PHC Catalyst

Building, organizing and internalizing knowledge about personal healthcare

Advisory report
Composed by PHC Catalyst Alliance
in cooperation with PNA-Group

Final 11-11-2020

PNA KNOWLEDGE PARTNER

PHC Personalised Healthcare Catalyst

This report is developed by the members of the PHC Catalyst Alliance and has been made possible by a financial contribution of Roche Nederland B.V.

Foreword

This report is the outcome of a project initiated by the Personalised Healthcare Catalyst.

The PHC Catalyst Alliance started in 2018 with the mission to accelerate the transition towards personalised healthcare (PHC), as rapid progress in biomedical, data science and AI, create new insights into health and disease that enable us to transform patient's lives by *delivering care tailored to the individual*, thereby helping to prevent, diagnose, and treat patients more effectively and quickly.

Though the progress in the various scientific areas is impressive, we do not fully enjoy the benefits yet, primarily due to the barriers in the receiving environment, in particular the way we currently have organized our healthcare system. In other words, science is running faster than its framework.

The PHC Catalyst Alliance is a 'coalition of the willing'; it is a multi-disciplinary group of professionals, each experts and innovators in their fields, who are united in their vision and ambition to create a healthcare system without barriers for PHC. This will allow healthcare to evolve from reactive 'one-size-fits-all' disease care towards proactive personalised healthcare, and will allow consumers to use personalised health information to improve their health as they observe the impact of their lifestyle decisions.

In 2020, the Personalised Healthcare Catalyst Foundation was established, a legal entity with the same purpose as the alliance. We look for opportunities to highlight and accelerate progress, and initiate and support projects to do so. We apply the methods of 'Combinatoric Innovation', which means that we do not reinvent the wheel, but focus on what is already out there and connect people, organisations, knowledge and data to demonstrate the value of PHC, shift mindsets, and break down implementation barriers.

This report is dedicated to one of the key topics in PHC and that is knowledge management. We define knowledge as the interplay between insights (past), information (present) and imagination (future) that enables us to make the right decisions and perform tasks that create value. The aim of strategic knowledge management is to ensure that we know what knowledge is relevant to achieve our goals, what knowledge is available, what knowledge is lacking, how to acquire missing knowledge. The operational part of knowledge management focuses on distribution and application of knowledge. The world of PHC is clearly a multi-stakeholder environment, consisting of patients, professionals, payers, management, government, scientists, solution providers, etc. Each stakeholder needs the right knowledge in order to assess the opportunities and challenges of PHC and consequently to decide what (not) to do.

This report is a great contribution to answering the question: what do the various stakeholders need to know and what knowledge gaps are there? To fill these gaps, knowledge acquisition needs to take place and this can happen in various ways, such as research, collaboration, practicing, etc. Education is of course a very important way of learning about what PHC is, what it (potentially) can bring and what it takes to make it happen. Of course the learning needs are different for the various stakeholders and this is exactly what has been researched in this project. And it became very clear that we have to deal with significant knowledge gaps for every stakeholder, which is a call for action. If doctors don't know the status and possibilities of PHC, how can they offer the possibilities to their patients? If health insurers don't understand the value case, how can they make the right (financial) decisions? If patients don't know how they can benefit from and contribute to PHC, how can they make the right decisions to protect and restore their health?

This lack of knowledge jeopardizes a rapid transition towards PHC and therefore education is of the utmost importance. This report gives a good overview of suggestions for education, including available and potential educational programs for various stakeholders, with special emphasis on (younger generation) health professionals.

This report is one in a series that we are developing and we hope that the results will inspire people to further develop and implement the insight and ideas that have been acquired during the process. We also hope that more people and more organisations will work together on changing the society and the healthcare system in particular, to make personalised healthcare affordable and accessible for everyone.

On behalf of the PHC Catalyst, I want to thank and compliment the authors on their important work and the insights and recommendations that they have presented in this report. We invite the reader to give feedback by contacting the PHC Catalyst or the authors.

United we stand, departed we fall!

Content

Executive Summary

The road to tailored, personalized healthcare (PHC), using an interdisciplinary, data-driven and integrated "systems" approach, is paved with good intentions, but still a bit rocky. There are several reasons for this, but one of them is the insufficient awareness of the main decision makers in the healthcare field, and, related to that, the lack of adequate education about personalized healthcare. In this study we describe a framework for PHC Education: which knowledge should a stakeholder in the healthcare field have about PHC, i.e. what is the *demand* for knowledge about PHC? Based on this framework, we identify whether the current *supply* of education is sufficient to satisfy this demand. We also look at *awareness* of PHC, of the different stakeholders in the field. Our focus is the Netherlands, but we looked at best practices and examples with respect to PHC Education in other countries as well.

Regarding *awareness*, our study indicates that medical specialists and general practitioners estimate themselves to be less skilled and interested in PHC compared to other stakeholders in the field. They feel they are inadequately supported by healthcare management/insurers to apply PHC. Other stakeholder groups are neutral in this regard. A more general observation is, that there seems to be some indifference regarding PHC, across all stakeholder groups. This is not withstanding the fact that people who actually participated in the study, supposedly a little bit biased, are actually very excited about PHC; they indicate that data sharing, -omics technologies and more attention for the individual are very important. Also, they indicate PHC is more than just genetic profiling.

Regarding the *supply of education*, we conclude that there is a world to be won. Most courses touch one or sporadically a few knowledge domains relevant for PHC, but an integral PHC viewpoint is missing. Many courses are for a specialized target audience, making them inaccessible for a most PHC practitioners. University programs are scarce; only three university programs are specifically dedicated to PHC.

We conducted an analysis of the gap between education supply and demand. The more significant gaps are found in the data related knowledge domains. On the other hand, for most knowledge domains in the biological sciences the available education can provide the desired need for PHC education.

In general, we conclude that changes in healthcare and attitude towards health in general are necessary, to achieve the new health paradigm. Healthcare currently is focused on diagnostics and treatment. In PHC, prevention and monitoring are equally important. Moreover, the approach is a two-pronged attack. Firstly, a shift in mindset is required. A shift from looking at a patient through the lens of a medical specialty (or specific disease) towards looking at an individual as a whole. Systems medicine is an important part of the necessary mindset change. This also necessitates further collaboration between specialisms, involving multidisciplinary teams.

Our research resulted in several recommendations. In our view, the only stakeholder who is able to coordinate this change, is the government, as is shown by PHC frontrunner countries, such as Finland, Estonia, and the UK. This is reflected in our recommendation *to approach the responsible ministries (VWS and OCW), and to ask them to take up the gauntlet.* The benefits that are at stake are huge, but the government needs to do more than it currently does to stimulate and coordinate systems medicine, as well as to establish curricula to train PHC in all relevant stakeholder groups of the Dutch healthcare system. Moreover, *the Dutch people, being the primary benefiter of PHC, should be approached using a communication plan to raise awareness* about PHC and create a "demand" for personalized healthcare. *Universities, and more specifically medical faculties, should be approached*

with an outline PHC curriculum. Knowledge about PHC should be shared more effectively among stakeholders, preferably using an *interactive platform*. And last but not least, we recommend to formulate a *uniform PHC definition*, as we noticed a Babylonian confusion of tongues with respect to terminology. In our report, we propose a first version of such a definition.

Introduction

Education and raising awareness about Personalized Healthcare (PHC) are key in making PHC a success. For this reason, the PHC Catalyst Alliance commissioned an investigation into PHC education and awareness, the result of which can be found in this document.

During our investigations we applied different research methods. At first we conducted in depth searches for information sources in the public domain. Secondly we interviewed several experts in the PHC Catalyst on the subject of education. Thirdly we approached the main interest groups in the Netherlands. And last, but not least, together with Springer Healthcare, DTLS, Elevate-Health and IPSOS we conducted a survey on the subject of personalized healthcare.

To effectively communicate about the PHC topic, we first establish a definition for personalized healthcare. We propose a definition, which has been reviewed by the respondents of the aforementioned survey.

This report is structured as follows. In chapter 2, we present the PHC definition. Chapter 3 is a justification of our research methodology. Chapter 4 contains the results of the study. Based on these results we draw conclusions and recommendations in the last two chapters. The appendices contain background information we used and developed during the study.

1 PHC definition

1.1 Definition

During our investigations it became clear that there is a multitude of terms and definitions used to identify PHC. Personalized medicine, precision medicine, precision healthcare are examples of terms used in the PHC area. Different definitions are used, not just for different terms, but also for the same term.

In order to accurately define the education framework for PHC it should be clear what PHC entails for the PHC Catalyst Alliance. Our proposed definition is:

Personalized healthcare is a person-centered health paradigm where monitoring, prevention, diagnosis and treatment are based on relevant biological, environmental and behavioral characteristics of the individual.[1]

In this definition the terms monitoring, prevention, diagnosis and treatment required further clarification.

Monitoring is a means to continuously gauge the health of an individual, also outside of treatment.

Prevention is an active means by which disease or injury and thus treatment can be prevented.

Diagnosis is a judgment about what a particular disease or disorder is, made after examining it.

Treatment is the management and care to combat disease or disorder.

1.2 Foundation for the definition

The proposed definition of PHC is based on an analysis of a number of definitions in the world of PHC. Definitions are provided by e.g. the European Union, the Topol review, the precision medicine action plan for California, ICPermed (International Consortium for Personalised Medicine, PMC (personalized Medicine Coalition) and EAPM (European Alliance for Personalised Medicine).

In our interviews and in the survey we asked about the definition of PHC.

Not a single definition, documented by others or from the interviews we did ourselves, encompasses all areas listed in the other definitions. There was overlap, but there were also quite some differences.

These definitions, documented by others or derived from the interviews and survey, were similar in some respects, but also showed some differences.

Consequently we decided not to re-use an existing definition, but to draft a new definition covering all elements mentioned in other definitions.

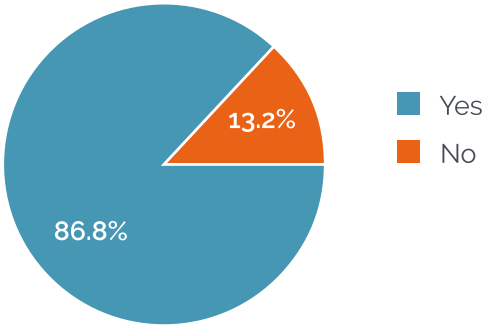
1. Translation in Dutch: Gepersonaliseerde zorg is een persoonsgericht zorgsysteem waarin monitoring, preventie, diagnose en behandeling gebaseerd zijn op relevante biologische, omgevings- en gedragskenmerken van het individu.

1.3 Validation of the definition

In the survey we validated this definition. We have asked the respondents if they agree with the PHC definition, as shown in figure 1. From all the 134 respondents 86,8% answered that they agree with this definition.

A definition of Personalized Healthcare is: "Personalized healthcare is a person-centered health paradigm where monitoring, prevention, diagnosis and treatment are based on relevant biological, environmental and behavioral characteristics of the individual." Do you agree with this definition?

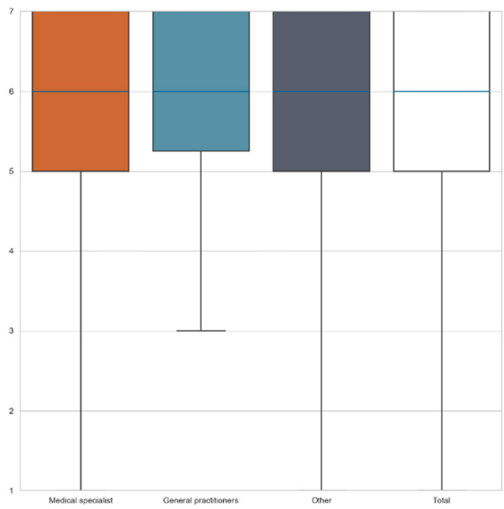
Figure 1. Agreement with proposed PHC definition.



13,2% of the respondents did not agree with this definition. The main reasons for disagreeing are:

1. **The needs and characteristics of the individual are not emphasized sufficiently**
2. **The definition contains nothing on the outcomes of the care**
3. **It focuses on healthcare instead of health**

One question in the survey related to the definition was a statement on the primary goal of PHC: The main goal of PHC is putting the individual at the center.



50% of all answers was a score between 5 and 7, meaning that the majority of the respondents responded to the statement in a positive manner.

1.4 PHC associations from survey

Prior to the validation of the definition mentioned above we asked the respondents to provide a number of terms they associate with PHC. To make the aggregate of terms visible a phrase cloud is constructed with these terms. Terms that were entered often appear bigger in the cloud. The survey is in Dutch, so the responses are in Dutch too.

Figure 2. Phrase cloud for PHC associations

From this cloud we can determine the main terms mentioned in the survey:

- individual (individueel, individu),
- personal (persoonlijk),
- fitting (passend),
- patient-centered (patient central),
- tailor-made (maatwerk, op maat),
- tailor-made care (zorg op maat),
- tailored to the needs of the patient (afgestemd op de behoefte van de patiënt),
- shared decision making,
- efficient (efficiënt),
- attention (aandacht),
- goal-oriented (doelgericht),
- empathy (empathie),
- effective (effectief),
- individual responsibility (eigen verantwoordelijkheid),
- holistic care (holistische zorg)
- affordable (betaalbaar).

2 Research Methodology

2.1 General Approach

Below we outline the steps, our research framework and the information sources we used in our study.

Steps

1. **Stakeholder map PHC awareness**
   a. **Determine relevant stakeholders and stakeholder groups, and determine awareness level and awareness level variation**, based on interviews and literature review. We have interviewed PHC Catalyst members, and conducted a representative number of interviews with representatives of various stakeholder groups. We have used a standard questionnaire to calibrate and determine the awareness level based on interview results, and the variation in awareness levels. The stakeholder groups and awareness levels have been mapped onto each other into a stakeholder matrix.
   b. **Determine short term action plan per stakeholder group.** Depending on the number of stakeholder groups, we have prioritized them, and action plans have been made for the groups that are designated "high priority". Actions in the plans are prioritized too.

2. **Overview PHC education current situation**
   a. **Develop PHC education framework**, based on existing education frameworks in PHC sub-domains. The framework is a means to an end (the goal is to classify the information we collect on education curricula), so we did not focus too much on it as a separate deliverable. However, it is important, also for communication purposes, to have a complete and consistent framework that supports the classification of all education possibilities in a meaningful and consistent way.
   b. **Populate the PHC education framework**, based on an extensive internet search, and in addition to that some interviews and a survey. The search and interview results, as well as the survey results, have been used to populate ("fill in") the framework, resulting in an overview of all PHC-related education.

3. **PHC Knowledge Map**
   a. **Develop knowledge requirements.** Using a standard knowledge model and using the PHC education framework developed in step 2a, we have made an inventory of knowledge needs, in terms of forms and types of knowledge, and in terms of the various domains identified in the PHC education framework. We conducted a number of interviews with experts in the field (inside and outside the PHC Catalyst alliance: scientists, patient representatives, doctors, government officials, commercial parties).
   b. **Map knowledge requirements on stakeholders.** Using the identified (prioritized) stakeholder group list, such as developed in step 1a, and based on the results of the interviews and workshops of step 3a, the requirements have been mapped onto the stakeholder groups, resulting in a PHC Knowledge Map.

4. **Action Plan**
   a. **Analyze gap**, by comparing the results of step 2 with the results of step 3.
   b. **Develop strategic action plan.** To address the gap identified in step 4a, a more general strategic action plan is developed, using results of 4a, but also using external sources such as Topol.[2]

2. See: https://topol.hee.nhs.uk/

Awareness and Internalization Levels

We have used the approach published by Wiig[3] to define different levels of internalization of knowledge, and use the same levels to indicate awareness. The table below briefly defines each of these levels. In general, there is a continuum of internalization, starting with the lowest level, the novice, who "does not know he does not know" — who does not have even an awareness that the knowledge exists — and extending to the mastery level where there is a deep understanding not just of the know-what, but the know-how, the know-why, and the care-why (i.e., values, judgments, and motivations for using the knowledge).

Figure 3. Levels of knowledge internalization

Level	Type	Description
1	Novice	Barely aware or not aware of the knowledge and how it can be used.
2	Beginner	Knows that the knowledge exists and where to get it but cannot reason with it.
3	Competent	Knows about the knowledge, can use and reason with the knowledge given external knowledge bases such as documents and people to help.
4	Expert	Knows the knowledge, holds the knowledge in memory, understands where it applies, reasons with it without any outside help.
5	Master	Internalizes the knowledge fully, has a deep understanding with full integration into values, judgments, and consequences of using that knowledge.

Knowledge forms are: public knowledge, shared expertise, and personal knowledge. *Public knowledge* is explicit, taught, and routinely shared knowledge that is generally available in the public domain. An example would be a published book or information on a public website. *Shared expertise* is proprietary knowledge assets that are exclusively held by knowledge workers and shared in their work or embedded in technology. This form of knowledge is usually communicated via specialized languages and representations. This knowledge form would be common in communities of practice and among informal networks of likeminded professionals who typically interact and share knowledge in order to improve the practice of their profession, such as the PHC Catalyst Alliance. Finally, *personal knowledge* is the least accessible but most complete form of knowledge. It is typically more tacit than explicit and is used non-consciously in work, play, and daily life.

Information Sources

Internet searches

We included 57 information sources in our investigation, see appendix II. The vast majority of this number is based on internet searches in which the following keywords were used:

- personalized healthcare, personalised healthcare, personalized medicine, personalised medicine, precision medicine, preventive medicine, predictive medicine.

in combination with:

- education, training, course, webinar, conference.

Moreover, we have used the equivalents of these keywords in the following languages:

- Dutch, German, French, Spanish, Italian.

Keywords in those languages did not lead to many useful results, probably due to the use of English as "lingua franca" in the academic and business world. The exception to this is the German language where even on an academic level German often seems to be the primary language.

3. Wiig, K., Knowledge Management Foundations: Thinking about Thinking. How people and organizations create, represent and use knowledge. Arlington, TX: Schema Press, 1993.

What to include and what not?
Results of the internet searches were included if the education material was explicitly linked to the context of personalized healthcare. For example, a generic course on machine learning is not included in the education materials, a course on machine learning in healthcare is. These choices were validated by a reviewer from the project team.

Interviews
In the earlier stages of the investigation, we held a number of interviews with members of the PHC Catalyst on the subject of education.

Professional associations
In addition to the interviews we also approached several professional associations for consultation. Unfortunately none of these associations were willing to cooperate.

Survey
Lastly, we set up an online survey with Springer Healthcare, DTLS, Elevate-Health and Ipsos, reaching close to 10,000 people in the medical field.

2.2 PHC Stakeholders and their Awareness

Stakeholder Groups
The following main stakeholder groups are in the PHC scope:

Table 1. Overview of main stakeholder groups

Stakeholder group	
Caretakers	Is a [stakeholder group] that consists of people that take care of [patients], but are not professionals.
Education providers	is a [stakeholder group] that consists of people that provide or are looking to provide education relating to [personalized healthcare].
General practitioners	is a [stakeholder group] and consists of doctors that have general training and are the first contact point for [personalized healthcare].
Government	is a [stakeholder group] that consists of people that work for {governments} and are involved in [personalized healthcare]
Health insurers	is a [stakeholder group] that consists of people that work for a health insuring company.
IT service providers	is a [stakeholder group] that consists of people that provide IT services for [personalized healthcare]
Laboratory workers	is a [stakeholder group] that consists of people that perform laboratory analysis regarding [personalized healthcare]
Medical specialists	is a [stakeholder group] that consists of doctors that are heavily specialized in a field of medicine.
Nursing staff	is a [stakeholder group] that consists of people that provide care and are professionally trained.

Paramedical specialists	a [stakeholder group] that consists of people that provide professional medical treatment but are not a doctor or dentist.
Patients	is a stakeholder group that consists of people that are treated by the [healthcare system]
Pharmacists	is a [stakeholder group] that consists of people that involved in distributing medicinal products to [patients] in pharmacies.
Producers	is a [stakeholder group] that consists of people in organizations that produce medicinal products
Regulators	is a [stakeholder group] that consist of organizations that create and enforce regulations regarding medicine and healthcare.
Scientists	is a [stakeholder group] that consists of people that perform academic research in the field of [personalized healthcare].
Service providers	is a [stakeholder group] that provides non-medical services that support healthcare.

Since it is very likely that we find more significant differentiation within these main groups, e.g. medical specialists, we introduced an additional level containing more than 60 different professional groups. A comprehensive overview of these professional groups can be found in Appendix I.

We determined these professional groups using numerous interviews with professionals in the field, literature study and brainstorm sessions.

The groups on the additional level were obtained by consulting sources such as health insurers, hospitals and exhaustive lists on Wikipedia.

Stakeholder Awareness

In order to determine the awareness levels of the main stakeholder groups, we conducted the following activities:

- We interviewed 12 people in 9 sessions in total, representing the 5 stakeholder groups listed below. One scheduled interview was cancelled. One party was not interested in cooperating, five parties did not respond at all.

- Based on the interview results, the project team individually scored every interviewed person on a scale of 1-5 for levels of knowledge internalization (Wiig).

- The individual results were compared. When the individual scores were all within one point, we took the average as the final score; when the individual scores deviated more than one point, we came to an agreement through team discussion.

Moreover, we studied multiple information sources for indications on PHC awareness. See Appendix II – Information sources.

We expanded our focus towards professional associations of the main stakeholder groups. We did an exploratory analysis of information sources (websites) of professional associations (such as the federation of medical specialists). This analysis was directed at the following stakeholder groups:

Table 2. Overview of professional associations approached for information

Main stakeholder group	Association
Medical practitioners and medical students	Koninklijke Nederlandsche Maatschappij tot bevordering der Geneeskunst (KNMG)
Caretakers	Verpleegkundigen en verzorgenden Nederland
General practitioners	Landelijke Huisartsen Vereniging (LHV) Nederlandse Huisartsen Genootschap (NHG)
Government	Ministerie van Volksgezondheid, Welzijn en Sport
Health insurers	Zorgverzekeraars Nederland
Laboratory workers	Nederlandse Vereniging van bioMedisch Laboratoriummedewerkers
Medical specialists	Federatie van Medisch specialisten
Nursing staff	Verpleegkundigen en verzorgenden Nederland
Paramedical specialists	Federatie Paramedisch Platform Nederland (PPN)
Oatients	Patiëntenfederatie Nederland
Pharmacists	Koninklijke Nederlandse Maatschappij ter bevordering der Pharmacie
Producers	Nederlandse brancheorganisatie voor medische technologie Vereniging van Nederlandse industrieapothekers Nederlandse Vereniging voor Farmaceutische Geneeskunde (NVFG)
Regulators	Nederlandse Zorgautoriteit

Based on the results of the website analysis we approached five professional associations. Four professional associations did not respond at all. One of the professional associations did respond and explained that it was not clear who to approach in her organization on this topic. She therefore considered approaching one of the members rather than someone from her one organization. We did not get further response from her.

Due to the lack of response by the professional associations, the attempted contact with the professional associations has not yet led to further information.

During our investigations we concluded that we needed a more solid foundation of the statements on PHC awareness in the Netherlands. To establish this foundation, we agreed on the setup of a survey on PHC awareness and education.

The survey is developed in cooperation with Springer, DTLS, Elevate-health and IPSOS.

2.3 PHC Education - current situation

For the courses identified during the investigation we documented:

- Topic
- Goal
- Target audience
- Accreditation
- Organizing party
- Language
- Method (e.g. webinar, video presentation, course materials)
- Duration
- Location

An overview can be found in appendix III.

The courses identified as being relevant for PHC are mapped to the knowledge domains of the education framework. The scores provide an indication (based on the publicly available information) of the minimum and maximum level of knowledge internalization (Wiig) the course is aiming for. For example: the course C001 - Genomics 101: Genomics in Healthcare applies to the knowledge domain Genomics and is aiming for knowledge level 2.

An overview can be found in appendix IV.

At the request of the PHC Catalyst, we also classified the courses for:

- Systems biology, with the values: biology, technology, computations.
- Systems medicine, with the values predictive, preventive, personalized, participatory.
- Healthcare system, with the values value recognition, mindset change, implementation.

Based on the information available to us, we have classified these courses according to the classification for systems biology, P4 and healthcare system. This classification is also included in the courses overview in appendix III.

2.4 PHC Knowledge Domains

Specifically for Personalized healthcare, we defined additional knowledge domains for:

- Biological science,
- Data sciences.

Biological sciences

Biological sciences are paramount in understanding individual biological characteristics. What characteristics are these? In addition, how can you utilize them in PHC?

Biological sciences are also relevant for treatments in PHC. Many medicinal products that are already used in generic treatments are produced using biotechnology, like insulin and immunotherapies. Medicinal products produced using biotechnology are also highly customizable, as the production organisms can be easily genetically modified to produce tailor-made medicine.

The role of biological sciences in PHC, therefore, is twofold:

- Defining and analyzing the biological characteristics that are essential in identifying what makes an individual biologically unique
- Facilitating the production of tailor-made and generic medicinal products that can be used in PHC.

Now that we know the roles that biological sciences play in PHC, we can identify the knowledge domains that are necessary in order to play these roles.

The -omics – understanding a person on the molecular level
Firstly, in PHC, it should be possible to identify an individual based on biological characteristics.

Research proved that DNA contains the hereditary information of organisms. It is therefore logical that the study of the DNA of an organism is relevant for PHC. The complete DNA sequence of an organism is called the genome. The genome contains all hereditary information. The study of the genome, which for PHC can identify the unique DNA sequence of an individual, is called genomics.

However, genomics as a knowledge domain is too narrow of a scope. The actual biological function of an individual is not determined just by DNA, but also by the RNA and proteins of an organism. Therefore, the study of the RNA and proteins, respectively called transcriptomics, proteomics and metabolomics, also need to be included.

The term used to group all these facets, is the –omics.

Biomarkers
Biomarkers are a naturally occurring molecule, gene, or characteristic by which a particular pathological or physiological process, disease, or state can be identified. Presence of biomarkers is useful for PHC, as this can indicate whether a certain medication will be effective or not. There also uses for AI in this knowledge domain. AI can be used to find correlations between certain biological molecules and physiological states; in other words to find biomarkers.

Medical imaging
Medical imaging provides a lot of information for healthcare providers. There is much potential for AI in this domain. Using AI for pattern recognition can for example be used to detect tumor growth very early.

The microbiome – as unique as a fingerprint
For each human cell that a human has, it contains 10 bacterial cells. It is no surprise that this abundance of bacterial cells has an enormous impact on an individual. Research has shown that the microbiome of a human has incredible impact on its biological function and health. A microbiome is the complete set of all microbial organisms in a given environment.

In order to understand an individual for the purposes of PHC it is necessary that you understand its microbiome.

Personalized medicinal products – a medicinal tailor
Biotechnology makes it possible to produce complex medicinal product molecules in biological production hosts like bacteria, yeasts, filamentous fungi or animal cell cultures.
Innovations in biotechnology offer possibilities to create medicinal product molecules that are tailored to an individual (e.g. Antibodies that target certain antigens present in an individual).

Bioinformatics – connecting the dots
- Not all medicines and treatments are equally efficacious for everyone.
- Bioinformatics is the link between the biological sciences and information technology.
- Bioinformatics allows for the quick analysis of data provided by the –omics.
- Big data and AI can play a role in matching biological traits of an individual to effective treatments.

Data sciences

In order to identify relevant knowledge domains, firstly we must know how PHC can benefit from data science.

In life sciences, data is represented in various different forms and describes a variety of biological systems. This contains medical information of different people and different populations, including the -omics, medical imaging and medical records. It is estimated that the size of medical/biological data is well beyond an Exabyte, and growing day by day.

Traditional statistical methods are not able to process this vastness and are not descriptive enough to answer the big data questions needed for PHC. We need tools and techniques that are used in data science to better understand these biological systems and apply them to the medical field.

Knowledge domains within data sciences

We have identified various knowledge domains in data science that will be essential in moving towards a personalized medical field, i.e. personalized health (care).

Getting the data: sourcing

The first step in any data science project is sourcing the data that is needed for the project. This can be done in a multitude of ways, ranging from getting the data yourself by performing experiments or taking measurements to receiving data from a party that has already done the measurements or experiments. High level knowledge of different data storage solutions is imported within this knowledge domain. Being able to efficiently store and retrieve data is essential for a streamlined data pipeline.

Wrangling

Data wrangling (or cleaning) is the process of manipulating the data in such a way that it is suitable for further analysis. These manipulations include cleansing, parsing, standardizing, augmenting, consolidating and unifying.

Wrangling is needed for further analysis. Any analysis will deliver better results when the data is clean. Some analyses might not even work when the data has not undergone even the most rudimentary form of wrangling. This is especially true for machine learning methods where the training data is expected to be correct and complete. Most of the time, unclean data will result in bad statistical models that do not represent the real world.

Analysis

Traditional statistical methods and machine learning are at the forefront of predictive and preventive healthcare. Being able to analyze large amounts of genetic and other biological data is essential in this. Building predictive models requires a high level of knowledge on multiple machine learning models. You need to know which model is best for which problem and data, and you need to know what problems you may face when using a certain model.

Interpretation & evaluation

Once the model has been trained, we need to evaluate how well it performs. So far, the model has only seen the data that has been used in training. Testing the model on other data is essential in determining the real world usefulness of a trained model. Correctly evaluating the performance of the model also helps with finding its flaws and limitations, potentially allowing for a better model on the next iteration. Data science is a iterative trial and error process where good initial and post evaluation can save a lot of time.

Interpretation is also important. Not being able to interpret the models' results can be catastrophic to their acceptance in practice. Image if you have a model that is able to diagnose people with a certain disease. If you cannot interpret the result and explain why a diagnosis is made, it will be difficult to convince a medical specialist that the diagnosis is valid.

Visualization

Effectively communicating findings and results from the analysis is important for their acceptance. Visualizations can be a good tool to effectively communicate. It is important that visualizations are clear and convey the message they need to convey. Bad visualization will only confuse the reader or, and this might even be worse, have the reader derive incorrect conclusion from them. Making clear and unambiguous visualizations is not a trivial task, which is the reason why visualization is an important knowledge domain in data science.

3 Results

3.1 Stakeholder map PHC awareness

In the publicly available information, little distinction is made in stakeholder groups. As can be observed in the quotes mentioned below, a difference is made between patients and healthcare professionals, but all healthcare professionals from specialists to nurses are lumped together.

Awareness is low among healthcare professionals.

A lack of awareness or a reticence (and even indifference or downright hostility) among healthcare professionals

Low patient demand resulting from low awareness is another hurdle to be overcome.

Education is needed to make patients aware of the available options.

Source: EAPM-Personalised medicine and healthcare for an immediate future

Survey

In our survey we attempted to map the awareness for all different stakeholder groups using statements for which respondents had to answer to which extent they agreed with that statement. Unfortunately, the response rate was too low get usable information on awareness for most stakeholder groups. The results presented here are therefore only an indication. All other stakeholder groups are represented by the category 'other'.

The full results of the survey can be found in Appendix VI.

3.2 PHC education - current situation

By performing desk research, information about available education related to PHC was gathered. As described in the justification, we assigned a knowledge level to this education, related to the knowledge domain covered.

Also the policies and the stance towards PHC of different countries was researched. This research was used to identify different approaches towards PHC and their advantages and disadvantages. Moreover, we asked two questions in the survey about the current situation of PHC education.

PHC related courses and university programs

The complete overview of the knowledge levels of the current education materials per knowledge domain can be found in appendix IV in this document.

For knowledge domains in the biological sciences a wide variety of courses spanning multiple knowledge levels were found. However, these courses mainly focus on one or a few knowledge domains within the biological sciences.

Also many university bachelor and master programs were found that cover bioinformatics. These programs provide courses that both cover biology and data science, be it at a high level. Bioinformatics programs are mostly focused on molecular biology research and do not cover or connect to healthcare. There are some Data Science programs that touch on PHC, but only very superficially. An example of such a program is the Masters program Data Science and Society of Tilburg University, which offers a Health track.

Three university programs were found that actually cover PHC. Two are in the UK (Ulster university, C065; University College London, C066) and one in Canada (Langara College, C067). All other countries were found to not have university programs specifically dedicated to PHC.

PHC is alive in Germany, especially at university hospitals. A few universities have courses in the field of PHC, like the Munich Technical University. We see that the German government takes an active stance on PHC. The Federal Ministry of Education and Research invests in activities and initiatives to collaborate in the field of PHC.

National approaches regarding PHC

In the US, Scandinavia and Germany, education on PHC related topics is primarily the responsibility of the conventional educational institutes (e.g. universities, universities of applied science, colleges). In the UK, the NHS, i.e. the government, is an important player in the coordination of education.

Survey

The survey contained two questions asking respondents about their knowledge of existing education regarding PHC. The results of these questions are shown in figure 4 and 5. 72% of the respondents did not know of courses or other forms of education for their professional group on the field of personalized healthcare. Of the group that knows about PHC Education, 60% has actually followed a course on personalized healthcare.

3.3 PHC Knowledge Map

We have investigated the desired knowledge level of all stakeholder groups, necessary to facilitate the wide-spread use of PHC. The results are shown in the table below.

How to interpret the table?

The rows contain the different stakeholder groups.

The columns contain the knowledge domains.

A cell represents the required knowledge level for knowledge domain per stakeholder group.

For example: the top left blue cell: 1

This means that a caretaker needs to have a knowledge level of 1 (Wiig scale) for the knowledge domain -omics to be active in a PHC environment.

Figure 4. PHC knowledge map summary

stakeholder group / knowledge domain	-omics	Systems biology	Personalized medicinal products	Genetic engineering	The human microbiome	Biomarkers	Medical imgaging	data sourcing	data wrangling	data analysis	model interpretation & evaluatio	model visualisation	results interpretation & evaluatio	results visualisation	Legal	Ethics
caretakers	1	2	1	1	1	1	2	1	1	1	1	1	2	2	2	2
citizens	1	2	2	2	1	1	2	1	1	1	1	1	2	2	2	2
education providers	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
general practitioners	3	4	3	3	4	4	2	4	1	1	1	1	3	3	3	3
government	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4
health insurers	2	2	2	2	2	2	2	4	1	1	1	1	3	3	4	4
IT service providers	2	3	2	1	1	3	2	5	5	5	5	5	5	5	3	3
laboratory workers	3	3	3	3	2	3	4	5	2	2	2	2	3	3	3	3
medical specialists	3	3	2	2	1	3	2	2	2	2	1	1	4	4	3	3
nursing staff	2	2	2	2	3	3	4	2	1	1	1	1	4	4	2	3
paramedical specialists	2	2	1	1	1	2	2	1	1	1	1	1	2	2	2	2
patients	1	1	2	2	2	2	2	1	1	1	1	1	3	3	3	3
pharmacists	3	3	4	2	2	2	2	3	1	1	1	1	2	2	3	3
producers	1	2	2	1	1	1	2	3	2	2	2	2	3	3	4	4
regulators	3	3	2	4	2	2	2	2	2	2	2	2	4	4	5	4
scientists	5	5	5	5	4	4	3	5	5	4	5	5	5	5	3	3
service providers	1	1	2	2	2	2	2	3	2	2	2	2	3	3	3	3

A complete overview for all stakeholder groups can be found in appendix V.

3.4 Gap analysis – Current education and required knowledge levels

A gap analysis was performed comparing the current available education and the required knowledge levels. This means that we compared:

- The knowledge levels that the current courses provide for a certain knowledge domain

with

- The required knowledge level per stakeholder.

This comparison shows whether there are gaps between the current education and the required knowledge levels. This is shown in the table on the next pages.

How to interpret the table?

The rows contain the different stakeholder groups.

The columns contain the knowledge domains.

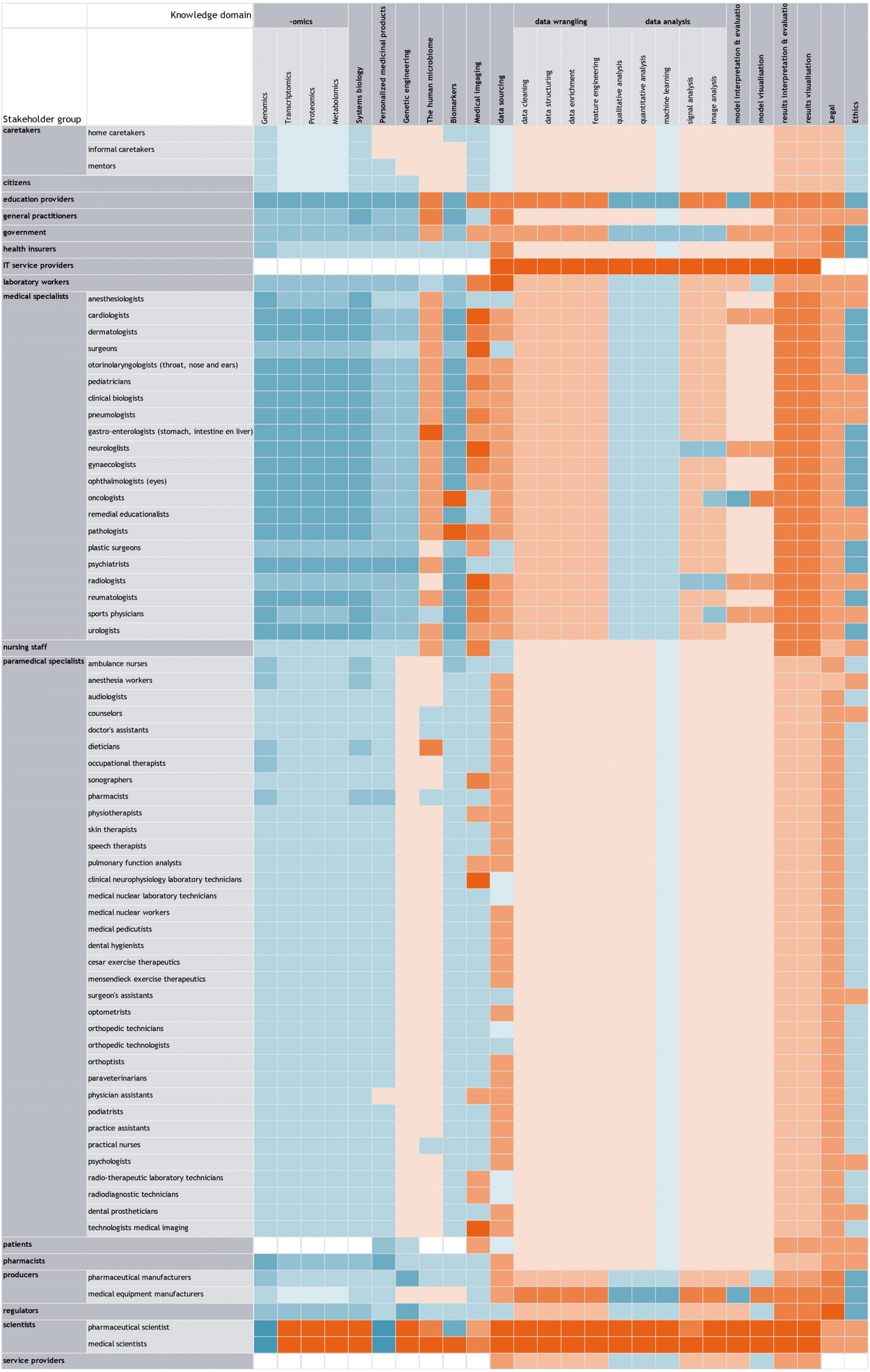
A cell represents:

- if the color is blue: there is education material available at the appropriate knowledge level
- if the color is orange: there is no education material available at the appropriate knowledge level

The appropriate knowledge level is visualized in different shades of blue and orange.

Materials available at knowledge level 1	No materials available at knowledge level 1
Materials available at knowledge level 2	No materials available at knowledge level 2
Materials available at knowledge level 3	No materials available at knowledge level 3
Materials available at knowledge level 4	No materials available at knowledge level 4
Materials available at knowledge level 5	No materials available at knowledge level 5
No values available	

The table corresponding to the gap analysis still shows a lot of orange cells. As orange cells indicate a lack of existing education, these are the gaps.


Knowledge domain
Stakeholder group
-omics
Genomics
Transcriptomics
Proteomics
Metabolomics
Systems biology
Personalized medicinal products
Genetic engineering
The human microbiome
Biomarkers
Medical imaging
data sourcing
data wrangling
data cleaning
data structuring
data enrichment
feature engineering
data analysis
qualitative analysis
quantitative analysis
machine learning
signal analysis
image analysis
model interpretation & evaluatio
model visualisation
results interpretation & evaluatio
results visualisation
Legal
Ethics
caretakers
home caretakers
informal caretakers
mentors
citizens
education providers
general practitioners
government
health insurers
IT service providers
laboratory workers
medical specialists
anesthesiologists
cardiologists
dermatologists
surgeons
otorinolaryngologists (throat, nose and ears)
pediatricians
clinical biologists
pneumologists
gastro-enterologists (stomach, intestine en liver)
neurologlists
gynaecologists
ophthalmologists (eyes)
oncologists
remedial educationalists
pathologists
plastic surgeons
psychiatrists
radiologists
reumatologists
sports physicians
urologists
nursing staff
paramedical specialists
ambulance nurses
anesthesia workers
audiologists
counselors
doctor's assistants
dieticians
occupational therapists
sonographers
pharmacists
physiotherapists
skin therapists
speech therapists
pulmonary function analysts
clinical neurophysiology laboratory technicians
medical nuclear laboratory technicians
medical nuclear workers
medical pedicutists
dental hygienists
cesar exercise therapeutics
mensendieck exercise therapeutics
surgeon's assistants
optometrists
orthopedic technicians
orthopedic technologists
orthoptists
paraveterinarians
physician assistants
podiatrists
practice assistants
practical nurses
psychologists
radio-therapeutic laboratory technicians
radiodiagnostic technicians
dental prostheticians
technologists medical imaging
patients
pharmacists
producers
pharmaceutical manufacturers
medical equipment manufacturers
regulators
scientists
pharmaceutical scientist
medical scientists
service providers

4 Conclusions

4.1 General conclusion

To achieve the new health paradigm, changes in healthcare and attitude towards health in general are necessary. Healthcare is currently focused on diagnostics and treatment. Therefore, this is also the best starting point for changing the health paradigm. It should be noted that for PHC, prevention and monitoring are equally important.

The approach towards change is a two-pronged attack. Firstly, a shift in mindset is required. A shift from looking at a patient through the lens of a medical specialty (or specific disease) towards looking at an individual as a whole. Often, a combination of biomarkers found in different medical fields lead to a loss of a biological function. Looking at the individual as a biological system, i.e. applying systems biology, tackles this problem. The application of systems biology in medicine is called systems medicine and this is an important part of the necessary mindset change.

Applying systems medicine also necessitates the existence of multidisciplinary teams. As individuals are viewed as biological systems, a single specialty should no longer take on the whole health responsibility of a person. Collaboration is essential.

Secondly, it is paramount for PHC that the ability to harness all data and technology tools at our disposal is realized. Big data and AI can be used to find biological patterns (genetic profiles or biomarkers) that allow a health plan that is tailored towards the individual. In order to realize these large amounts of data are required for analysis. Subsequently, data sharing is paramount.

4.2 Stakeholder map PHC awareness

Based on the awareness statements in the survey several conclusions can be drawn on PHC awareness.

Medical specialists and general practitioners estimate themselves to be less skilled and interested in PHC compared to the other respondents. They state themselves to be neutral (average response of 4) on the subject, while the other respondents are slightly positive (average response of 5).

Medical specialists and to a lesser extent general practitioners do not feel they are supported by healthcare management/insurers to apply PHC. Other groups are neutral in this regard.

Across all statements of the survey a neutral view of colleagues in the professional group of the respondents arises. The average awareness that respondents estimated for their colleagues was a neutral 4. This could indicate a widespread indifference regarding PHC, which is also supported by the low response rate observed for the survey.

In contrast to this, the overwhelming majority of respondents was very positive towards the importance of PHC. The respondents indicated that data sharing, -omics technologies and more attention for the individual are very important. Also, they indicate PHC is more than just genetic profiling. This is an expected result as respondents are expected to be the people that are already interested in the subject.

4.3 PHC education - current situation

Our research shows that education materials regarding PHC are, at the moment, not sufficient to provide the required knowledge for the stakeholder groups. Most courses touch one or sporadically a few knowledge domains relevant for PHC, but a PHC viewpoint is missing.

A lot of these courses are also for a specialized target audience, which makes it inaccessible for a lot of PHC practitioners.

Besides courses related to PHC, university programs dedicated to PHC are also scarce. Our research yielded only three university programs specifically dedicated to PHC. More university programs were found that touched on one or more knowledge domains, like bioinformatics, but these again are inaccessible for most stakeholder groups.

In conclusion, it is hard for most stakeholder groups to find proper education regarding PHC. Existing education in universities is too specialized or spread too thin globally. Also, courses are often specialized and do not focus specifically on PHC.

4.4 Gap analysis – Current education and required knowledge levels

This gap analysis revealed several gaps where education cannot provide the required knowledge level for stakeholder groups. For most knowledge domains in the biological sciences the available education can provide the desired need for PHC education. Gaps can be found, for example in medical imaging (regarding PHC).

The more significant gaps are, however, found in the data related knowledge domains. In these knowledge domains there are gaps for all stakeholder groups. The education that exists for these knowledge domains has no connection to (personalized) healthcare. This means that for people working in healthcare this information is inaccessible.

5 Recommendations

As a follow-up to this report, we recommend to be very action-oriented. We propose to conduct the following activities:

1. Approach the Dutch Government (“Ministerie van VWS” and “Ministerie van OCW”)

to raise awareness and change the attitude regarding PHC and PHC Education. During our research, we have experienced no involvement of the Dutch Government, which contrasts with countries such as Finland and the UK, and which is a missed opportunity given the huge benefits that are at stake. An underlying change of attitude concerns the silo’s that divide the medical profession, which is in contrast to the holistic system thinking of PHC and PHC Education. We realize that the removal of the traditional “walls” between specialisms is not carried out overnight, but the Government should stimulate this, and be aware of the massive advantages of PHC for the entire Health Care system. As a first step, the PHC manifesto is adequate, but not enough. We propose to share best practices (for instance, resulting from the multi-stakeholder patient journeys) with the Government, and start a discussion about a PHC curriculum.

2. Approach citizens (patients and potential patients)

to raise awareness about PHC and create a “demand” for personalized healthcare. Start with a communication plan and execute activities which can range from tv spots and billboard ads to more subtle communication channels such as articles in newspapers.

3. Develop the outline of a PHC curriculum,

to have an example of how such a curriculum could look like. For a large part, this curriculum can be made from available building blocks, in cooperation with, for instance, a “launching university”.

4. Approach medical faculties, hospitals and professional organizations with the outline PHC curriculum

in order to extend the basis of the PHC education and to sense, if there is a perceived need for PHC curricula.

5. Develop a platform to share knowledge among stakeholders.

A first prototype could be a knowledge platform for “Depression”, where medical staff, researchers, patients and other relevant stakeholders can exchange information and experience about this condition in the context of personalized healthcare. The platform is clearly multi-directional and should contribute to both an increase of awareness and, clearly, an increase of knowledge. We could use the results of the multi-stakeholder patient journey as well as the stakeholder map that is currently under development. It is yet to be seen if such a disease-specific knowledge platform should be extended to multi-disease PHC knowledge platform, which could add to complexity and implementation risks.

6. Develop a uniform definition of PHC.

We have noticed that there are still multiple views, sometimes contrasting, on PHC. An unambiguous definition, supported by all stakeholders, would help in moving the topic ahead, especially with respect to communication and education.

Building, organizing and internalizing knowledge about personal healthcare

Appendices

Appendix I: Stakeholder groups

Stakeholder group	Stakeholder subgroup
caretakers	home caretakers
caretakers	informal caretakers
caretakers	mentors
medical specialists	anesthesiologists
medical specialists	cardiologists
medical specialists	clinical biologists
medical specialists	dermatologists
medical specialists	gastro-enterologists (stomach, intestine and liver)
medical specialists	gynecologists
medical specialists	neurologists
medical specialists	oncologists
medical specialists	ophthalmologists (eyes)
medical specialists	otorinolaryngologists (throat, nose and ears)
medical specialists	pathologists
medical specialists	pediatricians
medical specialists	plastic surgeons
medical specialists	pneumologists
medical specialists	psychiatrists
medical specialists	radiologists
medical specialists	remedial educationalists
medical specialists	rheumatologists
medical specialists	sports physicians
medical specialists	surgeons
medical specialists	urologists
paramedical specialists	ambulance nurses
paramedical specialists	anesthesia workers
paramedical specialists	audiologists
paramedical specialists	cesar exercise therapeutics
paramedical specialists	clinical neurophysiology laboratory technicians
paramedical specialists	counselors
paramedical specialists	dental hygienists
paramedical specialists	dental prostheticians

Stakeholder group	Stakeholder subgroup
paramedical specialists	dieticians
paramedical specialists	doctor's assistants
paramedical specialists	medical nuclear laboratory technicians
paramedical specialists	medical nuclear workers
paramedical specialists	medical pedicurists
paramedical specialists	Mensendieck exercise therapeutics
paramedical specialists	occupational therapists
paramedical specialists	optometrists
paramedical specialists	orthopedic technicians
paramedical specialists	orthopedic technologists
paramedical specialists	orthoptists
paramedical specialists	para veterinarians
paramedical specialists	pharmacists
paramedical specialists	physician assistants
paramedical specialists	physiotherapists
paramedical specialists	podiatrists
paramedical specialists	practical nurses
paramedical specialists	practice assistants
paramedical specialists	psychologists
paramedical specialists	pulmonary function analysts
paramedical specialists	radio diagnostic technicians
paramedical specialists	radio-therapeutic laboratory technicians
paramedical specialists	skin therapists
paramedical specialists	sonographers
paramedical specialists	speech therapists
paramedical specialists	surgeon's assistants
paramedical specialists	technologists medical imaging
producers	medical equipment manufacturers
producers	pharmaceutical manufacturers
scientists	medical scientists
scientists	pharmaceutical scientist

Appendix II: Information sources

Title	Source
AI and digital health	article
AI in radiology	article
Amsterdam Medical Data Science	website
Applying Blockchain and Artificial Intelligence to Digital Health	article
Artificial Intelligence and Health Care	article
Artificial Intelligence for Mental Health and Mental Illnesses: an Overview	article
Artificial Intelligence in de zorg - begrippen, praktijkvoorbeelden en vraag-stukken	document
Big Data in Healthcare: New Methods of Analysis	article
BIOSB	website
Building an innovative model for personalized healthcare	document
Code of conduct for using AI in healthcare	article
Designing neural networks through neuroevolution	article
DTLS	website
Elevate Health	website
European Alliance for Personalised Medicine	website
Feasibility Study for Personalised Medicine in Estonia: Clinical Approach	document
From here to 2025 - personalised medicine and healthcare for an immediate future.	document
Genomics Education Programme	Youtube channel
Genomics Education UK	website
Genomics Education UK - competency framework	website
Genomics: insights	document
Handbook for Adequate Natural Data Stewardship (HANDS)	website
Health Education England	Youtube channel
How Artificial Intelligence Will Change Medicine	article
ICPerMed	website
ICPermed - an international survey about the future of personalized medicine	article
ICPermed Action Plan	document
ICPermed Vision Paper	document
Informatics and Mass Data Analysis in Digital Health	article
Integrating artificial intelligence into the clinical practice of radiology: challenges and recommendations	article

Title	Source
Kennisagenda Personalised Medicine - Nationale Wetenschapsagenda route Personalised Medicine	document
Lessons for artificial intelligence from the study of natural stupidity	article
Med student: Train us in AI now or watch quality suffer later	article
MEDLIB-ED - The Learning Destination for health information professionals	website
MedMij animatie	animation
National Network of Libraries of Medicine [NNLM]	Youtube channel
Next Generation Wellness: A Technology Model for Personalizing Healthcare	article
NHS Digital	website
NHS Digital Corporate Business Plan 2018-19	document
PAZIO	website
PCH Alliance	website
Personalised medicine - Implementatie in de praktijk en data-infrastructuren	document
Personalised Medicine in European Hospitals	document
PERSONALISED MEDICINE IN THE NORDIC COUNTRIES	document
PHC-Catalyst	website
Programma Personalised Medicine	website
Recent Deep Learning Techniques, Challenges and Its Applications for Medical Healthcare System: A Review	article
Reinforcement learning in artificial and biological systems	article
Strategies for integrating personalized medicine into healthcare practice	article
Summary of The Norwegian Strategy for Personalised Medicine in Healthcare	document
Technologie & Zorg Academie	website
Tess.Elixir	website
The importance of interpretability and visualization in machine learning for applications in medicine and health care	article
The practical implementation of artificial intelligence technologies in medicine	article
The Topol Review - Preparing the healthcare workforce	
to deliver the digital future"	document
Voorlichting aan patiënten en publiek over Next Generation Sequencing	website
Zorg van nu	website

Appendix III: Courses overview

Course ID	Course Name	Topic	Goal	Description	Target audience	Language	Method	Duration	Location	Accreditation	Organizer	Origination Country	Min allocated Wiig knowledge level	Max allocated Wiig knowledge level	systems biology	systems medicine	healtcare system
C001	Genomics 101: Genomics in Healthcare	Genomics	Learn about the fundamental principles of genomics and the applications in healthcare in this short, flexible online course	Advances in understanding and technology, coupled with a reduction in cost and time, now means that the use of genomics in routine NHS care is a reality. The information provided by analysing a person's genome – their DNA – can be used in a variety of clinical scenarios, from the diagnosis of rare disease to the tracking and treatment of infectious diseases.	healthcare professionals who have had limited or no exposure to genomics in their clinical roles. The course would also be suitable for those looking to refresh their knowledge or support training.	EN	online course	30 minutes	online	NHS (UK)	Genomics Education programme	UK	2	2	biology	unspecified	implementation
C002	Course Data analysis for Metabolomics	Data analysis, metabolomics	you will get a thorough basis for tackling the challenges in metabolomics data analysis.	Metabolomics experiments based on mass spectrometry (MS) or nuclear magnetic resonance (NMR) produce large and complex data sets. This course will introduce approaches to process and analyse data and design high-quality experiments. Through hands-on workshops and lectures highlighting the different concepts you will get a thorough basis for tackling the challenges in metabolomics data analysis.	This course targets professionals working in health and life sciences (e.g., food industry, breeding and seed business, pharmaceutical companies, hospital laboratories, biotech and agro chemical industry). Presumed knowledge: a background in and basic understanding of analytical chemistry or metabolomics by work or education. No prior knowledge of programming, mathematics or statistics is assumed.	EN	workshops and lectures	2 days	Wageningen	Organized by accredited university	Wageningen University	NL	2	2	technology	unspecified	implementation
C003	Machine learning applications for life sciences	Machine learning, Bioinformatics	to familiarise biomedical students and researchers with principles of Data Science.	Focusing on utilising machine learning algorithms to handle biomedical data, it will cover: effects of experimental design, data readiness, pipeline implementations, machine learning in Python, and related statistics, as well as Gaussian Process models. Providing practical experience in the implementation of machine learning methods relevant to biomedical applications, including Gaussian processes, we will illustrate best practices that should be adopted in order to enable reproducibility in any data science application.	Students and researchers from life-sciences or biomedical backgrounds who have or will shortly have the need to apply the techniques presented during the course to biomedical data.	EN	workshops and lectures	4 days	Cambridge	Organized by accredited university	University of Cambridge	UK	2	2	computations	predictive	implementation
C004	Data Science in Stratified Healthcare and Precision Medicine	(i) Sequence Processing, (ii) Image Analysis, (iii) Network Modelling, (iv) Probabilistic Modelling, (v) Machine Learning, (vi) Natural Language Processing, (vii) Process Modelling and (viii) Graph Data.	learn about some of the different types of data and computational methods involved in stratified healthcare and precision medicine.	An increasing volume of data is becoming available in biomedicine and healthcare, from genomic data, to electronic patient records and data collected by wearable devices. Recent advances in data science are transforming the life sciences, leading to precision medicine and stratified healthcare.	Intermediate level	EN	online course	~18 hours over 5 weeks	Online	Provided by accredited university	The University of Edinburgh	UK	2	2	technology	unspecified	implementation
C005	Bioinformatics	Bioinformatics, the -omics	To educate biological scientists or computer scientists in bioinformatics.	Bioinformaticians apply information technology to store, retrieve and manipulate these data and employ statistical methods capable of analysing large amounts of biological data to predict gene functions and to demonstrate the relationship between genes and proteiulate these data and employ statistical methods capable of analysing large amounts of biological data to predict gene functions and to demonstrate the relationship between genes and proteins.	People with a BSc in a biological field or a computer science field.	EN	full time programme	2 years	On campus at the WUR	NVAO	Wageningen University	NL	2	4	technology	unspecified	unspecified

Course ID	Course Name	Topic	Goal	Description	Target audience	Language	Method	Duration	Location	Accreditation	Organizer	Origination Country	Min allocated Wiig knowledge level	Max allocated Wiig knowledge level	systems biology	systems medicine	healtcare system
C006	Bioinformatics and systems biology	Bioinformatics, the -omics, systems biology	Education to become a bioinformatician or systems biologist.	Vast amounts of data have been collected through genomics initiatives. They provide a golden opportunity to research the secrets of life, to understand more of its complexities, to improve quality of life and to conquer major diseases. Converting this huge volume of data into real understanding is the basic challenge of Bioinformatics research. With the Master's programme in Bioinformatics and Systems Biology at VU Amsterdam you become an expert in this field.	People with a BSc in a biological field or a computer science field.	EN	full time programme	2 years	On campus VU/UvA	NVAO	Joint programme of the VU and UvA	NL	2	4	technology	unspecified	unspecified
C007	Bioinformatics and biocomplexity	bioinformatics	Education to become a bioinformatician.	Bioinformaticians and biocomplexity scientists can be found in many different laboratories, such as in the hospital to discover novel genes that cause a particular disease. Or, at research institutes and companies that study novel drug targets, explore ecological models or improve crop yield.	People with a BSc in a biological field or a computer science field.	EN	full time programme	2 years	On campus UU	NVAO	Utrecht University	NL	2	4	technology	unspecified	unspecified
C008	Bioinformatics	bioinformatics	Education to become a bioinformatician	The Bioinformatics master's specialisation integrates concepts and methods from both mathematics and computer science with (molecular) biology and biochemistry.	People with a BSc in computer science	EN	full time programme	2 years	On campus Leiden University	NVAO	Leiden University	NL	2	4	technology	unspecified	unspecified
C009	Bioinformatics	bioinformatics	Educate computer scientists to apply their knowledge to bioinformatics	The Bioinformatics specialisation is part of the Master program in Computer Science offering a closer look into life science applications of informatics.	MSc students in computer science of TU Delft	EN	Specialisation within master programme computer science	Part of 2 years	On campus TU Delft	NVAO	TU Delft	NL	2	4	technology	unspecified	unspecified
C010	Bio-informatica	bioinformatics	Education to become a bioinformatician	Puzzling behind a computer about plants, humans and animals. That is the core of bioinformatics.	People that want to become educated bioinformaticians.	NL	full time programme	4 years	On campus of university of applied sciences Leiden	NVAO	Hogeschool Leiden	NL	2	4	technology	unspecified	unspecified
C011	Bioinformatica	bioinformatics	Education to become a bioinformatician	The best breast cancer treatment because of your analysis? Making healthier food? Or developing medicines for severe illnesses? It is possible with the programme Bio-informatica: The programme for who loves IT and biology!	People that want to become educated bioinformaticians.	NL	full time programme	4 years	On campus of HAN	NVAO	Hogeschool Arnhem Nijmegen (HAN)	NL	2	4	technology	unspecified	unspecified
C012	Bioinformatics	bioinformatics	Exploration of the topic for bachelor students	Progress in the life sciences increasingly relies on the power of computation to answer biological questions. New devices generate large amounts of measurements, which can only be analysed by computer.	BSc students that want to explore and possibly specialize in the topic.	EN	BSc minor programme	6 months	On campus of the WUR		Wageningen University	NL	2	3	technology	unspecified	unspecified
C013	Bioinformatica en systeembiologie	bioinformatics, systems biology	Exploration of the topic for bachelor students	Explore bioinformatics and systems biology by using examples from science.	BSc students that want to explore and possibly specialize in the topic.	NL	BSc minor programme	6 months	On campus of the VU		VU	NL	2	3	biology	unspecified	unspecified
C014	Systems biology	systems biology	Education to become a systems biologist	Systems Biology will become mainstream in biological sciences this century. It can be used to systematically gather knowledge at all levels, from molecules to entire systems and its integration into quantitative (computer) models. These models make accurate simulation of biological processes possible.	People with a BSc degree in a biological science that want to specialize in systems biology	EN	full time programme	2 years	On campus of MU		Maastricht University	NL	2	4	biology	unspecified	unspecified

Course ID	Course Name	Topic	Goal	Description	Target audience	Language	Method	Duration	Location	Accreditation	Organizer	Origination Country	Min allocated Wiig knowledge level	Max allocated Wiig knowledge level	systems biology	systems medicine	healtcare system
C015	RNA-Seq analysis for differential expression	Transcriptomics, genomics	We will investigate the following items: Quality control of the sequence reads to detect biases or contaminating adapters Mapping of the reads to the reference genome with use of a transcript database model Quality control of the mapping results Adjusting the mapping data to compensate for artefacts like duplicates Calculate transcript counts usable for differential expression and merging of count tables Computing differential expression using EdgeR and DESeq2 The code pieces used during the training are made available through our Wiki as well as detailed results and can be copied and adapted for own user needs with minimal edits. Key results have been saved to our server and can be downloaded to fully reproduce the training.	Quality control of the sequence reads to detect biases or contaminating adapters Mapping of the reads to the reference genome with use of a transcript database model Quality control of the mapping results Adjusting the mapping data to compensate for artefacts like duplicates Calculate transcript counts usable for differential expression and merging of count tables Computing differential expression using EdgeR and DESeq2 The code pieces used during the training are made available through our Wiki as well as detailed results and can be copied and adapted for own user needs with minimal edits. Key results have been saved to our server and can be downloaded to fully reproduce the training.	Life Science Researchers, PhD students, beginner bioinformaticians, post-docs	EN	two day course	2 days	Leuven, België	Not applicable	VIB Bioinformatics Core	BE	3	3	biology	unspecified	unspecified
C019	Analysis of qPCR data using Qbase+	genomics, transcriptomics	This training specifically focuses on the ana	This hands-on training provides an introduction to the analysis of qPCR data using Biogazelle's qbase+ software. Although this software allows to do various types of analyses (gene expression, copy number analysis, miRNA profiling), we will focus in the training on gene expression analysis. qbase+ software is freely distributed by BITS to VIB scientists. Therefore the training will be limited to VIB scientists.	This training is intended for people with basic knowledge of the principles underlying qPCR.	EN					VIB Bioinformatics Core	BE	2	2	biology	predictive	unspecified
C020	Introduction to the analysis of NGS data	bioinformatics	Basic training for data analysis required for application in specific areas like transcriptomics.	This training is a prerequisite introduction to a series of trainings on the analysis of NGS data for different applications: 'Hands-on introduction to NGS variant analysis', 'RNA-Seq analysis for differential expression', and 'Hands-on introduction to ChIP-Seq analysis'. If you want to follow one of these trainings, you have to follow this introduction. The training will give you all the background that you will need in the later NGS trainings.	No prerequisites	EN					VIB Bioinformatics Core	BE	2	2	biology	predictive	unspecified

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C021	A tour of machine learning	machine learing, bioinformatics	This one-day workshop aims at transforming your keen interest into the workings of machine learning algorithms into practical knowledge on how to build accurate predictive models, mainly focussed on classification models.	Machine learning has become ubiquitous in biotechnology (as in many other fields), fueled largely by the increasing availability and amount of data. Learning algorithms can figure out how to perform important tasks by generalizing examples. Typical applications are diagnoses/prognoses, gene/protein annotation, drug design, image recognition, text mining and many others. However, building successful machine learning models requires a substantial amount of “black art” that is hard to find in textbooks. This course is an interactive Jupyter Notebook (Python) that will teach you how to build successful machine learning models. No background in machine learning is assumed, just a keen interest.	Python programming	EN		1 day			VIB Bioinformatics Core	BE	1	1	biology	predictive	unspecified
C022	Analysis of public microarray data using Genevestigator	genomics, transcriptomics, biomarkers	Understand what Genevestigator is Learn how to use Genevestigator to characterize your genes of interest Identify and prioritize novel targets or biomarkers Interpret lists of genes by grouping them by their response to biological contexts Learn how to combine Genevestigator with other software to answer biological questions	The morning session will give you an overview of the possibilities of Genevestigator, a search engine of curated and normalized publicly available gene expression data. The interface allows you to visualize spatio-temporal (tissue - developmental stage) and perturbational gene expression information of many species in a user-friendly graphical way. The afternoon session will focus on the practical applications in a hands-on tutorial on Genevestigator followed by concrete examples of software that can be used to further interpret the results of your Genevestigator searches, like Ingenuity Pathway Analysis and DAVID. Finally, you will be able to work on the questions that you want to answer in your own research under the supervision of the trainer.	Basic knowledge of biological processes	EN		half day			VIB Bioinformatics Core	BE	2	2	biology	predictive	unspecified
C023	Basic bioinformatics concepts, databases and tools	bioinformatics	Understand the capabilities and pitfalls of bioinformatics. Functioning of the most used bioinformatics algorithms and terms for reliable interpretation of the results. Navigate with confidence to numerous on-line data repositories. Know where to search for them. Basic analyses of single genes as well as groups of genes (gene lists)	During this 3-day introduction to bioinformatics, BITS will take you along a guided tour that covers all basic aspects of biological sequence analysis. This workshop is an ideal opportunity to get familiar with bioinformatics and its many faces! At the end, you should be able to start tackling any basic bioinformatics problem: how to obtain relevant information about your gene, you know where to get the required sequence data, manipulate the sequences, and how basic software and algorithms function so you can fine-tune it in order the get the most out of your analysis.	Understanding of basic biological concepts, such as transcription, translation and cellular structure.	EN		3 days			VIB Bioinformatics Core	BE	2	2	biology	unspecified	unspecified

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C024	Introduction to gene regulation	genomics, transcriptomics	To give researchers insight and hands-on experience in the analysis of the regulation of eukaryotic gene expression programs at the transcriptional and post-transcriptional levels and their connection to signaling pathways, using exploratory bioinformatic approaches.	This course presents a comprehensive overview of the principles and applications of studying eukaryotic gene regulation. The course combines lectures with hands-on exercises in which the participants learn to apply these principles to real data. The course will be based on freely available data and software.	Basic knowledge of molecular biology	EN					VIB Bioinformatics Core	BE	2	2	biology	unspecified	unspecified
C025	Protein structure analysis	proteomics	This training session will provide the basics of protein structure determination and how this information is stored in databases.	This training session will provide the basics of protein structure determination and how this information is stored in databases. We will explore and search in online databases containing protein structure information. With the aid of the Yasara View program we will visualize the structure. Different hands-on exercises will allow you to compare the structure of homologues, to predict a structural model of proteins without any structure information and to find homoloquous structures. We will use the FoldX program to quantify various interactions in the structures.	Basic knowledge of molecular biology	EN					VIB Bioinformatics Core	BE	2	2	biology	unspecified	unspecified
C026	Introduction to biopython	bioinformatics	Understand what Biopython is and what it can do. Learn how to get Biopython running. Learn how to retrieve data records from NCBI. Learn how to read and write sequence files. Learn how to run BLAST from Python and read the results. Learn how to read and write phylogenetic tree files. Learn how to read and write 3D structure files. Learn how to use the Biopython documentation, examples, and where to find help. Understand what alternatives to Biopython exist and what they can do.	Biopython is the best-known Python library to process biological data. This training is aimed to empower you to use Biopython to make your research more efficient.	No prerequisites	EN					VIB Bioinformatics Core	BE	1	1	technology	unspecified	unspecified
C027	Python programming with applications to bioinformatics	bioinformatics	Learning to apply python in bioinformatics	Learning to apply python in bioinformatics	Python programming	EN		1 week	Uppsala, Sweden		NBIS	SE	1	1	technology	unspecified	unspecified
C028	High performance computing (HPC) in life sciences	bioinformatics	This tutorial aims at presenting the general concepts about High Performance Computing (HPC) in Life Sciences.	t is based on the course material used to educate new users of the SIB Swiss Institute of Bioinformatics Vital-IT cluster. Examples are taken from this cluster, but concepts have been adapted to fit most if not all HPC systems in Life Sciences. The tutorial comprises the following topics: 1. Motivation: why use HPC? 2. General HPC concepts 3. Job submission - scripts 4. File management and storage		EN	e-learning				Swiss Insititue of Bioinformatics (SIB)	CH	1	1	computations	unspecified	unspecified
C029	A critical guide to the PDB	bioinformatics, proteomics	This Critical Guide in the Introduction to Bioinformatics series provides a brief outline of the Protein Data Bank	Specifically, this Guide introduces the principal features of the PDB, the nature (and quality) of its contents and how these may be interrogated.		EN	electronic guide				MyGlobet	NL	2	2	biology	unspecified	unspecified

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C030	RNA-seq data analysis: from raw reads to differentially expressed genes	bioinformatics, transcriptiomics	This course material introduces the central concepts, analysis steps and file formats in RNA-seq data analysis.	This course material introduces the central concepts, analysis steps and file formats in RNA-seq data analysis.	Basic knowledge of molecular biology	EN					MyGlobet	NL	2	2	biology	unspecified	unspecified
C031	Using bioinformatics to understand genetic diseases: a practical guide	bioinformatics	Understanding bioinformatics approaches that can be used to understand the molecular basis of genetic diseases.	This Practical Guide in the Bringing Bioinformatics into the Classroom series outlines a number of basic bioinformatics approaches that can be used to understand the molecular basis of genetic diseases. A rare variation in the insulin gene is discussed, and the impact of the variation on the gene product, and how this results in disease, is explored.		EN	electronic guide				MyGlobet	NL	2	2	technology	unspecified	unspecified
C032	Bioinformatics - the Power of Computers in Biology: A Practical Guide	bioinformatics	This Practical Guide in the Bringing Bioinformatics into the Classroom series introduces simple bioinformatics approaches for database searching and sequence analysis.	Specifically, this Guide introduces a popular Web-based tool for searching biological sequence databases, and shows how similar functionality can be achieved using the Linux command line. On reading the Guide and completing the exercises, users will be able to: i) search biological sequence databases using the online program BLAST, and navigate GenPept sequence records; ii) execute some basic Linux commands to perform a set of simple file-manipulation tasks; iii) perform BLAST searches via the Linux command line; and iv) evaluate the biological implications of search results, with reference to mutations and function.		EN	electronic guide				MyGlobet	NL	2	2	technology	unspecified	unspecified
C033	Introduction to bioinformatics	bioinformatics	An introduction to bioinformatics for bench biologists delivered as part of the EMBL Australia Masterclass on Protein Sequence Analysis http://oz-masterclass.wikispaces.com/ . Focuses on using UniProt to explore different reasons why information inferred by "direct assay" and "prediction" could be wrong, and what we can do to spot it.	An introduction to bioinformatics for bench biologists delivered as part of the EMBL Australia Masterclass on Protein Sequence Analysis http://oz-masterclass.wikispaces.com/ . Focuses on using UniProt to explore different reasons why information inferred by "direct assay" and "prediction" could be wrong, and what we can do to spot it.	bench biologists	EN	slide series				MyGlobet	NL	2	2	technology	unspecified	unspecified
C034	Workshop on Education in Bioinformatics 2014 - ISMB 2014 - Michael Love	bioinformatics	Provide an overview for education in bioinformatics	Dr. Love teaches the Data Analysis for Genomics course offered through edX. His research focuses on inferring biologically meaningful patterns from high-throughput sequencing read counts. He also develops open-source statistical software for the analysis of exome sequencing and RNA sequencing experiments for the Bioconductor Project. Dr. Love spoke on how open online courses operate and how they can (or cannot) be used to teach bioinformatics at WEB 2014 at ISMB 2014.		EN	mooc				MyGlobet	NL	2	2	technology	unspecified	unspecified
C035	Programming in the life sciences	bioinformatics	This is a OER around a six day course on using JavaScript to program the life sciences web, but with a focus on the Open PHACTS API.	In the life sciences the interactions between chemical entities is of key interest. Not only do these play an important role in the regulation of gene expression, and therefore all cellular processes, they are also one of the primary approaches in drug discovery. Pharmacology is the science studies the action of drugs, and for many common drugs, this is studying the interaction of small organic molecules and protein	Basic knowledge of java-scripts, open education resource	EN	online course	6 days	online	University Maastricht	Department of Bioinformatics - BiGCaT, Maastricht University	NL	2	2	technology	unspecified	unspecified

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C036	Extracting gene-disease evidence from literature, genetics, genomics and more	genomics	identify and prioritise new therapeutic targets. Relate genes and disease	Do you want to identify and prioritise new therapeutic targets? Are you looking for associations of your gene of interest with a specific disease? Do you work in the area of drug repurposing? Are you interested in disease biology? If you said yes to any of these questions, this webinar is for you. Watch to explore gene-disease relations using freely available tools from Europe PMC and Open Targets. Maria and Denise will show you how to access evidence from research literature, genetics, genomics and chemical data to obtain information at drug targets and disease levels.	scientists at any level	EN	webinar	45 minutes	online	Not applicable	European Bioinformatics Institue (EBI)	UK	1	2	biology	unspecified	unspecified
C037	Systems Medicine - Virtual Spring Seminar Series 2020	Systems medicine, Personalised medicine	share experiences with systems medicine.	Systems medicine is a field that will enable the translation of recent technological and scientific advances into the clinical practice. With systems medicine we will boost our understanding of disease mechanisms and the efficacy of treatments. Ultimately, systems medicine will bring a more personalised approach to healthcare, which may radically change the interaction between patients, doctors and other healthcare professionals. New healthcare approaches are an urging need, even accelerated in the Covid-19 era.	Physicians Life Science Researchers bioinformaticians Clinicians	EN	webinar	6 x 1 hour	Virtual	No	University of Ljubljana, Faculty of Medicine	SL	2	2	unspecified	personalized	mindset change
C038	Microbiome Summer School-Big Data Analytics for Omics Science 2017	bioinformatics in microbiome research	introduction to the use of bioinformatics in microbiome research as well as big data analytics applied to this field.	Course provides introduction to the use of bioinformatics in microbiome research as well as big data analytics applied to this field.	Researchers, Post-Doctoral Fellows, Biologists, Genomicists, Computer Scientists, Graduate students	EN	course materials	4 days	On site	No	the Canadian Institutes of Health Research (CIHR), Université Laval Big Data Research Centre, the Canada Excellence Research Chairs (CERC) Program, and CBW.	CA	2	2	biology	unspecified	unspecified
C039	Text-mining exercises	Data mining, Natural language processing, Metagenomics, Microbial ecology	The exercises will teach you how to: automatically highlight named entities in a web page use named entity recognition for synonym-aware information retrieval extract associations based on cooccurrence of entities in the literature discover novel, indirect associations between entities perform text-mining-based term enrichment analysis	Hands-on exercises using a variety of text-mining tools and databases based on text mining, to interpret the results from microbiome studies.	Bioinformaticians, Biologists	EN	course materials		Virtual	No	Novo Nordisk Foundation Center for Protein Research	DK			technology	unspecified	unspecified
C043	Bioinformatics for the terrified	bioinformatics	Basic instruction on possibilities of bioinfor	This course will give you a broad overview of how bioinformatics can enable bench-based research. It is aimed at experimental researchers in the molecular life sciences who have little or no previous experience of using bioinformatics databases or tools.	An undergraduate degree in a subject related to the molecular life sciences would be an advantage.	EN	online course	3 hours	online	Not applicable	European Bioinformatics Institue (EBI)	UK	1	1	technology	unspecified	mindset change
C044	Functional Genomics I-III	genomics	Learning basic functional genomics	This course will give you an introduction to functional genomics. We will introduce you to different types of functional genomics studies and discuss best practices when designing your own experiments.	beginner	EN	online course	4 hours	online	Not applicable	European Bioinformatics Institue (EBI)	UK	2	2	biology	unspecified	unspecified

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C045	Why share your data?	data management	Explore the value of sharing data	Our first speaker, Ewan Birney, is one of the directors of EMBL-EBI. He speaks about how the growth in data over the past decade has changed the way that we approach biology and how EMBL-EBI provides some of the infrastructure to allow data sharing. He finishes up by highlighting the benefits of data sharing to the EMBL-EBI and shares his top four reasons for sharing data. Our second speaker, Elisabeth Busch, is the head of the Vertebrate Genetics and Genomics Group at the Wellcome Sanger Institute and the University of Cambridge. She tells us about her experiences in sharing her own research data, and the reasons that she felt compelled to share her data including the advantages for her own research.	people who work with biological dat	EN	webinar	40 minutes	online	Not applicable	European Bioinformatics Institue (EBI)	UK	1	1	technology	unspecified	mindset change
C047	Masterclass NieuweZorg	generic	Diepe kennis van het huidige zorgstelsel Meer zicht op leiderschap voor Nieuwe Zorg Toekomstvisie voor eigen organisatie/afdeling Deelnemer, afdeling en organisatie klaar voor Nieuwe Zorg	Diepe kennis van het huidige zorgstelsel Hoog niveau met aansluitend de mogelijkheid voor Post-WO diplomering ABAN geaccrediteerd Toonaangevende, agendabepalende en actuele sprekers en gastdocenten Meer zicht op leiderschap voor Nieuwe Zorg Toekomstvisie voor eigen organisatie/afdeling Deelnemer, afdeling en organisatie klaar voor Nieuwe Zorg BLOK 3 - De zorg van morgen, hoe gaan we al die innovaties inbedden?	managers en directieleden in de zorg en aanverwante gebieden: politiek, zorgverzekeraars, farmacie, Medtech, Biotech, eerste- en tweedelijn, algemeen ziekenhuis, GGZ, patiëntenverenigingen enzovoorts.	NL	workshops and lectures	6 x 2 days	NL, BE	ABAN (40 pts)	Derks en Derks	NL	2	4	unspecified	unspecified	mindset change
C048	Topclass Bioinformatie – Erasmus achter de schermen	bioinformatics	kennisverbreding en verdieping	Middagprogramma in samenwerking met prof. dr. ing. Peter van der Spek (Hoogleraar en hoofd afdeling Bioinformatica, Erasmus MC) over Bioinformatica in de zorg bij het Erasmus MC, met o.a. rondleiding, presentatie en discussie over innovatieve zorg, een indrukwekkende demonstratie en een afsluitende netwerkborrel.	Masterclass NieuweZorg alumni	NL	workshops and lectures	half a day	Rotterdam	No	Derks en Derks	NL	2	2	biology	unspecified	unspecified
C049	Data en Artificial Intelligence in de Zorg	big data, AI	over de mogelijkheden en onmogelijkheden van de inzet van Data en AI in de Zorg	een van de gasten: Rob Bohte	voor iedereen die zich binnen de zorg met Data en AI bezig houdt	NL	podcast	1 hour	Virtual	No	Bruggink	NL	1	1	technology	unspecified	unspecified
C050	Introductie Zorgtechnologie	technology	biedt kennis over trends en ontwikkelingen van zorgtechnologie, hulp- en communicatiemiddelen en hoe je die kunt toepassen voor cliënten.	De zorgprofessional leert tijdens 6 tot 8 uur e-learning wat zorgtechnologie is en kent de voor- en nadelen en de risico's. Ook wet- en regelgeving komen aan bod. We gaan in op digitale communicatie, robots in zorg en welzijn, domotica, telemedicine etc.	geschikt voor zorg- en andere professionals	NL	blended learning	6-8 hours e-learning 3-4 hours workshop	Virtual + NL	Yes	TZA	NL	1	1	unspecified	unspecified	implementation

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C051	Ethiek & Zorgtechnologie	ethics	In deze module staat ethiek centraal en verken je onder andere je eigen waarden, standpunten en kennis op deze thema's aan de hand van diverse cases. Welke betekenis heeft dit voor jou? Ook wet- en regelgeving komt aan bod.	Door technologische ontwikkelingen ontstaan ook nieuwe ethische vraagstukken. Is het moreel verantwoord een robot in te zetten om eenzaamheid tegen te gaan? Kan een robot een menselijke band opbouwen en daarmee een mens vervangen? Welke ethische vragen komen er boven bij het gebruik van data in de zorg? Volgsystemen maken het mogelijk om toezicht te houden. Maar hoe zit het dan met de privacy van de cliënt?	geschikt voor zorg- en andere professionals	NL	blended learning	6-8 hours e-learning 3-4 hours workshop	Virtual + NL	Yes	TZA	NL	2	2	unspecified	unspecified	implementation
C052	Gesprekstechnieken bij beeldbellen in de huisartspraktijk (via Zoom)	telemedicine	U wisselt eigen behoeften uit op het gebied van digitale patiëntconsulten U experimenteert het stimuleren van patiënten om gewenst gedrag te vertonen U leert gesprekstechnieken toe te passen die helpen bij het opvangen van emoties van patiënten	Als huisarts heeft u onder andere te maken met angstige patiënten, patiënten die moeilijk te peilen zijn of bezorgde ouders die allemaal niet langs kunnen komen. Hoe vang je dan de emotie op? Of bijvoorbeeld de doelgroep 70+. Hoe staat u deze patiënt online te woord over moeilijke kwesties zoals "wilt u gereanimeerd worden" en "wilt u wel naar de ic?" En dan vooral: hoe doet u dat met video/telefoon? Deze online training via Zoom biedt u de mogelijkheid om in een kleine groep huisartsen met een trainer en patiënt-acteur te experimenteren met casuistiek uit uw eigen praktijk.	Aios Hid(ha) Praktijkhouder Waarnemer	NL	online course	1,45 hrs	Virtual	2 pts	lhv.nl	NL	2	2	unspecified	unspecified	unspecified
C053	Master Health Informatics - Health data science/Big data	data science / big data	Na het afronden van deze module bent u in staat om goede afwegingen te maken of, wanneer en hoe u data science technieken kunt toepassen in uw dagelijkse werk. U hebt uw eerste stappen gezet in het analyseren van gegevens en kunt samen met gespecialiseerde data scientists de goudmijn van zorgdata gaan ontginnen.	Iedereen in de zorg heeft te maken met 'data'. Deze data komen voor in allerlei vormen: van de consultnotities van de huisarts, continue metingen van fysiologische parameters op de intensive care, tot zelfmetingen van patiënten. Het is niet nieuw dat we nu allemaal met data te maken hebben, dat is nooit anders geweest. Wel is de hoeveelheid en het soort data toegenomen en zijn er nu legio mogelijkheden om deze data te analyseren. Enerzijds doordat de zorggegevens nu vrijwel altijd digitaal worden vastgelegd, anderzijds zijn er steeds meer analyse technieken beschikbaar om deze data te vermaken tot nuttige informatie. In aanvulling daarop zijn er ook meer gegevensbronnen beschikbaar om geanalyseerd te worden zoals de -omics onderzoeksgebieden, open data en sensoren (bijvoorbeeld wearables). De module HDS/BD laat u kennismaken met deze technieken, leert u hoe de analyse resultaten te interpreteren, en hoe u HDS/BD kan	minimaal een afgeronde HBO of WO opleiding te hebben en minimaal 2 jaar werkervaring in de zorg.	unknown	e-learning	12 studieweken	online	ABAN: 20 punten cluster 1, 2, 3	Amsterdam UMC	NL	2	4	technology	unspecified	unspecified
C054	Applied genomics and precision medicine (2014)	genomics				EN						US	5	5	biology	unspecified	unspecified
C055	Genomics Eduation Programme	genomics				EN						UK	4	4	biology	unspecified	unspecified

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C056	Case studies in personalized healthcare	PHC, genomics	Provide insight in how PHC can provide added value.	Learn how advances in biomedicine hold the potential to revolutionize drug development, drug treatments, and disease prevention: where are we now, and what does the future hold? This course will present short primers in genetics and mechanisms underlying variability in drug responses. A series of case studies will be used to illustrate principles of how genetics are being brought to bear on refining diagnoses and on personalizing treatment in rare and common diseases. The ethical and operational issues around how to implement large scale genomic sequencing in clinical practice will be addressed.	Professionals in biology or healthcare	EN	online course				Vanderbilt University	US	2	3	unspecified	personalized	value recognition
C057	Data Science in Stratified Healthcare and Precision Medicine	data science, precision medicine		An increasing volume of data is becoming available in biomedicine and healthcare, from genomic data, to electronic patient records and data collected by wearable devices. Recent advances in data science are transforming the life sciences, leading to precision medicine and stratified healthcare. In this course, you will learn about some of the different types of data and computational methods involved in stratified healthcare and precision medicine. You will have a hands-on experience of working with such data. And you will learn from leaders in the field about successful case studies.	Data science professionals	EN	online course				University of Edinborough	UK	1	4	computations	predictive	unspecified
C058	Big data, genes and medicine	data science, bioinformatics	Combining big data and (personalized) medicine	This course distills for you expert knowledge and skills mastered by professionals in Health Big Data Science and Bioinformatics. You will learn exciting facts about the human body biology and chemistry, genetics, and medicine that will be intertwined with the science of Big Data and skills to harness the avalanche of data openly available at your fingertips and which we are just starting to make sense of. We'll investigate the different steps required to master Big Data analytics on real datasets, including Next Generation Sequencing data, in a healthcare and biological context, from preparing data for analysis to completing the analysis, interpreting the results, visualizing them, and sharing the results. Needless to say, when you master these high-demand skills, you will be well positioned to apply for or move to positions in biomedical data analytics and bioinformatics. No matter what your skill levels are in biomedical or technical areas, you will gain highly valuable new or sharpened skills that will make you stand-out as a professional and want to dive even deeper in biomedical Big Data. It is my hope that this course will spark your interest in the vast possibilities offered by publicly available Big Data to better understand, prevent, and treat diseases.	Professionals in data science and bioinformatics	EN	online course				Sunny Online	US	2	4	computations	predictive	unspecified
C059	Introduction to genomic technologies	genomics	basics in genomic technologies	This course introduces you to the basic biology of modern genomics and the experimental tools that we use to measure it. We'll introduce the Central Dogma of Molecular Biology and cover how next-generation sequencing can be used to measure DNA, RNA, and epigenetic patterns. You'll also get an introduction to the key concepts in computing and data science that you'll need to understand how data from next-generation sequencing experiments are generated and analyzed.	People with basic knowledge of molecular biology	EN	online course				John Hopkins University	US	1	2	technology	unspecified	unspecified
C060	Genomic data science specialization	genomics, data science	specialization in combining genomics with data science	With genomics sparks a revolution in medical discoveries, it becomes imperative to be able to better understand the genome, and be able to leverage the data and information from genomic datasets. Genomic Data Science is the field that applies statistics and data science to the genome. This Specialization covers the concepts and tools to understand, analyze, and interpret data from next generation sequencing experiments. It teaches the most common tools used in genomic data science including how to use the command line, along with a variety of software implementation tools like Python, R, Bioconductor, and Galaxy.	Specialists in programming, data science and genomics	EN	online course				John Hopkins University	US	1	3	biology	unspecified	unspecified

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C061	Genetics and society: a course for educators	genomics, ethics	Looking at the impact of genetic technologies on society. Aims to teach teachers.	How have advances in genetics affected society? What do we need to know to make ethical decisions about genetic technologies? This course includes the study of cloning, genetic enhancement, and ownership of genetic information. Course participants will acquire the tools to explore the ethics of modern genetics and learn how to integrate these issues into their classrooms.	Teachers	EN	online course				American museum & natural history	US	2	4	unspecified	unspecified	mindset change
C062	Integrated analysis in systems biology	systems biology	specialization in systems biology	This course will focus on developing integrative skills through directed reading and analysis of the current primary literature to enable the student to develop the capstone project as the overall final exam for the specialization in systems biology.	People with knowledge of systems biology	EN	online course				Icahn school of medicine at mount Sinai	US	4	4	biology	unspecified	unspecified
C063	Introduction to systems biology	systems biology	teaching basics on systems biology	This course will introduce the student to contemporary Systems Biology focused on mammalian cells, their constituents and their functions.	People with basic knowledge of biology	EN	online course				Icahn school of medicine at mount Sinai	US	3	3	biology	unspecified	unspecified
C064	Myths and realities of personlised medicine: the genetic revolution	PHC, genomics	Getting a view of what PHC can and can't do.	Learn about personalised medicine and the impact that our enhanced understanding of genetics has on modern medicine and society.	Anyone with interest in PHC	EN	online course	5 weeks			UNSW Sydney	AU	2	2	biology	unspecified	unspecified
C065	Personalized medicine	PHC, -omics, data science	become an expert on personalized medicine	Personalised Medicine is at the cutting edge of a new era for medicine. Our ability to understand how genes, lifestyle and environment can influence disease promises to revolutionise healthcare practices. Personalised Medicine relies on using biomarkers (e.g. genes or protein) to stratify (or split) patients into specific groups for diagnosing or treating diseases. The ideals of Personalised Medicine will be realised with the development of technologies and systems to predict disease, select the best treatment, and reduce side effects for individual patients. This approach to streamline healthcare provides more accurate clinical decision making tools to identify 'the right treatment, for the right person, at the right time.'	People with a relevant degree in biology or a related field.	EN	Online programme	2 years		IBMS	Ulster University	IE	3	4	biology	personalized	implementation
C066	Personalized medicine and novel therapies	PHC, -omics, data science	become an expert on personalized medicine	Personalised medicine is the next generation of medicine and healthcare. It aims to improve the management of patients' health and to target therapies to achieve the best outcomes in the management of a patient's condition, their predisposition to disease and their prognosis. Personalised healthcare takes a multi-omics approach (one which incorporates data from a range of different sources, including genomic and epigenomic) directed at the development of novel therapies.	People with a relevant degree in biology or a related field.	EN	On campus education	1 year	London		University College London	UK	3	4	biology	personalized	implementation
C067	Personalized medicine	Omics, PHC	Specialization in PHC	Personalized medicine uses personal patient data – genome sequences, RNA and protein abundance measurements, key metabolic and physiological markers – in order to better design and implement health care treatments. Our Post-Graduate Certificate in Personalized Medicine will educate healthcare professionals on the benefits of these types of deep molecular assessments, including genetics and genomics.	healthcare professionals	EN	Combination of online and in-person teaching	8 months	Vancouver		snəw̓eyəɬ leləm̓ (Langara col	CA	3	4	biology	personalized	implementation
C068	Cycle of online conferences in Personalized Precision Medicine	Personalized & Precision Medicine		This cycle consists of 4 lectures, each given by an expert in the corresponding area, which are accompanied by a questionnaire. It will be necessary to answer the questions posed in the questionnaire in order to download the certificate issued by the UAM-Roche Institute Foundation for Personalized Precision Medicine Chair. To pass each questionnaire it will be necessary to answer the 5 questions correctly.	primary care physicians	ES	4 online lectures		Virutal		instituto roche	SP	1	3	biology		
C069	CLINICAL BIG DATA, ARTIFICIAL INTELLIGENCE AND ITS TRANSLATION TO PERSONALIZED PRECISION MEDICINE	Big Data, AI, genomics, medical imaging	clinical big data, artificial intelligence and its translation to personalized precision medicine			ES	Virtual workshop		Virtual		instituto roche	SP	3	5	computations		

Course ID	Course Name	Topic	Goal	Description	Target audience	Language	Method	Duration	Location	Accreditation	Organizer	Origination Country	Min allocated Wiig knowledge level	Max allocated Wiig knowledge level	systems biology	systems medicine	healtcare system
C070	Personalized precision medicine	molecular biology, genomics, transcriptomics, AI		During the three days that this training lasts, the enrolled students will be able to see first-hand the latest advances in molecular techniques in tissues, blood and fluids, which allow transferring Molecular Biology to personalized treatments for each patient; as well as the real applications of PPM that are already being implemented in areas such as Oncology or cardiovascular and metabolic diseases. With a look to the future, the course will also include a session dedicated to the use of artificial intelligence as an indispensable tool of Personalized Precision Medicine in the not too distant future; as well as its role in the prevention of hereditary tumors. All students interested in registering can do so through the Roche Institute Foundation website until next September 21st. Attendance diploma will be awarded and course accreditation has been requested.	Univeristy students	ES	Virtual workshop		Virtual		instituto roche	SP	2	4	computations		
C071	Artificial intelligence in health care	AI	Develop a grounded understanding of how the use of AI is transforming health care.	With this program, the MIT Sloan School of Management and the MIT J-Clinic aims to equip health care leaders with a grounded understanding of the potential for AI innovations in the health care industry. The Artificial Intelligence in Health Care online short course explores types of AI technology, its applications, limitations, and industry opportunities. Techniques like natural language processing, data analytics, and machine learning will be investigated across contexts such as disease diagnosis and hospital management.	leaders in both business and medical roles	EN	online course	6 x 8 hours	online	Unknown	MIT Sloan School of Management	US	3	4	computations	unspecified	unspecified

Appendix IV: Knowledge levels of the current education materials per knowledge domain

Knowledge levels of currently available courses per knowledge domain

course ID	course name (Knowledge domain →)	-omics	Systems biology	Personalized medicinal products	Genetic engineering	The human microbiome	Biomarkers	Medical imgaging	data sourcing	data wrangling	data analysis	model interpretation & evaluation	model visualisation	results interpretation & evaluation	results visualisation	Legal	Ethics
C001	Genomics 101: Genomics in Healthcare	2								0	0						
C002	Course Data analysis for Metabolomics	2								0	2						
C003	Machine learning applications for life sciences	0								0	2						
C004	Data Science in Stratified Healthcare and Precision Medicine	2		2				2		0	2						
C005	Bioinformatics	4	3	2	4	2	4			0	4						
C006	Bioinformatics and systems biology	4	4	2	4	2	4			0	4						
C007	Bioinformatics and biocomplexity	4	3	2	4	2	4			0	4						
C008	Bioinformatics	4	3	2	4	2	4			0	4						
C009	Bioinformatics	4	3	2	4	2	4			0	4						
C010	Bio-informatica	3	2	2	2		3			0	3						
C011	Bioinformatica	3	2	2	2		3			0	3						
C012	Bioinformatics	2	2				2			0	2						
C013	Bioinformatica en systeembiologie	2	3	2			2			0	2						
C014	Systems biology	4	4	2	4	2	3			0	0						
C015	RNA-Seq analysis for differential expression	3								0	0						
C016	Analysis of metabolome data	2								0	2						
C017	Introduction to networks biology	0	2							0	0						
C018	Hands-on analysis of public microarray datasets	2								0	2						
C019	Analysis of qPCR data using Qbase+	2								0	2						
C020	Introduction to the analysis of NGS data	2								0	2						
C021	A tour of machine learning	0								0	1						
C022	Analysis of public microarray data using Genevestigator	2								0	2						
C023	Basic bioinformatics concepts, databases and tools	0								0	0						
C024	Introduction to gene regulation	2								0	0						
C025	Protein structure analysis	0	2							0	0						
C026	Introduction to biopython	0								0	0						
C027	Python programming with applications to bioinformatics	0								0	0						
C028	High performance computing (HPC) in life sciences	0								0	0						
C029	A critical guide to the PDB	2								0	0						
C030	RNA-seq data analysis: from raw reads to differentially expressed genes	2								0	2						
C031	Using bioinformatics to understand genetic diseases: a practical guide	0								0	0						
C032	Bioinformatics - the Power of Computers in Biology: A Practical Guide	0								0	0						
C033	Introduction to bioinformatics	0								0	0						
C034	Workshop on Education in Bioinformatics 2014 - ISMB 2014 - Michael Love	0								0	0						
C035	Programming in the life sciences	0								0	0						
C036	Extracting gene-disease evidence from literature, genetics, genomics and more	1								0	0						
C037	Systems Medicine - Virtual Spring Seminar Series 2020	0		2						0	0						
C038	Microbiome Summer School-Big Data Analytics for Omics Science 2017	2				2				0	2						
C039	Text-mining exercises	0								0	0						
C040	Pathway visualization in the reactome pathway database	1								0	0		2				
C041	Visualization Approaches for Biomedical Omics Data:Putting It All together	1								0	0		2				
C042	Data visualization in proteomics	1								0	0		2				
C043	Bioinformatics for the terrified	0								0	0						
C044	Functional Genomics I-III	2								0	0						
C045	Why share your data?	0								0	0					1	1
C046	Comparison of long read methods for sequencing and assembly of a plant genome	2								0	0						
C047	Masterclass NieuweZorg	0								0	0						
C048	Topclass Bioinformatie - Erasmus achter de schermen	0								0	0						
C049	Data en Artificial Intelligence in de Zorg	0								0	0						
C050	Introductie Zorgtechnologie	0						1		0	0						
C051	Ethiek & Zorgtechnologie	0								0	0						2
C052	Gesprekstechnieken bij beeldbellen in de huisartspraktijk (via Zoom)	0								0	0						
C053	Master Health Informatics - Health data science/Big data	0		2			2	2		0	0	4					
C054	Applied genomics and precision medicine (2014)	5		5						0	0						
C055	Genomics Eduation Programme	4								0	0						
C056	Case studies in personalized healthcare	0		3						0	0						
C057	Data Science in Stratified Healthcare and Precision Medicine	0		2					1	0	4						
C058	Big data, genes and medicine	0		2					2	0	4						
C059	Introduction to genomic technologies	2								0	0						
C060	Genomic data science specialization	3	1	2					2	0	3						
C061	Genetics and society: a course for educators	2			2					0	0						4
C062	Integrated analysis in systems biology	0	4							0	0						
C063	Introduction to systems biology	0	3							0	0						
C064	Myths and realities of personlised medicine: the genetic revolution	2	2	2						0	0						
C065	Personalized medicine	4	4	4	3		3			0	0						
C066	Personalized medicine and novel therapies	4	4	4	3		3			0	0						
C067	Personalized medicine	4	4	4	3		3			0	0						
C068	Cycle of online conferences in Personalized Precision Medicine	2	2	2													
C069	clinical big data, artificial intelligence and its translation to personalized precision medicine	3	2				2							2		2	2
C070	Personalized precision medicine	3	2	2			2							2			
C071	Artificial intelligence in health care	0					2		2						3		

Appendix V: Required knowledge level per stakeholder group and knowledge domain

knowledge domain		-omics											data wrangling					data analysis											
stakeholder group	-omics	Genomics	Transcriptomics	Proteomics	Metabolomics	Systems biology	Personalized medicinal products	Genetic engineering	The human microbiome	Biomarkers	Medical imaging	data sourcing	data wrangling	data cleaning	data structuring	data enrichment	feature engineering	data analysis	qualitative analysis	quantitative analysis	machine learning	signal analysis	image analysis	model interpretation & evaluation	model visualisation	results interpretation & evaluation	results visualisation	Legal	Ethics
caretakers	1	2	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2
home caretakers	1	2	1	1	1	2	1	1	1	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2
informal caretakers	1	2	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2
mentors	1	2	1	1	1	2	2	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2
citizens	1	2	1	1	1	2	2	2	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2
education providers	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
general practitioners	3	3	3	3	3	4	3	3	4	4	2	4	1	1	1	1	1	1	1	1	1	1	1	1	1	3	3	3	3
government	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4
health insurers	2	3	2	2	2	2	2	2	2	2	2	4	1	1	1	1	1	1	1	1	1	1	1	1	1	3	3	4	4
IT service providers	2	3	3	2	2	3	2	1	1	3	2	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	3	3
laboratory workers	3	3	3	3	3	3	3	3	2	3	4	5	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3
medical specialists	3	3	3	3	3	3	2	2	1	3	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	4	4	3	3
anesthesiologists	3	4	3	3	3	4	2	2	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	4	4	3	3
cardiologists	4	4	4	4	4	4	3	3	3	4	5	3	2	2	2	2	2	2	2	2	2	2	2	3	3	4	4	3	4
dermatologists	4	4	4	4	4	4	3	3	3	4	4	3	2	2	2	2	2	2	2	2	2	2	2	1	1	4	4	3	4
surgeons	3	3	3	3	3	3	2	2	3	3	5	2	2	2	2	2	2	2	2	2	2	2	2	1	1	4	4	3	4
otorinolaryngologists (throat, nose and ears)	4	4	4	4	4	4	3	3	3	4	3	3	2	2	2	2	2	2	2	2	2	2	2	1	1	4	4	3	4
pediatricians	4	4	4	4	4	4	3	3	3	4	4	3	2	2	2	2	2	2	2	2	2	2	2	1	1	4	4	3	3
clinical biologists	4	4	4	4	4	4	3	3	3	4	3	3	2	2	2	2	2	2	2	2	2	2	2	1	1	4	4	3	3
pneumologists	4	4	4	4	4	4	3	3	3	4	4	3	2	2	2	2	2	2	2	2	2	2	2	1	1	4	4	3	3
gastro-enterologists (stomach, intestine en liver)	4	4	4	4	4	4	3	3	5	4	3	3	2	2	2	2	2	2	2	2	2	2	2	1	1	4	4	3	4
neurologlists	4	4	4	4	4	4	3	3	3	4	5	3	2	2	2	2	2	2	2	2	2	3	3	3	3	4	4	3	4
gynaecologists	4	4	4	4	4	4	3	3	3	4	4	3	2	2	2	2	2	2	2	2	2	2	2	1	1	4	4	3	4
ophthalmologists (eyes)	4	4	4	4	4	4	3	3	3	4	3	3	2	2	2	2	2	2	2	2	2	2	2	1	1	4	4	3	4
oncologists	4	4	4	4	4	4	3	3	3	5	2	3	2	2	2	2	2	2	2	2	2	2	3	4	4	4	4	3	4
remedial educationalists	4	4	4	4	4	4	3	3	3	4	2	3	2	2	2	2	2	2	2	2	2	2	2	1	1	4	4	3	3
pathologists	4	4	4	4	4	4	3	3	3	5	4	3	2	2	2	2	2	2	2	2	2	2	2	1	1	4	4	3	3
plastic surgeons	3	3	3	3	3	3	3	3	1	3	3	2	2	2	2	2	2	2	2	2	2	2	2	1	1	4	4	3	4
psychiatrists	4	4	4	4	4	4	4	4	3	4	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	4	4	3	4
radiologists	3	3	3	3	3	3	3	3	1	4	5	3	2	2	2	2	2	2	2	2	2	3	3	3	3	4	4	3	3
reumatologists	4	4	4	4	4	4	3	3	3	4	4	3	2	2	2	2	2	2	2	2	2	2	2	1	1	4	4	3	4
sports physicians	3	4	3	3	3	4	3	3	2	4	4	3	2	2	2	2	2	2	2	2	2	2	3	3	3	4	4	3	3
urologists	4	4	4	4	4	4	3	3	3	4	3	3	2	2	2	2	2	2	2	2	2	2	2	1	1	4	4	3	4
nursing staff	2	2	2	2	2	2	2	2	3	3	4	2	1	1	1	1	1	1	1	1	1	1	1	1	1	4	4	2	3
paramedical specialists	2	2	2	2	2	2	1	1	1	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2
ambulance nurses	2	3	2	2	2	3	2	1	1	3	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	2
anesthesia workers	2	3	2	2	2	3	2	1	1	2	2	3	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	3
audiologists	2	2	2	2	2	2	2	1	1	2	2	3	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	2
counselors	2	2	2	2	2	2	2	1	2	2	2	3	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	3
doctor's assistants	2	2	2	2	2	2	2	1	2	2	2	3	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	2
dieticians	2	3	2	2	2	3	2	1	4	2	2	3	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	2
occupational therapists	2	3	2	2	2	2	2	1	1	2	2	3	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	2
sonographers	2	2	2	2	2	2	2	1	1	2	4	3	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	2
pharmacists	2	3	2	2	2	3	3	1	2	2	2	3	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	2
physiotherapists	2	2	2	2	2	2	2	1	1	2	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	2
skin therapists	2	2	2	2	2	2	2	1	1	2	2	3	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	2
speech therapists	2	2	2	2	2	2	2	1	1	2	2	3	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	2
pulmonary function analysts	2	2	2	2	2	2	2	1	1	2	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	2
clinical neurophysiology laboratory technicians	2	2	2	2	2	2	2	1	1	2	5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	2
medical nuclear laboratory technicians	2	2	2	2	2	2	2	1	1	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	2
medical nuclear workers	2	2	2	2	2	2	2	1	1	2	2	3	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	2
medical pedicutists	2	2	2	2	2	2	2	1	1	2	2	3	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	2
dental hygienists	2	2	2	2	2	2	2	1	1	2	2	3	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	2
cesar exercise therapeutics	2	2	2	2	2	2	2	1	1	2	2	3	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	2
mensendieck exercise therapeutics	2	2	2	2	2	2	2	1	1	2	2	3	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	2
surgeon's assistants	2	2	2	2	2	2	2	1	1	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	3
optometrists	2	2	2	2	2	2	2	1	1	2	2	3	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	2
orthopedic technicians	2	2	2	2	2	2	2	1	1	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	2
orthopedic technologists	2	2	2	2	2	2	2	1	1	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	2
orthoptists	2	2	2	2	2	2	2	1	1	2	2	3	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	2
paraveterinarians	2	2	2	2	2	2	2	1	1	2	2	3	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	2
physician assistants	2	2	2	2	2	2	1	1	1	2	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	2
podiatrists	2	2	2	2	2	2	2	1	1	2	2	3	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	2
practice assistants	2	2	2	2	2	2	2	1	1	2	2	3	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	2
practical nurses	2	2	2	2	2	2	2	1	2	2	2	3	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	2
psychologists	2	2	2	2	2	2	2	1	1	2	2	3	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	3
radio-therapeutic laboratory technicians	2	2	2	2	2	2	2	1	1	2	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	2
radiodiagnostic technicians	2	2	2	2	2	2	2	1	1	2	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	2
dental prostheticians	2	2	2	2	2	2	2	1	1	2	2	3	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	3
technologists medical imaging	2	2	2	2	2	2	2	1	1	2	5	3	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	2
patients	1	2	1	1	1	1	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	3	3	3
pharmacists	3	4	3	3	3	3	4	2	2	2	2	3	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	3
producers	1	2	1	1	1	2	2	1	1	1	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	4	4
pharmaceutical manufacturers	2	3	2	2	2	2	2	4	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	4	4
medical equipment manufacturers	1	2	1	1	1	2	2	1	1	1	2	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
regulators	3	3	3	3	3	3	2	4	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	4	4	5	4
scientists	5	5	5	5	5	5	5	5	4	4	3	5	5	5	5	5	5	4	5	5	5	4	5	5	5	5	5	3	3
pharmaceutical scientist	5	5	5	5	5	5	5	5	4	4	3	5	5	5	5	5	5	4	5	5	5	4	5	5	5	5	5	3	3
medical scientists	5	5	5	5	5	5	5	5	5	5	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	3	3
service providers	1	2	1	1	1	1	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3

Appendix VI: Survey results

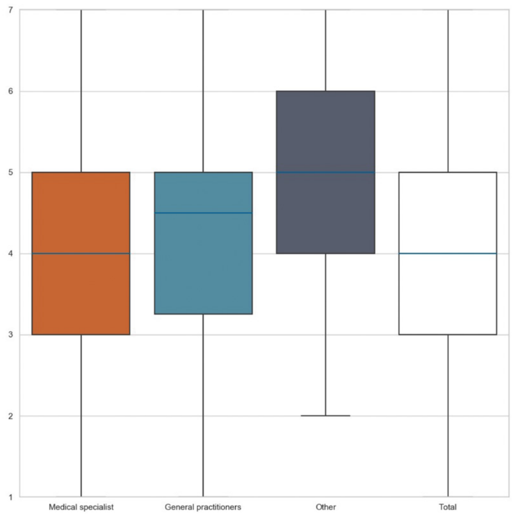
134 respondents filled in the online survey.

For each statement related to awareness a box plot was made for each category (medical specialists, general practitioners, other and total). In this graph, the box represent 50% of the responses. The whiskers show the minimum and maximum response. Lastly, the blue line represents the median response.

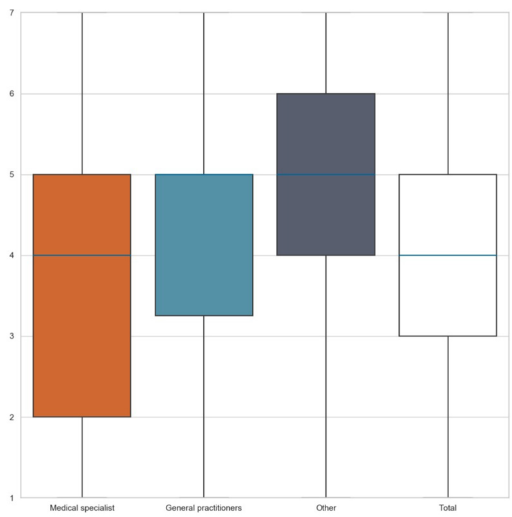
On the vertical axis the possible answer scores are shown.

Take the medical specialists in graph 1 for example. 50% of the respondents answered 3, 4 or 5 on that statement. There were respondents that answered 1 or 7. The median response to this statement by medical specialists is 4.

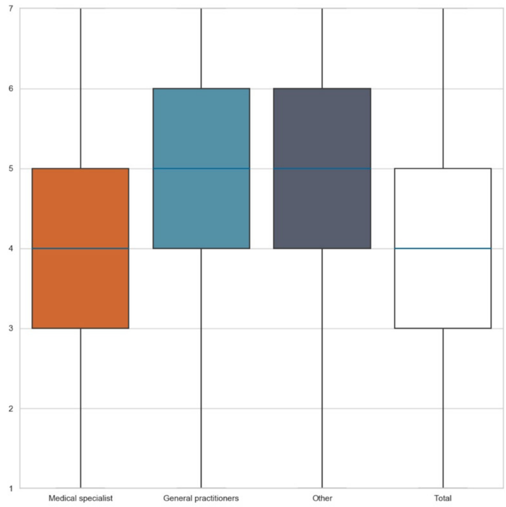
Statement 1 – I keep myself up to date on the latest developments in PHC.



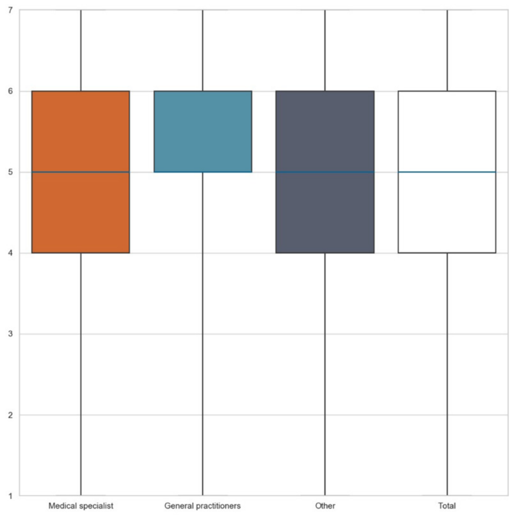
Statement 2 – I am well prepared for the introduction of PHC.



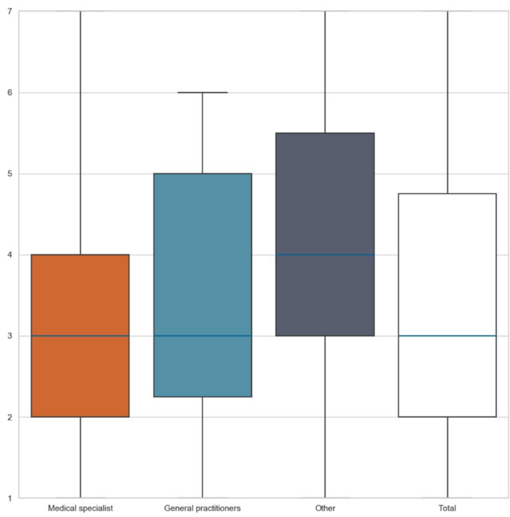
Statement 3 – I have sufficient knowledge to apply PHC in my work.



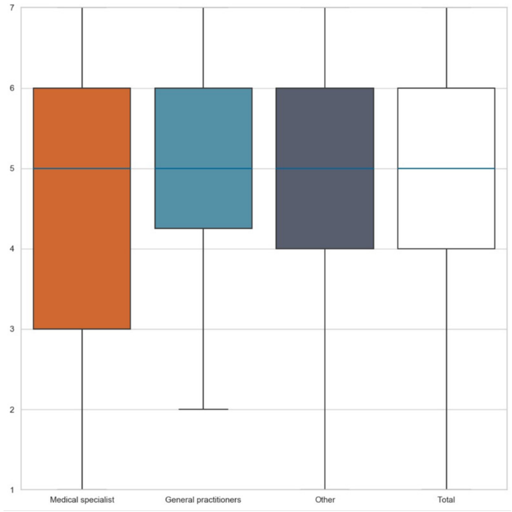
Statement 4 – I have the skills necessary to implement PHC in my work.



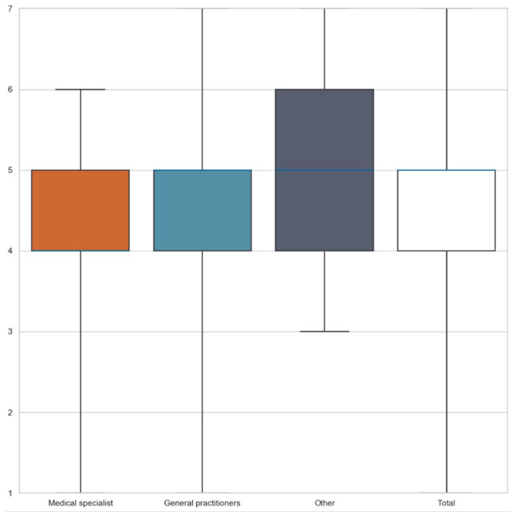
Statement 5 – I am sufficiently supported by management and/or health insurers to implement PHC.



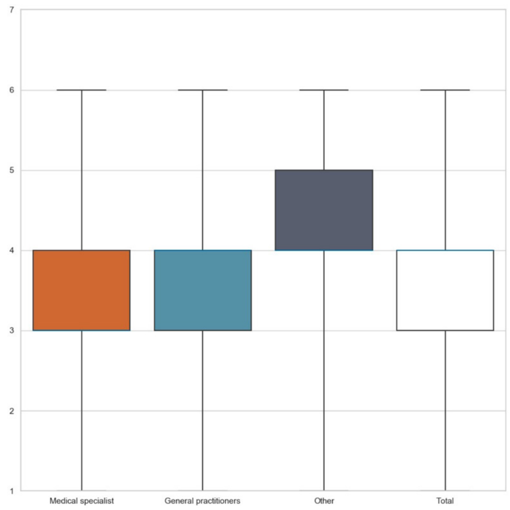
Statement 6 – I already apply PHC in my day-to-day work.



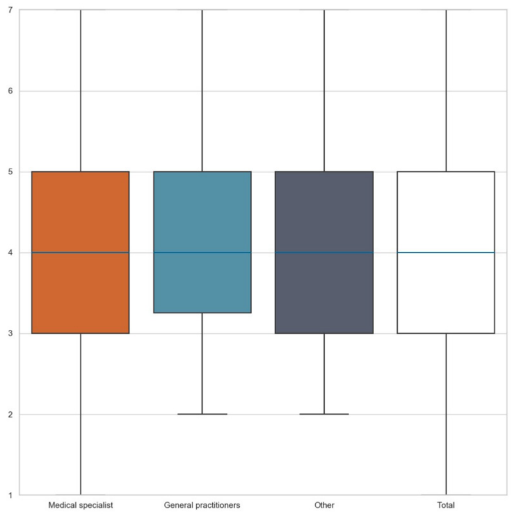
Statement 7 – People in my profession have a positive view of PHC.



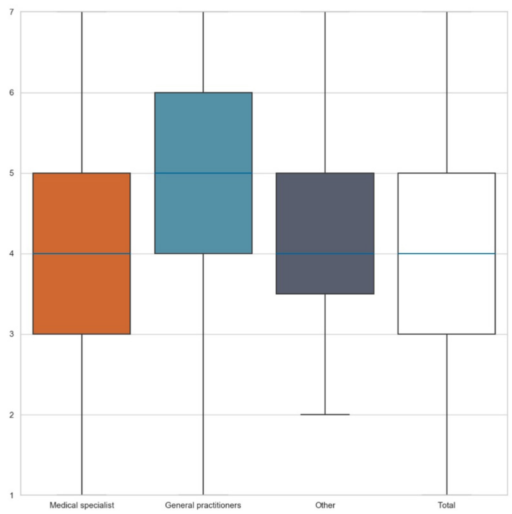
Statement 8 – People in my profession are up to date on the latest developments in PHC.



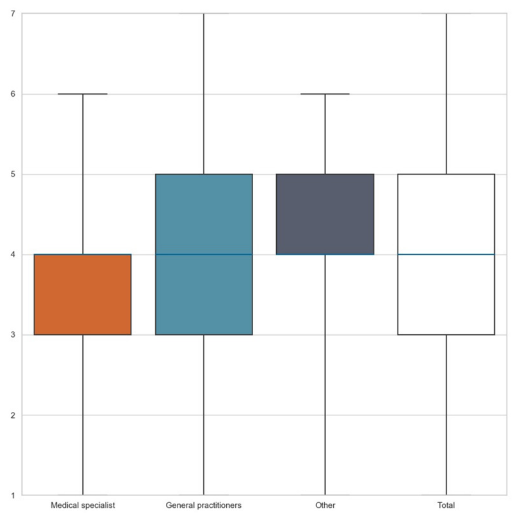
Statement 9 – People in my profession have sufficient knowledge to apply PHC in their work.



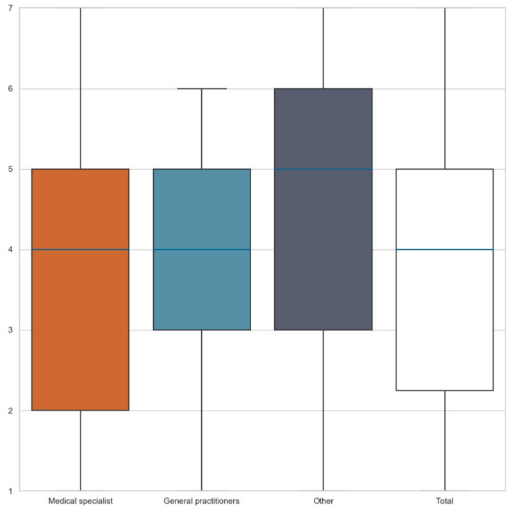
Statement 10 - People in my profession have sufficient skills to apply PHC in their work.



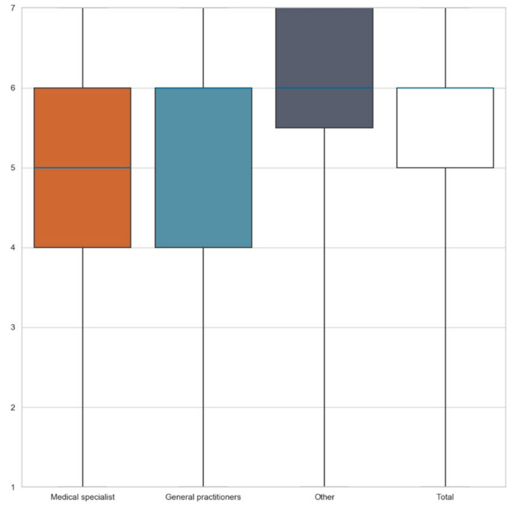
Statement 11 – People in my profession are well prepared for the implementation of PHC.



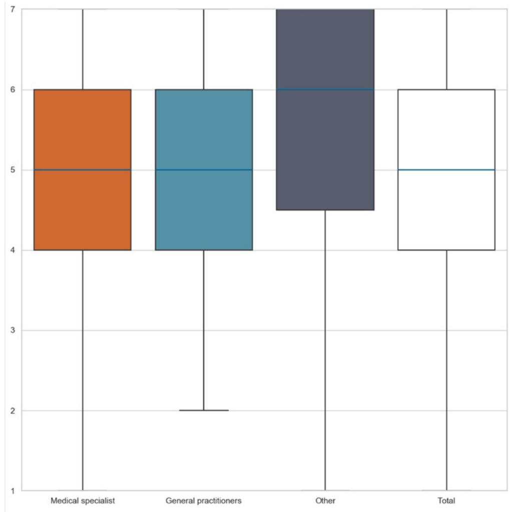
Statement 12 – To improve the healthcare process people in my profession already use data analysis.



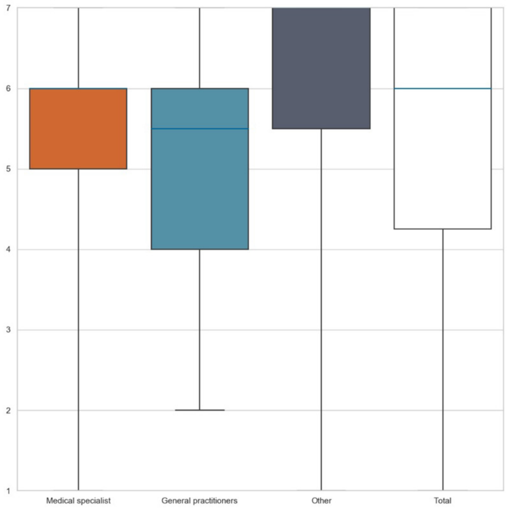
Statement 13 – Personalized healthcare is the future of healthcare.



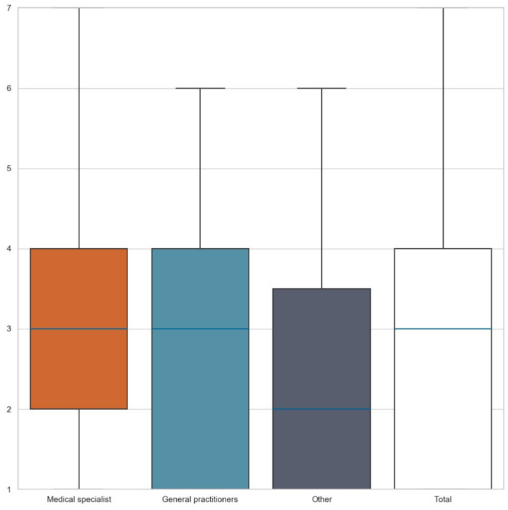
Statement 14 – The application of genomics and other '-omics' techniques will fundamentally change the future of healthcare.



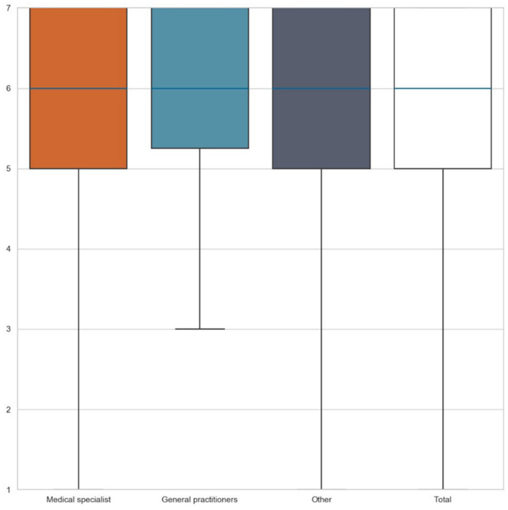
Statement 15 – To make PHC possible it is essential to share data within the healthcare system.



Statement 16 – When personalizing a treatment only genetic information of the patient and the disease is used.



Statement 17 – The main goal of PHC is putting the individual at the center.



Appendix VII: Concepts and definitions

In this advisory report we use the following terms with the corresponding definitions.

bioinformatics

{bioinformatics} is the use of information technology to analyze, store and access molecular biological data, like [DNA] and [protein] sequences.

biomarker (biomarkers)

A {biomarker} is a naturally occurring molecule, gene, or characteristic by which a particular pathological or physiological process, disease, or state can be identified.

caretaker (caretakers)

{caretaker} is a [stakeholder group] that consists of people that take care of [patients], but are not professionals.

data

{data} is any sequence of symbols that can be interpreted to give it meaning.

data analysis

{data analysis} is the process of discovering useful information from a dataset to draw conclusions and make informed decisions.

data cleansing

{data cleansing} is the process of correcting or removing incomplete, incorrect, inaccurate and irrelevant records from a [data] set.

data enrichment

{data enrichment} is the process of merging multiple [data] sets in order to enhance their expressiveness.

data sourcing

{data sourcing} is the process that encompasses the creation, collection and querying of [data].

data structuring

{data structuring} is the process of homogenizing a [data] set or multiple [data] sets.

data visualization

{data visualization} is the process of graphically representing raw or processed [data] in order to visually understand trends, patterns or find outliers in the dataset at hand.

data wrangling

{data wrangling} (or [data cleansing]) is the process of manipulating the [data] in such a way that it is suitable for further analysis. These manipulations include cleansing, parsing, standardizing, enriching, consolidating and unifying.

deoxyribonucleic acid (DNA)

{DNA} is a polymer of deoxyribonucleotides linked by phosphodiester bonds that carries genetic information.

education provider (education providers)

{education provider} is a [stakeholder group] that consists of people that provide or are looking to provide education relating to [personalized healthcare].

epigenetics

{epigenetics} is the study of changes in [gene] function that are mitotically and/or meiotically heritable and that do not entail a change in [DNA] sequence.

ethics

{ethics} are the branch of knowledge that studies moral principles and behaviour.

evaluation

{evaluation} is the process of determining how well a statistical model predicts or explains the phenomenon at hand.

feature engineering

{feature engineering} is the process of extracting features from raw [data] in order to improve further analysis. This extraction is usually based on domain knowledge.

gene (genes)

A {gene} is a region of [DNA] that is transcribed as a single unit and carries information for a discrete hereditary characteristic.

general practitioner (general practitioners)

{general practitioner} is a [stakeholder group] and consists of doctors that have general training and are the first contact point for [personalized healthcare].

genome (genomes)

A {genome} is the complete DNA base sequence of an organism.

genomics

{genomics} is an [-omic] that studies [DNA] sequences and properties of entire [genomes].

government (governments)

{government} is a [stakeholder group] that consists of people that work for {governments} and are involved in [personalized healthcare].

health insurer (health insurers)

{health insurer} is a [stakeholder group] that consists of people that work for a health insuring company.

healthcare system (healthcare systems)

A {healthcare system} is the organization of people, institutions, and resources that deliver health care services to meet the health needs of target populations

human microbiome (human microbiomes)

A {human microbiome} is a [microbiome] in a human individual.

image analysis
{image analysis} is a specialized form of [quantitative analysis] where the [data] as hand is in the form of one or more images.

IT service providers (IT service providers)
{IT service providers} is a [stakeholder group] that consists of people that provide IT services for [personalized healthcare].

laboratory worker (laboratory workers)
{laboratory worker} is a [stakeholder group] that consists of people that perform laboratory analysis regarding [personalized healthcare].

legal
{legal} is a knowledge domain that is related to all {legal} matters regarding [personalized healthcare].

machine learning
{machine learning} is a method in artificial intelligence that allows a system to learn predict, classify or explain a phenomenon based on historical [data] and experience.

medical imaging
{Medical imaging} is a medical discipline that creates images of the human body for diagnostic and treatment purposes.

medical specialist (medical specialists)
{medical specialist} is a [stakeholder group] that consists of doctors that are heavily specialized in a field of medicine.

metabolism
{metabolism} is the complete set of all biochemical reactions in a cell.

metabolome (metabolomes)
A {metabolome} is the total complement of small molecules and metabolic intermediates of a cell or organism.

metabolomics
{metabolomics} is the study and analysis of the [metabolome].

microbiome (microbiomes)
A {microbiome} is the complete set of all microbial organisms in a specific environment.

monitoring
{monitoring} is a means within [PHC] to gauge the health of an individual continuously, also outside of treatment.

nursing staff
{nursing staff} is a [stakeholder group] that consists of people that provide care and are professionally trained.

-omic (-omics)
The {-omics} are novel, comprehensive approaches for analysis of complete genetic or molecular profiles of organisms or viral particles.

paramedical specialist (paramedical specialists)
{paramedical specialist} is a [stakeholder group] that consists of health professionals that are specialized in

participatory

patient (patients)
{patient} is a stakeholder group that consists of people that are treated by the [healthcare system].

personalized

personalized healthcare (PHC)
{Personalized healthcare} is a person-centred health paradigm where monitoring, prevention, diagnosis and treatment are based on relevant biological, environmental and behavioural characteristics of the individual.

personalized medicinal product
A {personalized medicinal product} is a medicinal product that is applied to an individual for the purpose of [personalized healthcare].

pharmacist (pharmacists)
{pharmacist} is a [stakeholder group] that consists of people that involved in distributing medicinal products to [patients] in pharmacies.

predictive

prevention
{prevention} are active means by which disease or injury and thus treatmen can be prevented.

preventive

producer (producers)
{producer} is a [stakeholder group] that consists of people in organizations that produce medicinal products.

protein (proteins)
A {protein} is a polypeptide or group of polypeptides forming a molecule of specific biological function.

proteome (proteomes)
A {proteome} is the whole of all proteins expressed by a [genome].

proteomics
{proteomics} is the study and analysis of the [proteome].

qualitative analysis

{qualitative analysis} is the process of analyzing qualitative [data] such as documents and interview and survey results. The goal of qualitative analysis is usually to understand a phenomenon rather than to predict or explain it.

quantitative analysis

{quantitative analysis} is the process of analyzing quantitative data. {quantitative analysis} is largely driven by statistical analyses.

regulator (regulators)

{regulator} is a [stakeholder group] that consist of organizations that create and enforce regulations regarding medicine and healthcare.

ribonucleic acid (RNA)

{RNA} is a nucleic acid that consists of a polymer of ribose with nitrogen base linked by phosphodiester bonds.

scientist (scientists)

{scientist} is a [stakeholder group] that consists of people that perform academic research in the field of [personalized healthcare].

service provider (service providers)

{service provider} is a [stakeholder group] that provides non-medical services that support healthcare.

signal analysis

{signal analysis} is a specialized form of [quantitative analysis] where the [data] as hand is in the form of a signal.

stakeholder group (stakeholder groups)

A {stakeholder group} is a group of people or organizations that are invested in some way in [personalized healthcare].

systems biology

{systems biology} is the study of the behaviour of complex biological organization and processes in terms of the molecular constituents.

systems medicine

{systems medicine} is the application of [systems biology] in medicine.

transcriptome (transcriptomes)

A {transcriptome} is the complement of all RNA produced in an organism under a specific set of circumstances.

transcriptomics

{transcriptomics} is the study and analysis of the [transcriptome].

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