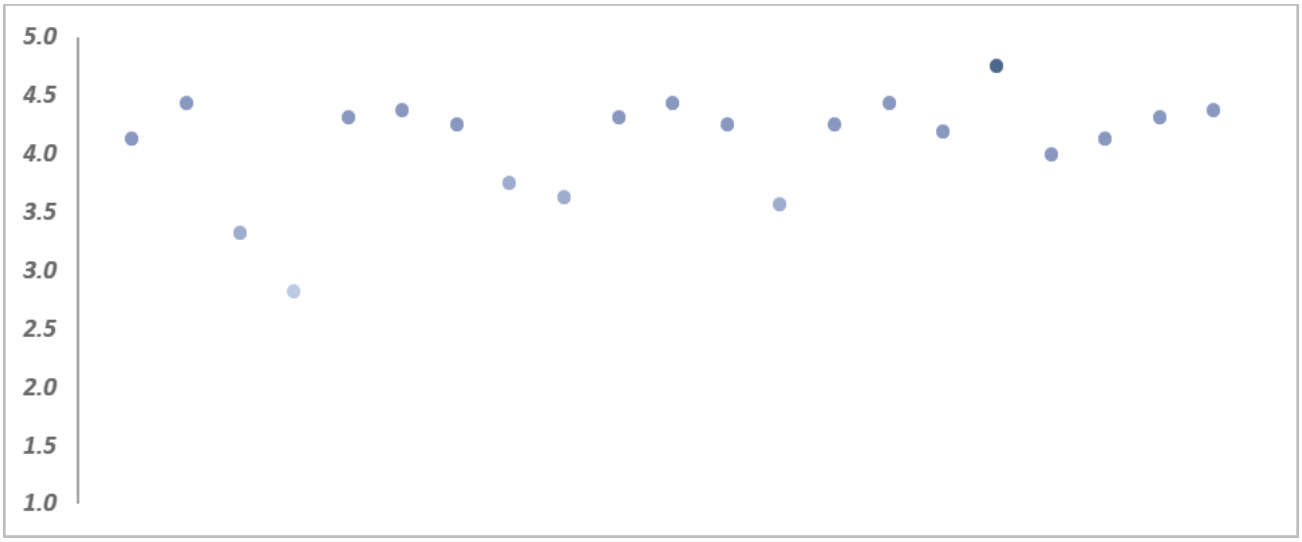

Figure 2: Equity Sensitivity Scores of the Respondents

The scores shown in Figure 2 suggest that most of the respondents were *benevolents*, with the average equity sensitivity score of the sample being 4.10 There were no significant statistical differences between the scores for trainees and current/former NHS clinical bioinformaticians.

Table 6: Equity sensitivity average score, by interviewee type

	Average Score	Number of Respondents
Trainees	4.03	12
Current NHS clinical bioinformaticians	4.24	4
Former NHS clinical bioinformaticians	4.14	5
All	**4.10**	**21**

The result of the survey suggests that most of the interviewees, and by extrapolation the clinical bioinformaticians, have a high threshold for a perceived inequity between their inputs and outcomes. Although the interviews did not specifically probe equity sensitivity perspective, many interviewees expressed opinions that were relevant, such as acknowledging that they could have

better pay in another job but that was not an essential factor to them for leaving the NHS. Furthermore, even when trainees mentioned negative issues with their training and trusts, they often still wanted to stay at their trusts to work there after they complete the programme.

The lack of difference between the equity sensitivity scores of current and former NHS clinical bioinformaticians implies that specific conditions or events during their time in the NHS were the reason for them leaving. If there had been a significant difference between the scores of current and former NHS clinical bioinformaticians, it would have implied that the decision to leave was a function of their personality.

4.3. Themes from the Workshop

Various workshop participants shared their opinions and experiences regarding different aspects of the employment of clinical bioinformaticians in the NHS. These opinions can be grouped under the following themes:

There is a lack of understanding of the role and importance of clinical bioinformatics in the NHS trusts

Many departments are not sufficiently aware of the clinical bioinformatics activities within their trust, therefore, people in these departments are not informed about the capabilities of clinical bioinformaticians. In addition, even the departments working with clinical bioinformaticians do not fully understand their skills and qualifications. This situation implies an under-utilization of clinical bioinformaticians, as it seems most departments are not able to collaborate with them or benefit from their work when they need it.

There is also a lack of understanding of the value of clinical bioinformaticians at the managerial level. People in senior positions are not sufficiently aware of the importance, needs, and capabilities of clinical bioinformaticians. This might have been affecting the employment of clinical bioinformaticians, especially when there is a job that requires qualifications for clinical bioinformatics, but the managers are not fully aware of such requirements.

The title “clinical bioinformatician” may be creating confusion

The title “Clinical bioinformatician” might not have been properly representing all the 3 streams in the STP, namely genomics, health informatics, physical sciences. Many people, especially in the industry and academia, believe that clinical bioinformaticians only focus on genomics data. Moreover, even the NHS staff sometimes do not understand that clinical bioinformaticians in different streams are doing very different jobs in different parts of the NHS.

There is a very limited number of clinical bioinformaticians in senior roles in the NHS trusts

As clinical bioinformatics is a new discipline in the NHS, there are few clinical bioinformaticians in relatively senior roles, such as consultant scientists. As a result of this, clinical bioinformatics is not well represented in decision-making processes in the NHS trusts. This may have been preventing clinical bioinformaticians from effectively conveying their needs to the management of their trusts.

Although HSST provides opportunities for promotion in the NHS, some clinical bioinformaticians do not see the potential for promotion and professional growth due to the limited number of clinical bioinformaticians in senior roles. They feel that they can only be promoted if senior staff in this field leave their positions. Some clinical bioinformaticians believe that as they cannot gain experience in more senior roles, they cannot develop the skills they need to create significant impact. Thus, some of these people are leaving, even though they might want to work in the NHS. According to a participant in the workshop, a clinical bioinformatician who left the NHS said *"I want to come back. This is just where I believe I can get those skillsets".*

People want to become clinical bioinformaticians to make a positive social impact

People do not choose clinical bioinformatics career pathways solely for financial reasons. While there are higher-paying jobs in different sectors, clinical bioinformaticians are motivated to work in this profession to have an impact on society. Clinical bioinformaticians in the NHS are inspired by the idea of having a direct effect on improving patient outcomes.

Having to change location reduces the motivation of clinical bioinformaticians to stay in the NHS

STP graduates may be having difficulty finding jobs in their preferred location. In addition, some clinical bioinformaticians are having to change jobs due to short-term contracts. A participant in the workshop stated that "*These contracts are quite short, and I have been relocating every 3 years and now in my 30's and not having a confirmed contract meaning I have to relocate again*".

4.4. Themes from the Interviews

NHS clinical bioinformaticians' career motivations are mostly altruistic

When asked about their motivations for enrolling in the STP, most trainees and alumni stated that they had followed their career path for primarily altruistic reasons. This was a repeated pattern across all the STP streams, namely, genomics, health informatics, and physical sciences. Some interviewees expressed a desire to do something beneficial for society with their skills and knowledge, whereas others wanted to work closely with patients. Such altruistic drives were universal from new trainees to experienced clinical bioinformaticians, including those that left the NHS.

> *"The thing that draws most people to healthcare, especially me, is the fact that you know that your work is actually going to have an impact and help people and patients … That was a big draw. I just think the NHS has so much respect and so it does feel like a very prestigious place to work."*

The benefits package is fair, but not an important retention factor for most interviewees

One of the strongest findings from the interviews was that income had not been an essential factor for the career choices of the NHS clinical bioinformaticians. Trainees, as well as both current and former NHS clinical bioinformaticians, felt that the wages they received in the NHS were fair. Furthermore, they thought that the additional benefits, such as the NHS pension, holiday entitlement, and maternity/paternity leave, were better than those in the private sector.

Some of the trainees who entered the programme directly after graduation from bachelor's or master's degrees stated that their income was higher than that of many of their peers. The trainees who entered the programme after doctoral or post-doctoral studies shared this opinion in most cases.

Interviewees sometimes expressed the opinion that they could be earning more in the private sector. However, most stated that they were content with their current income. Amongst the bioinformaticians who had left the NHS, most did not cite income as being a factor in changing jobs. In fact, one of the interviewees even took a pay cut at their new job.

> *"I have no complaints about it [income and the other benefits] at the minute. I think there is a very fair balance. I could go into pharma and make more money, but I would lose my weekends. You get good holidays, get benefits, etc. You get a years of worth for maternity leave."*

Clinical bioinformaticians in the NHS are generally happy with their work/life balance

Amongst those interviewees who were currently working in the NHS trusts, either as STP trainees or qualified clinical bioinformaticians, was a consensus that the line managers encouraged timely working and did not put undue pressure on team members to work extra hours. However, some of the clinical bioinformaticians who had left the NHS cited undue pressure from line managers and a poor work-life balance as factors contributing to their decision to leave the NHS.

> *"I think it [work/life balance] is better in the NHS, it is more protected here. Even if you are working a bit late, your line manager is trained for being aware of stress, to take care of you. One night I mailed my line manager at 10.30, I was frustrated with something about the script. And he responded back saying 'why are you working at 10.30, what can we do to avoid that, to make you less stressed… is it too much stress?' I do not think you get that [support] in pharma or academia."*

There are no significant inadequacies with equipment or IT infrastructure

Interviewees did not express issues or problems resulting from a lack of equipment or IT infrastructure in their trusts. Such issues were not cited as a contributing factor for their decision the leave the NHS by any of the former NHS clinical bioinformaticians.

Clinical bioinformaticians generally see limited promotion opportunities

The promotion opportunities available to the clinical bioinformaticians in the NHS was a major theme brought up by the interviewees. Most of the interviewees expressed the opinion that there were limitations for promotion as a bioinformatician in the NHS. They observed that there were only a few senior bioinformatician positions and that they were already full. Thus, many of the current NHS clinical bioinformaticians did not think they would have a chance to be promoted soon if they wished to stay in the same trusts. Some of the former NHS clinical bioinformaticians stated that the lack of promotion opportunities was a factor in their decision to leave the NHS. The STP trainees were generally more optimistic about promotion opportunities, however, these interviewees generally placed less importance on promotion.

While many interviewees shared a similar opinion about current promotion opportunities, there were differences in their thoughts about the future. Some interviewees believed that the field of clinical bioinformatics would grow and increase in importance, thus leading to more senior roles in the future. Others believed that clinical bioinformatics would remain a relatively unknown discipline within the NHS, and the situation for promotion would not improve.

> *"I am very happy in the position I am in now… But I suppose things [promotion opportunities] are a little bit more limited… We have a team lead and there are only 7 of us. So, what is next from here on? You would have to move between trusts but that depends on availability because someone must leave. There is definitely a ceiling."*

> *"The ceiling you could hit can flip the balance [between the income and benefits] where you say, 'I am stuck in this position now'. It is just one of the roles compared to other roles in the NHS that the skillset you have is quite a desirable one. I get contacted [by recruiters] about once a week saying, "are you interested?". I turn them down, but if you get to a ceiling these can be more tempting."*

The nature of work is an important reason to stay in the NHS

Most interviewees were enthusiastic about the work they carried out in the NHS. They stated that they felt the work they did was interesting, and they were happy that they could have a positive impact on the lives of patients.

However, a considerable number of interviewees, especially those who were current or former NHS clinical bioinformaticians, stated that they were required to perform a lot of maintenance tasks. While technically within the remit of what they were trained to do, such tasks were not effective usages of their time. They stated that because so much of their time was taken up with this type of tasks, they had less time to do the actual work they enjoy, the work that created value for the NHS trusts. A few interviewees described having to do completely unrelated tasks to their qualifications and position.

> *"I think what I do here is very interesting, it is definitely a nice role. Compared to the private sector, we do a quite wide range of different projects, which is great. It is also good to know that you are making actual impact on patients' lives. Aside from those, there is always continued learning, a lot of packages, languages that you learn…I really like this role."*

Recognition for the work clinical bioinformaticians do is present but could be better

Most STP trainees and current NHS clinical bioinformaticians reported receiving recognition for the work they do from their immediate colleagues and line managers/training officers. However, they stated that outside of their departments few people in the trusts gave them recognition for their work. More generally, these interviewees reported that there was low awareness of who they were and what they did. However, most of these interviewees explained that recognition was not an essential factor for them. They stated that their own sense of accomplishment was more important.

Nevertheless, the lack of wider awareness of clinical bioinformatics and clinical bioinformaticians seems to have strong indirect effects. When senior management do not understand what clinical bioinformaticians do, they are less likely to provide support and, more importantly, the required resources. Amongst the former NHS clinical bioinformaticians, the lack of recognition and awareness from management were cited as contributing factors in their decisions to leave.

> *"It [Awareness and recognition] varied, so sometimes people thought we were just IT supports. I got occasionally called to help fix projectors, which usually involved turning it off and back on again. The more senior geneticists recognized what we did was very important, but they kept us on running the pipeline somewhere. But we often got involved in helping fix spreadsheets and get them working properly."*

Clinical bioinformaticians usually prefer not to change the location of their work

Location was almost always within the top factors that interviewees highlighted for deciding on what job to take. Typically, STP trainees expressed a desire to remain in the same trust where they were getting trained, or at least to remain in the same geographic location. The current and former NHS clinical bioinformaticians also preferred to be employed in organizations that were close to where they lived. This may reflect the fact that qualified clinical bioinformaticians are often over 30 and are keen on settling in a specific region of their choice.

Some interviewees explained that they would rather leave the NHS than being relocated to another trust in a different region. This problem may be compounded by the fact that clinical bioinformaticians are usually employed by larger NHS trusts, and these trusts are geographically distant from each other. This further reduces the opportunity for clinical bioinformaticians to change trusts without having to relocate.

The creation of Genomic Laboratory Hubs (GLHs) might have made this situation worse for the clinical bioinformaticians working in genomics. It was perceived by some interviewees that the infrastructure due to the formation of GLHs had increased the centralization of services in each region and thus reduced the opportunities for clinical bioinformaticians to find work in other trusts in the same geographic area.

> *"Realistically, quite a lot of people when they finish the STP they have done something before the STP, it could be a PhD or if not, there were some people working in the labs for couple of years. So, when they finish the STP, they are not 24-year-old grads that are happy to move to anywhere in the world without no ties. They are around 30, married, some people have kids. I do not think everyone is flexible to move."*

> *"My family all live [where I work] … and I would not want to move away from them, it is also where my best friends are. Also, I do not want to be spending a lot of time traveling to work and traveling back home, it needs to be somewhere that is relatively easy for me to get it and is not going to take me an hour to arrive."*

Workplace flexibility was very positively received by clinical bioinformaticians

The interviewed STP trainees and current NHS clinical bioinformaticians shared the opinion that the nature of their work allowed them to work from home easily. However, it was understood that this was not a common practice before the COVID-19 pandemic. The interviewees explained that they had moved to complete or near-complete working from home during the pandemic. This had been positively received by all the interviewees. Furthermore, remote working and flexibility were cited as important factors when choosing where to work by most of the interviewees. Some even stated that if they had a guarantee that they could work remotely for a significant portion of their time, they would consider working in trusts that are geographically distant from where they live.

Remote working for clinical bioinformaticians is not the same as isolated working; almost all the interviewees stated that they felt best when they had regular contact with colleagues. These interviewees expressed that they were happy with the communication they had with colleagues, even when working from home due to COVID-19 restrictions. However, a lack of good workplace communication was associated with a desire not to continue working in that trust.

> *"I do not know if I would be willing to travel to a trust far away from where I want to live. But if I knew I could work from home for at least 2 days a week then I would not mind traveling. We are working over our computers so it should be possible to do."*

Uncertainty regarding job offers from the NHS may be negatively affecting retention

Many interviewees complained about the lack of timely human resources planning by the trusts. This appears to create uncertainty for the trainees concerning their employment after completing the STP. Most of the trainees were concerned about not being able to plan for the future, as they had no idea if there would be a job for them in the trusts where they received their training in. Although it was understood by the interviewees that employment upon graduation was not guaranteed, many of them felt that their trusts could do more to clarify whether they would be able to employ their trainees. This opinion was expressed by trainees, as well as current and former NHS clinical bioinformaticians.

Most interviewed trainees stated that they would like to continue working in the trusts where they were trained. However, they explained that if the trust could not make an offer before the end of the STP, they would have to look for positions elsewhere, as they were not willing to risk unemployment.

> *"I heard once that a colleague of mine did not get offered a job [after graduation] and then found another job a month later, and her trust said 'we want you back, we have got two vacancies' … So then they are never going to go back because it is a very bad experience for them to finish this training program and have this panic of 'where I am going to work'"*

> *"I do not really know if I will get an offer from my trust when I graduate. I do like to stay in my trust but if I do not get an offer, I will have to look for a job elsewhere…"*

Constant "firefighting" is reducing the value clinical bioinformaticians create for the NHS

Several interviewees indicated that their trusts suffered from what they referred to as *firefighting*, which means that bioinformaticians often find themselves in a position in which they spend a large amount of their time fixing problems to keep the system they work with running. Although such duties are within the remit of clinical bioinformaticians, they are typically not value-added tasks. For example, a clinical bioinformatician in genomics might need to spend all his/her time correcting problems created by poorly designed pipelines, and not have the time needed to build new pipelines that would fix all the relevant problems. This issue creates pressure and stress for the clinical bioinformaticians and was cited as one of the reasons for qualified and experienced staff leaving the NHS.

When NHS trusts try to fix this issue by taking on STP trainees, it may make the problem worse by increasing pressure and stress, as the existing staff may have to deal with training duties on top of *firefighting*. In addition, clinical bioinformatics is a fast-moving field and those working in it require continuous up-skilling. Having to perform time-consuming conventional tasks reduces the free time clinical bioinformaticians have for professional development. This may further reduce the value that clinical bioinformatics can create for the NHS.

Firefighting by itself does not seem to be a direct cause of workforce attrition. However, it appears that when trusts do not sufficiently respond to the concerns of their clinical bioinformaticians, this may contribute to their decision to leave. The interviewees who worked in departments that suffered from this issue understood that this was a difficult problem to solve, and better workforce planning and support from senior responsible colleagues were cited as possible solutions.

> *"We want to learn new things, but we don't really have the time … We spend too much time on firefighting, and it has turned into a routine now. This also can make people leave because they are looking to learn new things, but they can't really do that when they are constantly trying to finish multiple tasks under time pressure."*

> *"There were many things that we could have done to do things more stable and more automatic and less prone to human error but there was little time to put things in place because we needed to run the service … But always had different tasks: we had the production, we were involved in the development of new pipelines so we had to put things in place so there is a new service, and everything is going to work, new investigations, data analysis, etc. … We did not have enough support. I brought it up, but our manager was never able to get more people into the team. We had a position that never got filled …"*

The lack of awareness may be negatively affecting the utilization of bioinformaticians

Interviewees stated that there was a general lack of awareness over what clinical bioinformatics was and what clinical bioinformaticians could do. This may have been reducing the value that clinical bioinformaticians could create for the NHS. For example, some clinical bioinformaticians believed that they were not given access to the required resources or tools by their trusts' IT departments because of a misperception of what bioinformaticians needed to perform their tasks. In a similar vein, some interviewees also complained about not being able to establish fruitful collaborations, as other departments had little or no information on what clinical bioinformaticians could accomplish with their skillset and knowledge.

One example is the NHS Test and Trace application, for which different interviewees expressed the opinion that they could have added value to the development of the national software. They appreciated the need to move quickly for the development of this software, however, they felt that it was a good example for an initiative that would be aligned well with their skillsets. Similar examples were provided at the trust level, when information systems or applications had been developed, either in-house or externally, but the trust's own clinical bioinformaticians had not been involved or even consulted. This is especially relevant for the clinical bioinformaticians from the health informatics and physical sciences streams.

> *"I feel like the people I work closely with, and the lab staff we directly interact with, they understand what we do and what we can do so we get recognition from them. But outside of that, I think a lot of people are not aware that we exist and what we can do. We hear about people having hard times doing things that we can easily make into something a lot better and help them with, but they are completely oblivious to the fact that we can help and there are things we can do. I feel like there is only a small number of people that know bioinformatics is actually a thing."*

Working in isolation reduces the effectiveness of clinical bioinformaticians

Multiple interviewees highlighted issues related to working in isolation. Several current and former NHS clinical bioinformaticians mentioned first- or second-hand accounts of trusts employing only a single clinical bioinformatician in a department, which resulted in them working in isolation. It was generally agreed on by the interviewees that bioinformaticians did not thrive in such conditions, as they work best in groups. According to them, clinical bioinformatics is a complex field and many of the problems that clinical bioinformaticians work on require brainstorming and a combination of different perspectives to achieve solutions. Having bioinformaticians work in teams, therefore, was argued to be a better way of utilizing them.

> *"I do not think it is preferrable among bioinformaticians to be the only bioinformatician in the trust. I think particularly in this field it is good to have multiple voices to attack a problem. I feel comfortable in such situations because there are others who I can collaborate with. But I also have some colleagues who do not have other bioinformaticians around and they are not particularly happy."*

The title "clinical bioinformatician" may not be ideal for all

Interviewees generally felt that the title of clinical bioinformatician was appropriate for those working in genomics. On the other hand, some of the interviewees, specifically those from health informatics and physical sciences streams thought that the title was not appropriate for them. Some trainees felt that they did not know where to find NHS jobs that reflected their training as the trusts did not have obvious departments where they could look for work. Some interviewees even reflected that some trusts advertise positions perfectly suited to the skillset and knowledge of clinical bioinformaticians but did not consider clinical bioinformaticians who graduate from STP for these positions, rather looking for people with scientific computing backgrounds.

From the interviews with line managers, it was understood that scientific computing departments were not common in the NHS trusts. However, some trusts had managed to set up such departments, which enabled them to bring together clinical bioinformaticians and other staff working on scientific computing in a single department. This made it possible for them to create larger departments with more flexibility, scope, and reach, as well as reducing duplication of work.

Although there was a feeling amongst some interviewees that the title of clinical bioinformatician was not appropriate, others supported the title, as they believed it provided the opportunity to create a new and distinct discipline in the NHS. They thought that titles such as computer scientist or scientific computing specialist might be too easily confused with IT staff.

> *"Everyone asking me what I do, I've got to say I am a bioinformatician which basically boils down to scientific and clinical computing. When the description of what you do is a sentence well … Also when you google bioinformatician it takes a while to get physical sciences. You scroll all over genomics stuff first. That is also a clue that a naming issue is there."*

> *"Bioinformatician has always been historically related with the genomics data. Now maybe other people are trying to reclaim the term and make it more generic. For me that doesn't work. I still see bioinformatics very genomics related. In physical sciences, health informatics, and genomics streams, there is quite overlap in some of their applications and skills they require but the data they are dealing with is totally different."*

> *"I quite like it [the title clinical bioinformatics]. I think in general it's becoming more known and the reason I quite like it is that it's clearly not IT. The role is clearly not IT."*

Some trusts have insufficiencies related to training

A common complaint from the interviewees was that trusts had some shortcomings in providing training. However, this seemed to be a complex and multi-dimensional issue.

Several interviewees shared first- or second-hand experiences in which there were no qualified personnel in the trusts to oversee the training. Other interviewees stated that there appeared to be no appropriate plan for their training when they started their placement in the trust. In addition, disinterest from supervisors was mentioned as a problem by some of the trainees. Other reports included a lack of personal computers, which are essential for all clinical bioinformaticians whether qualified or in training. Furthermore, some trainees explained that they had to arrange their own placements for completing competencies.

There was a belief among some of the trainees that some trusts were requesting STP trainees not to train them with the intent of possibly employing them, but to have them as an additional source of labour that the trusts did not have to pay for. Since the trainees are funded not by the NHS trusts but HEE, some trusts reportedly took STP trainees to utilize them as what some of the interviewees called "free labour" for tasks that might not be related to clinical bioinformatics. This was not a universal finding, as many trainees and STP alumni were satisfied with the behaviour of their training trusts.

> *"I think some [trusts] are taking trainees on to do free stuff for years. Because it is not coming out of their budget. It is HEE's budget. They get this extra member of staff they do not need to pay and get them to do work. Some trusts seem to get loads and loads of trainees every year the same team is getting more and more. But you do not have the qualified staff to train them. Some of my colleagues are not really happy with their trusts because they are not being properly trained."*

Access to research funding is not a priority for NHS clinical bioinformaticians

Most of the interviewed trainees as well as the current NHS clinical bioinformaticians were not interested in actively participating in externally funded research programmes, such as UK Research and Innovation (UKRI) awards. They were typically happy to contribute to peer-reviewed publications but as supporting authors. However, several of the interviewees stated that they had specifically left academia to get away from the demands associated with participating in research projects.

Some of the interviewed line managers explained that they did have external funding to support their department through partnerships with research institutions, such as universities. These were important to help smooth funding, such as being able to offer positions to STP graduates without having to wait for the trust to approve funding. These line managers stated that being able to manage their trust's budget more effectively during such partnerships was more important than increasing the accessibility to external funding. One way this can be achieved is using innovation budgets inside the NHS trusts.

> *"R&D allows us to put those projects through under the arm of innovation, which means we don't have to grapple with the central trust finances, which are a black hole of hideousness, which would basically mean we would never make any progress anywhere. Yeah, because we have the relative freedom of utilising the R&D, I hold several research budgets. Whenever we get a large project that gets its own budget. When we have a project, we've got a collaboration with, so that gets its own budget. We have another budget which is kind of our dumping ground, so it's called computing research. It's very generic and were able to put money in there, because it's innovations. There [with innovations budget], the oversight is different. For example, at the end of the year, we can argue to carry money over based on future activity and what we expect to spend the money on and so on, which would be a lot harder if we went through this central trust finance."*

5.Interpretation of Themes

The themes identified in the previous chapter represent the feelings and opinions of clinical bioinformaticians and other relevant stakeholders in the NHS ecosystem. However, these themes by themselves do not fully explain the underlying drivers of both the successes and challenges related to retention and utilization of clinical bioinformaticians. The following sections aim to bring together themes and other collected information to achieve a deeper understanding of the current situation in the NHS concerning clinical bioinformatics.

5.1. Major Factors Affecting Retention and Utilization

Altruism and benevolence are common traits for NHS clinical bioinformaticians that promote retention

One of the most striking findings from the interviews and the workshop was that NHS clinical bioinformaticians are strongly altruistic and benevolent. The STP trainees were strongly motivated by the idea that as clinical bioinformaticians they would be able to do things beneficial for the society. Also, current NHS clinical bioinformaticians were content with being paid less than their peers in other industries. The benevolence of those engaged in clinical bioinformatics in the NHS ecosystem means that they are willing to endure issues with the work, and not want to change their job.

However, the willingness of the interviewees to stay in the training programme and NHS trusts is not without limits. When they feel they are no longer able to do their job or that their work is not making a difference anymore, then they are likely to leave the NHS and look for work elsewhere. It can be concluded that the benevolence of NHS clinical bioinformaticians covers pay and working conditions but does not tolerate issues related to the nature of the work. The NHS clinical bioinformaticians want to stay only if they can do the work that they are trained for.

Thus, having a strong altruistic workforce of clinical bioinformaticians is only beneficial if the NHS trusts can ensure sufficiently interesting and challenging work. When trusts can find a way to keep their clinical bioinformaticians engaged and satisfied with the work they do, the clinical bioinformaticians will likely stay.

The STP trainees want to stay in their training trusts, but this is often not possible

When discussing their future with the STP trainees, it was clear that the majority (more than 90%) wanted to stay in the NHS, preferably in the same trust that they were trained in. However, most training trusts are not able to employ all their trainees. This is because most of the experienced clinical bioinformaticians are concentrated in a relatively small number of trusts, and only these trusts have the capabilities to train new clinical bioinformaticians, and these trusts have a relatively low need for new clinical bioinformaticians. From the interviews, we observed a strong resistance to relocation amongst the STP trainees. In some cases, the interviewed trainees stated that they would rather leave the NHS than being relocated to a trust in a different region.

The strong desire from the STP trainees to remain in the same trust or region where they are receiving their training could be related to their ages and experience. 81% of the interviewed STP trainees had doctoral degrees compared to only 40% of the interviewed alumni. This suggested that the current cohort of STP trainees are entering the programme relatively later in life and with more experience. This could be a reason why they are strongly motivated to remain in the same location after completing their training.

During interviews with the STP alumni, it was observed that those who remained in their training trust were less likely to still be working in the NHS than those that changed their trust after graduating. There was no direct evidence for why this might be the case. However, it is possible that when a clinical bioinformatician moves to a new trust he/she has greater potential to professionally grow and develop. The trusts that are actively searching for clinical bioinformaticians may be more motivated to provide the needed resources for their new staff to thrive as they need those staff to grow their clinical bioinformatics departments.

This creates an incongruity where trainees want to stay in their training trust, but they might have a better long-term prospect in the NHS if they change trusts.

The nature of the work in the NHS is a big pull factor, however, firefighting is pushing some people out

This study did not look at the content of the training programme at all, as it was an out-of-scope topic. However, it was understood from the comments of the interviewees that the content of the programme aligns very well with the skills needed in NHS clinical bioinformatics. A large proportion of the interviewees stated that the nature of the work was a motivating factor for them to enter the STP and seek work in the NHS. In addition, the working hours and general work/life balance were reported as very positive factors contributing to many interviewees' desire to stay in the NHS.

However, not all the jobs that NHS clinical bioinformaticians do in their trusts are equally rewarding from their perspective. The current and former NHS clinical bioinformaticians explained that they had been typically involved in 4 different activities in the trusts:

1. Core clinical bioinformatics work, such as developing pipelines or creating applications;
2. Routine and maintenance work, such as validating genomics reports and fixing errors with pipelines or other interfaces;
3. Research work, such as supporting academic partners with the collection and analysis of data for publications; and
4. Training activities.

Most interviewees stated that they entered the profession primarily to conduct the core clinical work, but they understood that their job would involve a balance of these different types of tasks. The clinical tasks, along with training activities, allow the clinical bioinformaticians to keep up to date with development in their fields. They also feel that these are the tasks that create the most value for their trusts, since having sufficient time to develop newer pipelines or software reduces the need for routine and maintenance work.

Out of all the tasks that NHS clinical bioinformaticians are involved with, it is the routine and maintenance work that appears to be most strongly correlated with poor retention and under-utilization. The majority of former NHS clinical bioinformaticians cited an excess of these types of

tasks, sometimes referred to as "firefighting" as a contributing factor in their decisions to leave. However, it was not just the firefighting that caused people to leave the NHS by itself. When there was an excess of these routine and maintenance jobs, the interviewees felt that they were not able to upskill and grow professionally. One interviewee who had worked in a trust for a few years stated that the new STP trainees had a better understanding of current clinical bioinformatics than s\he did. This knowledge gap was attributed to a lack of time to upskill as a direct result of "firefighting".

Thus, to keep clinical bioinformaticians in the NHS, trusts need to help them do the work that motivated them to follow the career path into the NHS in the first place, as well as to make sure they have the time they need for professional growth and continual upskilling. An interesting additional observation is that, although NHS clinical bioinformaticians enjoyed being involved in research activities, it was not a priority area for most. Some interviewees stated explicitly that if they had wanted to do research they would have stayed in university for doctoral or post-doctoral studies.

A perceived lack of promotion opportunities may be causing relatively experienced staff to leave the NHS

There was a consensus amongst the interviewees that promotion opportunities in the NHS trusts were limited. This was not a critical factor for most of the people interviewed as they expected that either they would change jobs in the future or promotion opportunities would improve within the NHS ecosystem. Given that clinical bioinformatics is a relatively new field in the NHS, it is normal to have relatively few clinical scientists at band 8 and above, and little representation within senior management in the NHS trusts.

It is unclear whether the glass ceiling described by some interviewees was real or perceived. However, what is important when considering effects on retention is the perception of promotion opportunities. Staff members may look for work outside of the NHS simply because they believe there are no promotion opportunities, even when they exist. Amongst those former NHS clinical bioinformaticians, most expressed that although they had wanted to work in the NHS, they would not consider returning because in most cases this would be equivalent to a demotion.

What is clear from the interviews is that those who were training to work in the NHS wanted to continue working in the NHS trusts for a long time. This sentiment was echoed by most of the current NHS clinical bioinformaticians that were interviewed. They would accept lower pay than their peers for the opportunity to do the work that satisfied them in the NHS. However, if the NHS cannot retain these experienced staff, then this will have a series of knock-on effects:

- Fewer experienced senior clinical bioinformaticians may result in the continuation of lower representation of this discipline at senior levels in the NHS trusts.
- Low representation at senior levels is likely to perpetuate the low awareness of clinical bioinformatics in the NHS trusts.
- Low awareness in the NHS trusts may in turn reduce the available resources clinical bioinformaticians have and result in high levels of "firefighting" and high staff turnover.
- High staff turnover will reduce the number of experienced clinical bioinformaticians able to apply for more senior roles.

This is an example of a worst-case scenario but may reflect what is already happening in some trusts.

The HSST programme provides a pathway for clinical bioinformaticians to acquire the qualifications needed to progress into more senior roles in the NHS. Amongst the interviewed STP trainees that did not have doctoral degrees, there was a positive opinion of HSST. However, the STP trainees with doctoral degrees, as well as the current and former clinical bioinformaticians were generally less enthusiastic about the HSST programme. The lack of enthusiasm about HSST may be contributing to the perceived lack of promotion opportunities, as some clinical bioinformaticians feel that they cannot be promoted unless they complete HSST, however, they do not want to or are not able to participate in this programme.

Low awareness of what bioinformaticians can do is reducing the value they generate for the NHS

The field of genomics appears to have become well established in the NHS trusts. Work such as "The 100,000 Genomes Project" and the establishment of the Genomic Medicines Service in the NHS has raised the awareness of genomics. As bioinformatics has been traditionally associated with genomics, some of the awareness associated with this field appears to have transferred to clinical bioinformatics. However, interviewees, both from the genomics and other clinical bioinformatics streams, reported that awareness regarding their profession was still low.

This lack of awareness falls into 2 main categories:

1. Knowing about the outputs clinical bioinformatics produces, but not being aware of the work needed to create those outputs; and
2. Not knowing which outputs clinical bioinformaticians can produce.

The first category was most often cited by interviewees from genomics, although it was also noted as a problem by some interviewees from health informatics and physical sciences streams. Some interviewees stated that no one noticed the work they did unless something went wrong. In other cases, clinical bioinformaticians had conflicts with IT departments over network or storage requirements, where the IT departments felt the clinical bioinformaticians', requests were unreasonable. Some of the more senior clinical bioinformaticians explained that they felt invisible to management. They could be doing ground-breaking work but no one outside of the department would notice. The reason cited for this lack of awareness was usually that most of the work that clinical bioinformaticians do is invisible and only the output can be seen. For those that do not have a comprehensive understanding of clinical bioinformatics, it can be hard to understand how much work can go into creating its outputs.

The second category of awareness issues was mentioned mostly by those working in health informatics and physical sciences. There was a perception that outside of the immediate department they worked in, people did not know what bioinformaticians did or could do. An interviewee gave an example in which a trust needed a clinical software application and tendered its development externally when they had qualified clinical bioinformaticians that could have built the application internally. Other issues that come from this lack of awareness can be multiple employees with similar skillsets working separately from each other and thus not able to benefit from each other's experience, or in the worst case, duplicating work.

The title "clinical bioinformatician" could be somewhat responsible for the lack of awareness especially related to health informatics and physical sciences. Over the years, trusts have

acquired specialists in clinical computing, scientific computing, health informatics, and other similarly titled roles. Many of these roles have large overlaps or are completely covered by the scope of clinical bioinformatics. Some trusts are aware of this issue and have, formally or informally, grouped together programmers, scientists, software engineers, and clinical bioinformaticians that have similar skills to improve their effectiveness.

The issues related to the lack of awareness that clinical bioinformaticians reported seems not to have a strong direct effect on retention. Rather, they appear to be reducing the value that this critical workforce can create for the NHS. Yet, the lack of awareness is having indirect effects as well, such as reducing the resources available to clinical bioinformaticians which may, in turn, create "firefighting" issues, eventually leading to increased staff turnover.

5.2. Additional Observations

Not all the observations from the interviews and workshop are strongly related to the utilization and retention of clinical bioinformaticians in the NHS. These include observations concerning a small number of trusts or a specific group of clinical bioinformaticians, as well as the ones that are related to areas which are important but not actionable within the scope of phase 2 of the project.

When people leave the NHS, it is sometimes because of specific issues in their trusts or personal lives

The results from the ESP survey suggest that there were no significant differences in equity sensitivity scores, between those who stayed in the NHS and those who left. Therefore, we can consider these two different groups as similar in terms of their equity sensitivity profiles. This observation leads us to the conclusion that, for some of the people who left the NHS, there were trust-specific and/or personal factors that drove their decisions to leave. This is an important point as it implies that energy and resources would be best directed to improving the situations in NHS trusts where staff retention is low.

Some of the most common trust-specific issues raised in the interviews were:

- The lack of timely job offers from the trust during the final year of STP trainees;
- Weak relationships between clinical bioinformaticians with others in their department and/or trust;
- Indifference and/or resistance from the trust's IT department; and
- A lack of awareness from senior staff in the trust of the needs of clinical bioinformaticians.

The needs of clinical bioinformatics may be at odds with the culture of some trusts

It was suggested by a few of the interviewees that the work culture in some trusts was a contributing factor in people leaving the NHS. While this sentiment was not explicitly expressed

by all the interviewees, there was a general feeling amongst the respondents that sometimes the culture of NHS trusts was not aiding clinical bioinformatics.

Although many interviewees spoke in positive terms about the NHS in general, there was a sentiment during the interviews that the NHS trusts could be inflexible and resistant to change. Given that clinical bioinformatics is a new and dynamic field, the lack of flexibility in trusts might have created tensions between clinical bioinformaticians and the trusts' administrations. Although there were few specific examples of cases when such tensions had a direct effect on retention or utilization, it was understood from the interviews that indirect effects were existent.

If the culture of the NHS trusts is negatively affecting retention and utilization, this is a relatively difficult problem to address. However, it was observed that there were partnerships formed between universities and the NHS trusts in the field of clinical bioinformatics, which have the potential to transfer flexibility from academia to the NHS ecosystem. Such partnerships present, at least in the short term, a solution to the issue of cultural clashes between clinical bioinformatics and the more traditionally focused trusts.

Lack of equipment and IT infrastructure is not a factor in underutilization and attrition

Perceived underfunding in the NHS is a much-discussed subject in England. Thus, it would be reasonable to expect that utilization and retention issues in clinical bioinformatics could be related to a lack of physical resources, such as computers, servers, software, or other IT infrastructure. However, during the interviews, this was not observed to be an issue. There were occasional discussions of specific problems with trusts' IT departments, such as lack of timeliness in responding to requests or issues with running specific software on some trusts' networks, but generally, most interviewees felt that they had the equipment and software they needed to do their work.

There is a high proportion of post-doctoral STP trainees who have particular interests

From the interviews, it was observed that the majority of STP trainees had doctoral degrees. The level of education and experience that these clinical bioinformaticians have needs to be considered when formulating career and learning and development plans. Their expectations may be different from the trainees who entered with bachelor's or master's degrees that were common in the previous cohorts. Some important observations related to the post-doctoral STP trainees include the following:

- They were less interested in the salary levels, as they knew they could earn much better wages in the private sector. They chose to work for the NHS for better working conditions and less stressful work environments.
- These trainees typically did not want to relocate after completing their STP training.
- They mostly were not interested in participating in research projects. Some explicitly stated that they left academia to get away from the traditional research culture.
- The post-doctoral trainees were the least interested in the HSST programme out of all the interviewees. They felt that it would be a waste of their time as they already had doctoral degrees, and that if they needed to gain management experience there should be shorter and easier ways to obtain the relevant skills.

6. Recommendations

6.1. Training and Commissioning

1 – Survey NHS trusts and integrated care systems (ICS) to identify additional departments where clinical bioinformatics training could be provided

For the clinical bioinformatics genomics stream, there are very clear indicators of which departments are appropriate for STP trainees. In addition, the GLH and public-private partnerships for genomic services are creating a comprehensive and well-connected network of facilities for the trainees. However, for the health informatics and physical sciences streams, there may still be room to expanding training activities to a wider range of organisations. It is possible that some NHS trusts and associate organisations that could participate in the STP training programme have not yet taken any trainees.

According to some interviewees, the NHS trusts had been employing staff with skillsets similar to that of clinical bioinformaticians that work under health informatics and physical sciences streams. These staff worked in various departments under different titles, including, **scientific computing, clinical computing, software engineering, and medical physics**. It was suggested by some interviewees that many trusts may have people in these roles and these trusts may not have been aware that the STP clinical bioinformaticians training would be available for them to train more staff.

Thus, it is recommended that HEE investigates this possibility by surveying trusts to look for the existence of such staff, and factors in these into future demand scoping for STP commissioning.

2 – Set out a proposed model of how to involve external partners in the commissioning and training of clinical bioinformaticians by looking at research departments, especially those in universities with existing links to NHS trusts

Given the importance of bioinformatics for the research institutions and the private companies, it is prudent to consider engaging with these organisations to improve commissioning. One suggestion has been to have partnerships between the NHS trusts and other organisations to improve training and create long-term collaborations that will keep more clinical bioinformaticians in the NHS. However, the trainees amongst the interviewees in this study generally indicated that they did not want to work for research institutions or private companies, since most trainees had chosen the STP specifically to work in the NHS.

This does not mean that it would not be beneficial to further investigate the possibility of such partnerships, as there may be selected cases in which they could work. It is suggested to start with situations where there is already active collaboration between trusts and external organisations, such as universities already associated with NHS trusts. During the interviews, several people explained that they either worked for an NHS trust but had an honorary contract with a university, or they worked for a university but had an honorary contract with an NHS trust.

To encourage such partnerships, HEE could investigate creating a special partnership programme for collaboration between NHS trusts and research groups. In such a programme, the parties should together create a plan to demonstrate how the partnership would add value to the training process and improve post-graduate employment prospects for the trainees. This kind of

collaboration could also be incentivized with one-off payments to the research groups to support setting up the partnerships. If such NHS-research group partnerships prove successful, then the programme could be extended to include private companies.

3 – Develop a strategy to provide timely information about post-graduation employment opportunities to STP trainees

The uncertainty surrounding whether the trainees are going to be offered employment in their training trusts is causing them distress, especially towards the end of their final year of training. Although the trainees are aware that employment is not guaranteed, not knowing if they are going to be able to continue working in their trusts is leading them to search for employment opportunities outside of the NHS. When trainees leave the NHS in such a way, it does not only constitute a missed opportunity for the trusts, but it also amounts to a waste of public resources.

Although HEE cannot make trusts employ their trainees after they complete the STP, it may be possible to develop protocols to encourage trusts to give their trainees more clarity on what will happen after graduation. In addition, such protocols could help connect final year trainees with other trusts that are looking for clinical bioinformaticians. Some possible components of the protocols could be:

- NSHCS can formally request that the trusts provide a firm decision to their trainees on post-graduation employment at least 3 months before graduation. This should be followed up with the trainees to see if such a decision was provided.
- A clearing process can be created for trainees that wish to continue in the NHS but do not have job offers from their training trusts. Such a process should be open to all trusts looking to employ clinical bioinformaticians. If the clearing process is opened early in the final year of the trainees, it will also encourage the training trusts to make more timely offers, as otherwise they would risk losing their trainees to other trusts.

4 – Proactively encourage the use of elective units for trainees to visit other NHS trusts during the STP

An important observation from the interviews was that the trainees generally did not want to change their location after graduation, but that those clinical bioinformaticians that did change trusts were more likely to remain in the NHS several years after graduation. Thus, promoting trainees to move to new trusts after graduation could be an effective way to improve retention. In addition, dispersing clinical bioinformaticians to more trusts may increase the number of trusts that are able to train more clinical bioinformaticians in the future, thus increasing the supply in the long-term.

One of the interviewees explained that s\he had used an elective unit to work in a different trust in a city where the interviewee wished to move after completing the STP. The interviewee explained that s\he now works in that trust and is very happy with the decision to use the elective in that way. If this would be promoted for more trainees, it could increase post-graduation employment for clinical bioinformaticians in the NHS.

This could be done by creating a forum where the NHS trusts can express their interest in taking a clinical bioinformatician trainee for their elective. HEE could promote and advertise this to all the NHS trusts. On the other hand, the NSHCS may consider providing a small support budget to trusts that wish to take trainees from other trusts for their elective unit, to further promote this

process. In addition, trainees can be encouraged to leave feedback on their experiences in a specific trust for other trainees to review. This will help regulate the process, ensuring trusts that take trainees work hard to give them a good experience while allowing the trainees to pick trusts that seem best aligned with their interests and/or personality.

5 – Explore the option to develop alternative programmes that will complement the Higher Specialist Scientist Training (HSST), commissioned by HEE

The clinical bioinformatics HSST is a novel programme in the NHS. However, the interviewees of this study were generally not positive about the HSST for their personal career pathway. This may not reflect any specific features of the programme but rather of the fact that it is so new, and people have not yet recognised its value.

Some interviewees suggested that, rather than participating in the HSST, they would prefer to complete continuing professional development (CPD) units in their own time, which would build towards developing the skills needed for promotion to more senior roles. They suggested that it might be better for them to have an equivalence pathway for reaching the position of consultant clinical scientist. This was expressed to be preferable especially by those clinical bioinformaticians who already held doctoral degrees.

Thus, although HSST is clearly an important component in the development of comprehensive clinical bioinformatics in the NHS, it could be beneficial to investigate complementary alternatives. Developing and promoting CPD modules focused on upskilling current NHS clinical bioinformaticians would provide formalised personal growth pathways as well as improving clinical bioinformaticians' perception of promotion opportunities.

6 – Plan for medium- to long-term increases in funding for the clinical bioinformatics STP

The inputs from all the stakeholders, both during the workshop and the interviews, indicate that currently there is no need for additional funding for STP clinical bioinformatician training. None of the interviewees who were involved in commissioning stated that they were unable to get STP trainees when they needed them. Moreover, there was no evidence of excess demand for clinical bioinformaticians according to the stakeholders inside HEE.

However, many of the interviewees and workshop participants confirmed the observations from HEE Digital Readiness Programme's demand forecasting report[6], which suggest that there is currently a high demand for clinical bioinformaticians in the NHS and that demand will grow significantly in the future. In addition, implementation of some of this report's recommendations will most likely increase the demand for clinical bioinformatician trainees. Thus, it is reasonable to believe that the volume of clinical bioinformatician training will grow faster compared to other STP trainings. It is recommended that HEE makes itself prepared for a steady increase in the funding requirements associated with clinical bioinformatician training.

[6] https://www.hee.nhs.uk/our-work/building-our-future-digital-workforce/data-driven-healthcare-2030

6.2. Stakeholder Engagement

7 – Ensure that an extensive and inclusive selection of stakeholders are fully engaged for phase 2 of the project via the HEE Clinical Bioinformatics Advisory Group (HEE-CBIAG)

The advisory group terms of reference that were developed as part of this project include the possibility to bring in temporary members as needed. This should be used to engage with a wide range of stakeholders that may contribute to the improvement of retention and utilization of clinical bioinformaticians. As phase 2 of the project progresses, and strategies are fully developed and implemented, different groups of stakeholders may become relevant. The advisory group can quickly and effectively engage with these stakeholders by making them temporary members.

This will allow the HEE to engage with any organisations or groups without conflicts of interests, as the advisory group is an arm's length organisation.

8 – Develop alternative promotion activities to raise awareness of clinical bioinformatics, especially within the trusts and integrated care systems (ICS)

From the discussions with line managers and experienced NHS clinical bioinformaticians, it was understood that various staff inside the NHS ecosystem often do not have the opportunity or time to learn about clinical bioinformatics. In the long term, clinical bioinformatics is expected to become better known in the trusts. However, for the short term, it is proposed that alternative and creative promotion activities are needed. Examples of such activities could be the following:

- **A conference sponsored by HEE and/or other NHS entities to showcase NHS clinical bioinformatics.** Existing partners (e.g. universities and private companies in the industry) could be invited to such a conference to present alongside NHS trust representatives, current NHS clinical bioinformaticians, and STP trainees. This conference could also serve as a recruitment and networking event, bringing together employers and employees.
- **Effective communication campaigns within the NHS trusts that focus on explaining what clinical bioinformatics is.** Such campaigns may have an emphasis on the unique value created by the profession, with practical and accessible examples of how clinical bioinformaticians can create value in the NHS trusts.

6.3. Infrastructure and Support

9 – Create a portal to facilitate communication of clinical bioinformaticians with each other and with other clinical scientists and managers in the NHS

The interviewed trainees explained that they were in regular communication with other trainees and that this informal network was helpful for them. They used it to get advice on various matters, such as how to complete their competencies or find appropriate projects/departments for specific rotations. In addition, some of the STP alumni for the first cohorts of the programme explained that they developed an informal network to support each other after they graduated.

To expand such useful communication practices, it is recommended that HEE investigates creating an online portal to facilitate interaction between clinical bioinformaticians. Such an interface could be used by the bioinformaticians to connect with each other and support professional and training activities. It could also be used by other NHS staff to connect with clinical

bioinformaticians with the purpose of benefiting from their capabilities, as well as advertising permanent jobs or short-term projects for them. Such a portal would also work as an additional tool for HEE to understand what the current trends and challenges are facing clinical bioinformaticians in the NHS, thus, allowing for faster reactions to issues before they become critical problems.

10 – *Define and promote the best practices for work-from-home in the post-pandemic world*

Clinical bioinformaticians have been able to adapt quickly and effectively to work-from-home. This is due, at least in part, to the strong computational component of their work. Interviewees were almost universally in favour of continuing work-from-home practices after the end of Covid-19 restrictions. Since clinical bioinformaticians feel that these practices are beneficial they may help reduce the number of STP trainees that leave the NHS after graduation. Some interviewed trainees stated that they would be willing to take work in more geographically distant NHS trusts if there were formal guarantees of flexible work-from-home allowance.

Thus, it is recommended that HEE supports work-from-home approach for clinical bioinformatics as much as possible. This could be part of a larger effort, especially if other NHS clinical scientists are strongly in favour of extending this form of workplace flexibility. Supporting work-from-home practices can be realized at multiple levels:

- The NSHCS can request that training trusts give this flexibility to their trainees;
- HEE can create promotional materials concerning clinical bioinformatics for trusts that include guidelines and recommendations for work-from-home practices; and
- The senior members of HEE can voice their support for such practices as part of any reviews by NHS or other governmental bodies.

7. Advisory Group

An additional output of phase 1 of this project is to create an advisory group. This group will review the findings and recommendations of this report and provide feedback. It will also be responsible for monitoring and reviewing the second phase of the project through a review cycle framework.

The following functions regarding the review cycle will be within the scope of the advisory group:

- Approving the review cycle framework;
- Providing oversight for the collection and analysis of data;
- Approving all deliverables; and
- Providing strategic guidance on future directions.

The advisory group will have both permanent and temporary members to represent different stakeholders that are relevant for clinical bioinformatics. The permanent members will provide relatively high-level inputs and expert opinions, whereas the temporary members will offer their know-how that pertains to certain subjects or specialties. The members of the advisory group are proposed to be drawn from various entities and groups that will include the ones presented in the table below.

Table 7: Entities that can be represented in the advisory group, by membership type

Permanent Members	Temporary Members
NSHCS	Current NHS Clinical Bioinformaticians
HEE Digital Readiness Programme	Former NHS Clinical Bioinformaticians
Higher Education Institution that provides training for Clinical Bioinformatics STP	Current STP Clinical Bioinformatics Trainees
Public Health England	Genomic Laboratory Hubs
Academic Health Science Networks (AHSN)	University Research Groups
Association of British HealthTech Industries (ABHI)	
Association of the British Pharmaceutical Industry (ABPI)	

To form the advisory group, the relevant stakeholders should be communicated via open invitations for joining the group. Communication strategies suggested for different types of stakeholders are shown in the following figure.

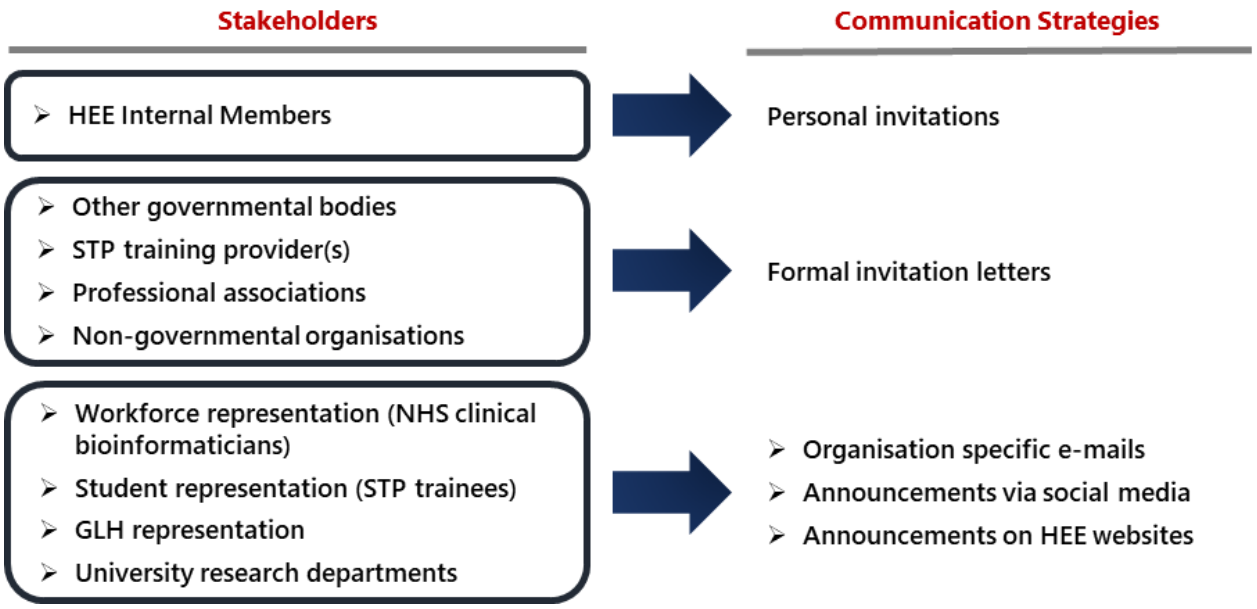

Figure 3: Communication protocols for different types of advisory group members

Personal invitations can be used to contact potential members from inside of HEE. This will be the fastest and most effective way to bring in the needed internal expertise. To invite selected groups of members from outside of HEE, formal invitation letters can be used. These can be addressed to specific individuals within an organisation who are known to have an interest in NHS clinical bioinformatics, or to department/organisation leaders.

The advisory group should include representation from those professionally involved with clinical bioinformatics, both inside and outside of the NHS. To ensure this, potential members can be invited through e-mails by NSHCS and/or HEE, which can be tailored to specific groups of interest, such as current STP students, current NHS clinical bioinformaticians and academic staff at university research departments. In parallel, calls should be made through social media and websites to ensure that all those who are interested in participating have an opportunity.

It is expected that for the representation of most groups, 1 or 2 members will be sufficient. When public invitations are responded by more people, for the selection of permanent members, it is proposed that HEE decides based on the qualifications and experiences of the applicants. For temporary members, a two-stage transparent process can be used:

1. The removal of unqualified or inexperienced applicants; and
2. A random selection from the remaining potential members.

In this process, the initial filtering can be done internally by HEE or by the advisory group itself.

8.Review Cycle Framework

One of the main responsibilities of the advisory group will be carrying out the review cycle, which will be used to monitor, assess and revise the actions that will be taken in phase 2 of this project to improve the retention and utilization of clinical bioinformaticians in the NHS. The review cycle will help develop insights into where the phase 2 actions are working and where additional improvement is needed. The advisory group will not develop data collection tools, conduct data collection/analysis, or prepare reports. Rather, they will oversee the whole process, in which a third-party organization will perform all these tasks.

8.1. Data Collection

In line with the abovementioned objectives, relevant data for the review cycle will be mainly collected from 3 groups of people:

1. Current STP trainees;
2. Current NHS clinical bioinformaticians, including STP alumni, HSST trainees, and those who qualified through the AHCS pathway;
3. Former NHS clinical bioinformaticians and STP trainees who are currently working elsewhere; and
4. Line managers, trainers, and senior administrators of NHS trusts.

Obtaining information from these important groups of stakeholders will make it possible to closely monitor the retention and utilization of clinical bioinformaticians in the NHS. Such information will enable the advisory group to develop a comprehensive understanding of the issues experienced by each of these groups.

To undertake the review cycle, various types of primary data can be collected through two different instruments, namely, *surveys* and *interviews.* Standardized surveys with the NHS trusts will make it possible to keep up-to-date statistics regarding some key figures, such as the numbers of STP trainees currently in training, clinical bioinformaticians working in the NHS, trainees who left the training programme and clinical bioinformaticians who left the NHS. Furthermore, more granular data at the trust/individual level can be collected via surveys, such as the distribution of trainees and clinical bioinformaticians by trust and region, and the destinations of those who left the NHS.

Surveys will also be useful in collecting qualitative data from a large cohort of people to develop a high-level understanding of the experiences, opinions, and future of the trainees and NHS clinical bioinformaticians. Information regarding retention and utilization can be gathered by asking respondents about their agreement with statements on a 5-point Likert scale questionnaire, in which some exemplary statements can be the following:

- “Leaving the NHS is not in my plans for the future.”
- “I am certain that I will be offered a job in the trust I am training in.”
- “I think my skillset is being fully utilized in my trust.”

It is necessary to combine surveys with interviews to reach more granular information regarding the employment of clinical bioinformaticians, such as the root causes of problems that lead to decisions of leaving the NHS. Performing in-depth interviews with trainees, current/former clinical bioinformaticians, line managers, trainers, and trust administrators will make it possible to extract more detailed and open-ended information about their opinions, experiences, and futures.

Surveys and interviews can be administered annually for the purposes of the review cycle. Data from trainees can be collected from the entire cohort each year, and data from qualified clinical bioinformaticians can be collected from random samples of people. Furthermore, it is suggested that ad-hoc exit surveys and/or exit interviews be given to those who leave the training programme or the NHS.

In addition to primary data collection, supplementary information should be regularly obtained from the advisory group members. The advisory group represents a wide range of stakeholders that are relevant to clinical bioinformatics, including experts on the commissioning, training, and employment of clinical bioinformaticians in the NHS. Since the advisory group members will be instrumental in the design and implementation of the strategies during phase 2 of the project, they will be best positioned to provide information related to all the initiatives to be implemented.

8.2. Analytical Approach

After collecting and collating the data from annual surveys and interviews, the emphasis of the analysis should be on the changes in the patterns and themes regarding retention and utilization of clinical bioinformaticians. Firstly, it is necessary to investigate quantitative trends in the workforce numbers. Secondly, a thematic analysis should be conducted to review previously identified themes and discover new ones. Once the major themes and patterns in the data relevant to retention and utilization are established, the analysis should focus on whether they are changing and to what extent. Such an analysis will make it possible to develop an understanding of the effectiveness of the actions implemented as part of phase 2 of the project.

8.3. Reporting

The third-party organisation responsible for data collection and analysis should generate periodic update reports to present the findings to the advisory group and other relevant stakeholders. The update reports should culminate in a final report by the end of the project to document the overall effectiveness of the implemented initiatives. Once the update reports and the final report are generated, they should be sent to the advisory group for feedback and finalized accordingly.

8.4. Timeline

The relevant data regarding the status of the clinical bioinformatics workforce in the NHS should be collected and analysed annually to follow up periodic changes. To see the long-term effects of

implemented initiatives related to commissioning and employment, it is recommended that this annual data collection and analysis activity is continued for a minimum of 4 years.

Data collection, analysis, and reporting phases should be planned prior to the onset of the review cycle. These plans should be sent to the advisory group for their review and final confirmation. Annual update reports should be sent to the advisory group not more than 3 months after the data is collected.

9.Conclusions and Next Steps

In this study, a wide range of stakeholders were engaged to help build an understanding of the current situation concerning the retention and utilization of clinical bioinformaticians in the NHS. A comprehensive set of data was collected through a workshop, in-depth interviews, follow-up questionnaires, and secondary research. Thematic analysis of this data led to the synthesis of a comprehensive picture of the factors affecting utilization and retention of clinical bioinformaticians in the NHS, and the development of recommendations for improvement.

From this investigation, it has been concluded that those who seek to work as clinical bioinformaticians in the NHS tend to be altruistic and benevolent; moreover, they are mostly happy with the nature of work and working conditions in the NHS. However, in some trusts, clinical bioinformaticians have excessive undemanding and conventional tasks that are reducing the value they can create for the NHS. In situations where NHS clinical bioinformaticians feel undervalued, or when they believe there are no promotion opportunities, they are more likely to consider leaving the NHS. The underutilization of this important workforce is at least in part due to low awareness of their capabilities, especially at the more senior levels inside the trusts.

To help improve the retention and utilization of clinical bioinformaticians in the NHS, 10 recommendations have been developed. 6 of these recommendations concern the training and commissioning processes for the clinical bioinformatics STP. These focus on keeping the STP alumni in the NHS and increasing the number of organisations involved in the STP. 2 recommendations focus on stakeholder engagement to improve awareness of clinical bioinformatics and thus increase the value they can create for the NHS. Finally, 2 recommendations seek to strengthen the support clinical bioinformaticians receive in the NHS through improving networking and flexible working.

In addition, the terms of reference and communication protocols for recruiting members have been created for the HEE Bioinformaticians Advisory Group (HEE-CBIAG). The advisory group will be instrumental in translating the recommendations of this report into actions, as well as ensuring an independent and transparent evaluation of the effects of the changes to be implemented.

To facilitate HEE-CBIAG's monitoring and evaluation activities during phase 2 of the project, a review cycle framework has been created. This includes a timeline for the evaluation as well as suggestions for data collection, analysis and reporting.

The next steps for this project are the following:

1. HEE will form the advisory group (HEE-CBIAG) by bringing together the stakeholders needed for phase 2 of the project;
2. This report will be reviewed by the key stakeholders to be involved in phase 2 of the project, including but not limited to, HEE-CBIAG, HEE Digital Readiness Programme, and the National School of Healthcare Sciences;
3. This report will be made available to the public via HEE's website. In addition, HEE will use its social media channels to publicise this report and invite interested parties to provide their feedback and additional input;
4. Feedback and inputs from all stakeholders concerning the findings and recommendations in this report will be used to refine the scope and requirements for phase 2 of the project; and
5. Partners and/or organisations will be engaged to start phase 2 of the project.