Fellowship in Clinical Artificial Intelligence:

Clinical Artificial Intelligence Curriculum 2023

Version 2.7 (Cohort 2)

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Who we are

The faculty for Fellowship in Clinical Artificial Intelligence is based in the Clinical Scientific Computing department of Guy's and St Thomas's NHS Foundation Trust. We are supported by NHS Digital Academy and NHS England's *AI & Digital Medicine Workforce* department.

1. Introduction

It is vital for the UK's place as a global AI superpower to implement training pathways for the NHS frontline workforce to gain expertise in clinical AI. This document describes such a pathway.

Artificial Intelligence (AI) technologies will provide tools to improve diagnosis and care across many patient pathways. The effective use of AI within the NHS requires not only AI experts, but also clinicians with AI expertise to act as the bridge to clinical insights and implementation. The clinician is increasingly important in the development and evaluation of AI technologies, with at least 9 distinct roles identified[1]. Internationally, there are initiatives to embed artificial intelligence training within medical training[2].

Mainstream academic routes to AI expertise are not designed to be integrated with clinical work or training in the UK. These routes deter trainees with high up-front costs and interruptions to clinical training. Furthermore, most routes lack curricula relevant to *clinical* AI and the application of AI software in live hospital environments. Therefore, there is an unfulfilled need for a route to clinical AI expertise that is integrated within existing clinical training. This need was explicitly highlighted in *The Topol Review*[3]:

"*The NHS should create or increase the numbers of* ***clinician****, scientist, technologist and knowledge specialist posts with* ***dedicated, accredited time,*** *with the opportunity of working in partnership with academia and/or the health tech industry to design, implement and use digital,* ***Artificial Intelligence*** *and robotics technologies."*

-Recommendation *DM4/AIR5* from the Digital Medicine and AI & Robotics Panels.

[1] Scheek, D., Mehrizi, M.H.R. and Ranschaert, E., 2021. Radiologists in the loop: the roles of radiologists in the development of AI applications. *European radiology*, pp.1-9.

[2] Wiggins, W.F., Caton, M.T., Magudia, K., Glomski, S.H.A., George, E., Rosenthal, M.H., Gaviola, G.C. and Andriole, K.P., 2020. Preparing radiologists to lead in the era of artificial intelligence: designing and implementing a focused data science pathway for senior radiology residents. Radiology: Artificial Intelligence, 2(6), p.e200057.

[3] Topol, E., 2019. The Topol Review. *Preparing the Healthcare Workforce to Deliver the Digital Future*, pp.1-48.

2. Purpose

The purpose of this document is to specify a curriculum which describes expertise in clinical artificial intelligence. It is designed to be an enduring curriculum for NHS frontline workers to develop expertise in clinical AI within their clinical training. This curriculum specifies the educational framework for the **Fellowship in Clinical Artificial Intelligence** designed by Guy's and St Thomas's NHS Foundation Trust and supported by NHS Digital Academy.

In this fellowship, the fellows are embedded in a clinical AI team at an NHS Trust. They will directly develop, deploy, and evaluate clinical AI models. They will gain AI expertise through immersive project work, didactic and self-paced learning activities, and applied research.

The curriculum is aligned with Health Education England's *A Health and Care Digital Capabilities Framework*[4] and the Faculty of Clinical Informatics' *Core Competency Framework for Clinical Informaticians*[5].

[4] Health Education England, 2018. *A Health and Care Digital Capabilities Framework.*

[5] Faculty of Clinical Informatics. *Core Competency Framework for Clinical Informaticians* (https://facultyofclinicalinformatics.org.uk/core-competency-framework)

3. Learning content

The learning content of this curriculum is illustrated below in two different formats:

- In Figure 1, the delivery methods are mapped according to the relevant stage in the AI life cycle.
- In Table 1, learning objectives are listed along with specific resources relevant to each learning objective.

The delivery methods are:

1. Immersive project in clinical AI
    - Fellows work under the supervision of a senior clinician in an NHS Trust with expertise in clinical AI. This project is a primary focus of the fellowship year and enables the fellow to develop skills in clinical AI deployment which can only be gained through experiential learning. There may be opportunities for publication and research (see Section 4 below for further details). Projects are proposed by supervisors and approved by the faculty if suitable for the fellow's learning objectives. The fellow's supervisor also has additional responsibilities as per Section 5 below.
2. Small group workshops
    - Fellows have a bespoke programme of interactive small group masterclass workshops occurring monthly. These workshops are delivered by invited experts in various domains of clinical AI. The topics of discussion are designed to complement and extend beyond the didactic and self-directed elements of the curriculum.
3. E-learning
    - Fellows are enrolled in an established AI and machine learning course, the KCL Innovation Scholars Programme. They will complete didactic modules on 'Demystifying AI', "Python- Software Carpentry", and "Applied AI".
    - Fellows are provided a subscription to an online education platform for the duration of the fellowship, allowing unlimited access to pre-recorded lectures and interactive exercises on statistics, machine learning and software development. Assignments and deadlines for progress are managed by the faculty to prompt engagement with the resource.

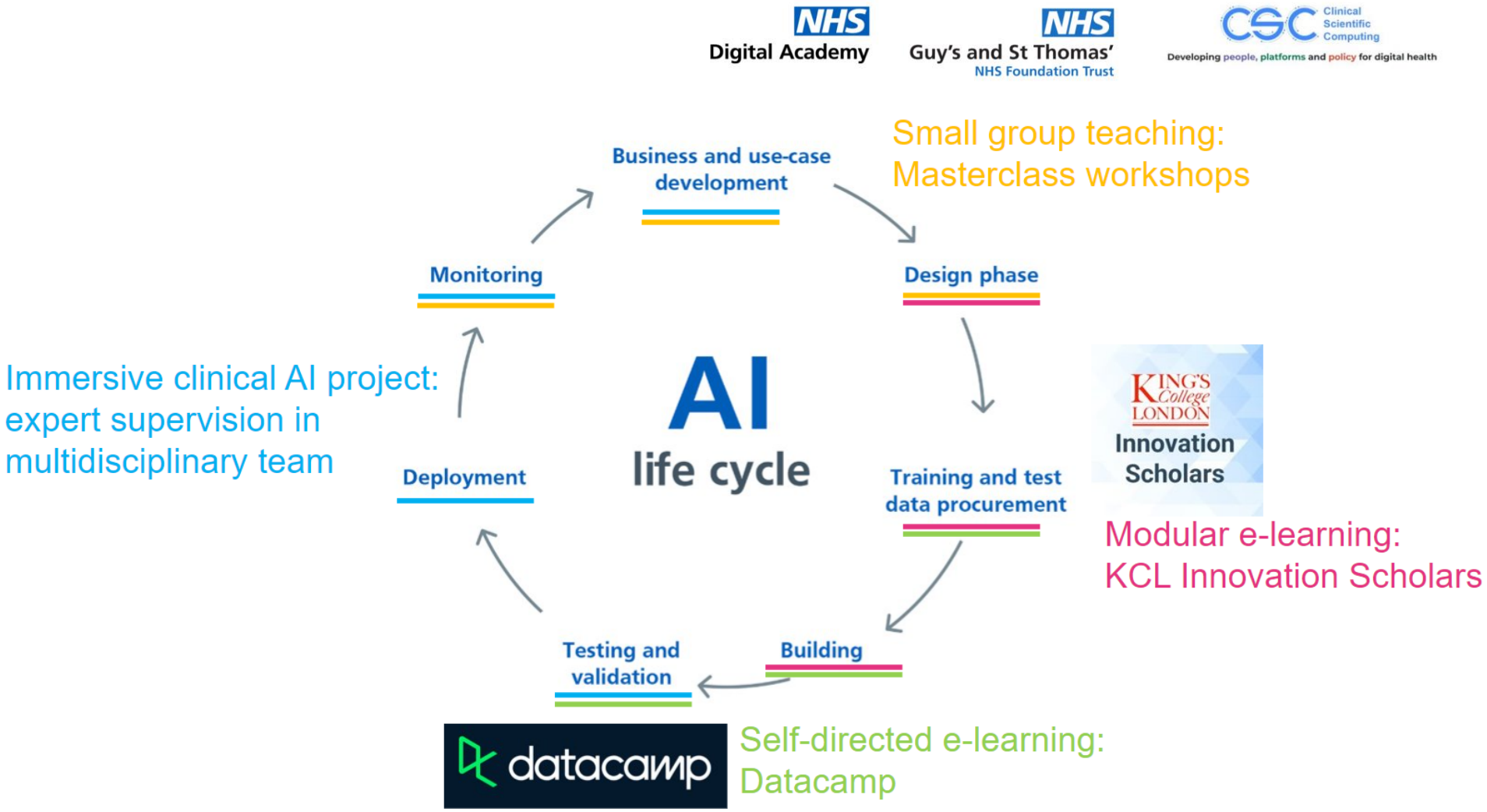

Figure 1. Learning content of the Clinical AI Curriculum as mapped onto the life cycle of AI (adapted from NHSX). The full scope of the life cycle is encompassed by the 4 delivery methods of immersive clinical project work, small group teaching, large group teaching, and self-directed learning.

Learning objective	Resources	HEE Digital Literacies domains	FCI Core Competency Framework
Artificial Intelligence fundamentals	Online education platform Innovations Scholars	2a: The ability to use digital technologies and tools for personal learning and professional development 3a: The ability to find, manage, organise, store and share digital information, data and content 4c: The ability to use digital technologies to support or create new ideas, methods, solutions and decisions	3.1 Analytical Methodologies and Applications 3.2 Data Sources and Characteristics 3.3 Data Structure, Standards, and Linkage 3.4 Data Management 3.6 Data Visualisation
Regulation and standards	Immersive project Masterclass workshops	3b: The ability to understand and act upon appropriate guidelines, protocols, regulations and safeguards in the use of differing media, information, data and content to meet legal, ethical, cultural and security rules, requirements and expectations when working with personal, public, professional and/or confidential information, data and content 3d: The ability to understand and adhere to digital copyright, intellectual property and privacy rules and regulations	1.2 Clinical Governance 2.3 Selecting and Procuring Information Systems and/or Technology 2.6 Data security and Cyber Security 3.5 Information Governance, Accessibility and Ethics
Validation and evaluation	Immersive project Masterclass workshops	3c: The ability to critically analyse, evaluate and/or interpret information, data, content and their sources 4a: The ability to create new digital resources and/or curate existing ones working individually or in collaboration with others 4b: The ability to use devices, technologies, techniques and applications in research, quality improvement, audit and scholarly activities 4e: The ability to lead on and champion the effective, appropriate, creative and innovative use of digital technologies in research, scholarship and other activities.	1.7 Scientific and Research Skills 2.7 Maintenance and Support for Healthcare Information Systems 2.8 Evaluation of Information Systems 4.1 Quality Improvement and Clinical Safety 4.6 Evaluation 5.1 Evidence-based Practice 6.4 Project Leadership
Integration and systems impact	Immersive project Masterclass workshops	3d: The ability to work with and champion the effective, secure, appropriate and innovative use of information, data and content in order to solve problems, make decisions and to achieve successful outcomes for specific goals and objectives 5c: The ability to resolve technical challenges and problems both individually and with others 5d: The ability to use technical knowledge to problem solve and achieve expected outputs	1.3 Models of Care Delivery 1.4 Health Administration and Services 1.5 Informatics Strategies 1.6 Informatics in Health 2.4 Interoperability and Integration 2.5 System Architecture 4.4 Usability and Design 5.3 Clinical Decision Making and Support
Strategy and culture	Immersive project Masterclass workshops	1c: The ability to work collaboratively with others using digital technologies and tools to produce shared outcomes to meet shared goals 1d: The ability to participate actively in and across digital networks. 2b: The ability to use a wide range of digital technologies and tools in teaching, coaching, mentoring others 4d: The ability to act as a digital champion or change agent 6a: The ability to develop, promote and safeguard appropriate digital identity(-ies) that support a positive personal and organisational reputation	2.2 Working and Communicating with Project Stakeholders 4.2 Change Mangement 4.3 Behaviour Change 4.5 Patient Involvement and Engagement 6.1 Multi-disciplinary and Organisational Working 6.5 Informatics Strategy and Innovation 6.6 Planning

Table 1. Learning objectives of the curriculum. Examples of recommended learning resources are provided. Relevant curriculum links to HEE's *A Health and Care Digital Capabilities Framework*[4] and the Faculty of Clinical Informatics' *Core Competency Framework for Clinical Informaticians*[5] are listed. The learning content and structure of this programme are adapted from Wiggins *et al.* (2020)[2].

The learning objectives are grouped into themes as follows[6]:

Artificial Intelligence fundamentals

- Understand and apply different types of AI algorithms for different tasks (for example, logistic regression, decision trees, support vector machines, random forest, K-means clustering, neural networks, Bayesian approaches)
- Understand data provenance, quality and structure requirements for training AI algorithms
- Perform data extraction and wrangling (for example, feature labelling/extraction, dimensionality reduction, normalisation)
- Understand types of training for AI algorithms (for example, supervised, unsupervised, reinforcement learning, ensemble learning, distributed learning)
- Code using languages and frameworks used for the creation and analysis of AI algorithms *(*for example, Python, R, SQL)
- Understand and apply AI algorithm training and optimisation (for example, tuning hyper parameters, internal validation, optimal stopping)
- Understand and apply common metrics for AI algorithm performance (for example, precision, recall, F1 score, Receiver Operator Characteristic analysis)
- Understand AI algorithm validation methods (for example, hold out method, cross validation)

Regulation and standards:

- Understand CE/UKCA marking and methods for obtaining certification for different classes of medical device for AI software
- Understand and apply GDPR to AI software
- Understand and apply NHS Digital's Clinical Risk Management standards to AI software (for example, DCB0129, DCB0160)
- Understand and apply HRA definitions of clinical research and service evaluation as they relate to AI evaluation and implementation, following the appropriate governance for each.
- Understand legal frameworks applying to the use of AI software in clinical decision making. E.g. negligence, product liability

[6] Adapted from NHS AI Lab & Health Education England, 2022: *Developing healthcare workers' confidence in AI Report 2 of 2,*

Validation and evaluation

- Critically appraise the published literature relating to AI algorithms, using established evidence standards where appropriate (e.g. NICE evidence standards framework)
- Understand the process of local model validation, including prospective clinical studies of AI software
- Understand and apply the principles of medical algorithmic audit
- Establish and manage post-deployment monitoring, evaluation, and iteration of AI software, including processes for detecting, reporting, and managing adverse effects or serious incidents related to AI
- Understand, measure, and mitigate potential sources of error and bias in AI algorithms, including circumstances leading to inequitable distributions of patient outcomes

Integration and Systems impact

- Integrate AI software with existing healthcare IT systems
- Design and re-design clinical workflows to integrate AI software
- Evaluate the impact of AI software in health economic measures, service efficiency, patient outcomes, and workforce
- Understand how user interactions with AI software may be affected by human cognitive biases (e.g. automation bias, aversion bias, confirmation bias, rejection bias, and alert fatigue)
- Understand AI failure modes and how these differ from human errors in clinical reasoning and decision making (e.g. outlier detection)
- Understand the principles and limitations of AI explainability

Strategy and culture:

- Participate in and develop multi-disciplinary teams for the creation and deployment of AI software
- Collaborate effectively with colleagues in academia and industry
- Understand and apply the principles digital transformation and effective change management
- Establish leadership buy-in and support internal champions for change for AI software
- Understand the learning and development needs of NHS staff for AI software

4. Activities and duties

The duration of each Fellowship in Clinical AI is 12 months at 0.4 full time equivalent work pattern (2 days per week). This allows sufficient time for fellows to achieve the learning objectives outlined in Section 3, and to make significant contributions to an immersive project in applied clinical AI (representative project summaries from Cohort 1 are in Table 2).

Trainees begin the programme with an induction period (shown in Figure 2), during which they work-shadow established team members of their clinical AI team to allow full immersion in the culture and working practices.

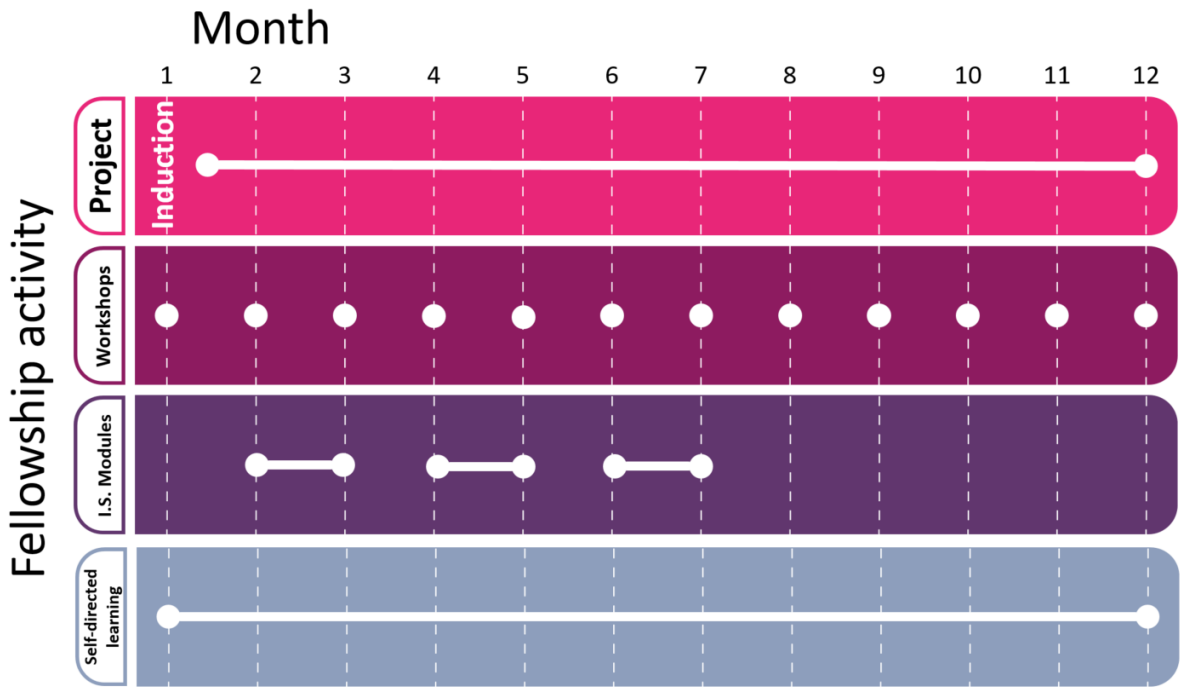

Figure 2. Gantt chart of activities throughout the fellowship year

Duties and responsibilities of fellows in clinical AI include:

1. Work energetically as a member of an agile multidisciplinary team including: AI specialists, medical physicists, IT, health economists, and clinicians.
2. Communicate effectively with key stakeholders in clinical AI including: hospital management, patients, clinicians, regulatory bodies, and software developers.
3. Curate clinical datasets in accordance with data-protection laws and regulations.
4. Deploy clinical AI in a way that is safe, legal, equitable, and effective.
5. Critically evaluate the performance of clinical AI in hospital workflows.
6. Present scientific findings in clinical AI including clinical trials and quality improvement projects.
7. Understand and develop policies and standards for the regulation of clinical AI.

Table 2. Representative project titles, medical specialty and educational aims of clinical AI projects from Cohort 1

Project	Medical specialty	Educational aims
High-dimensional modelling of the focally injured human brain	Neurology Stroke Medicine Radiology	In connecting with multiple aspects of an end-to-end translational programme, this project will expose the fellow to neuroimaging and clinical data acquisition; data curation and pre-processing; assisted ground truth labelling; high-dimensional multi-modal model development, coding, and evaluation; product design and clinical validation; and evaluation of clinical and operational utility
Novel predictive algorithm development and implementation for high-cost early mental health care	Psychiatry	The fellow will gain invaluable experience in truly applied clinical AI, developing initial skills in the coding involved in data extraction and processing (including natural language processing [NLP] development) at scale, followed by assembly and evaluation of ML and other predictive modelling approaches in AI, followed by clinical validation and exposure to deployment and post-deployment processes.
Deep learning cardiac motion analysis	Cardiology Radiology	Computer vision, training and inferencing in DL, time-to-event statistics, interactive visualization and user interface design.
Evaluation of the an AI platform for personalised, evidence-based treatment planning in multidisciplinary cancer care	Oncology	The clinical fellow may choose to contribute to one or more aspects of the proposed project: Clinical workflow re-design to incorporate AI; design of the clinical validation; data collection and validation analysis.
Chest X-ray AI Engine: Clinical Validation and Implementation	Radiology	Mathematical principles of AI, data curation, clinical validation and regulation, post deployment monitoring

5. Supervision and development

A senior clinician with expertise in AI is appointed as the AI supervisor for each fellow. The supervisor provides direct supervision (at least 1hr per week) during the fellowship to discuss their personal development plan, project progress, and troubleshooting. Tools for the documentation of supervision include templates for: an induction meeting, a midpoint review, and end of programme appraisal. The supervisor will provide trainee feedback during the fellowship *ad hoc*, and in writing at a mid-point review at end of programme appraisal.

On starting the fellowship, fellows complete a personal development plan (PDP) to list their specific goals and describe how these are aligned with their clinical training and broader career aspirations. There are many different roles within the clinical AI development cycle, and fellows should identify specific learning objectives (Section 3) to focus on during the fellowship. Fellows may use the SWOT tool (Figure 3) to identify and anticipate their training needs during the fellowship and discuss these with their supervisor.

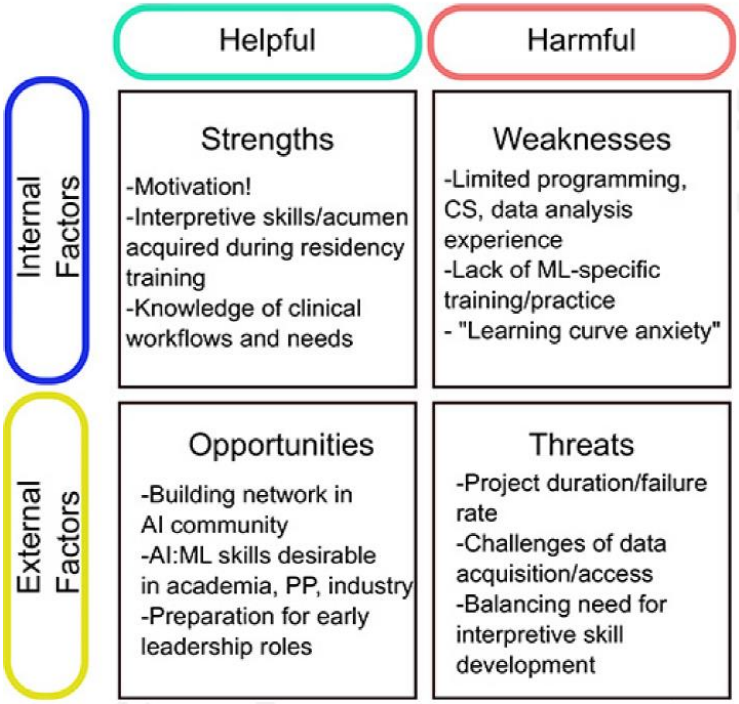

Figure 3. Example of a completed SWOT (Strengths, Weaknesses, Opportunities, Threats) tool for a fellow in a clinical AI fellowship. From Wiggins *et al.* (2020)[2].

Trainees should maintain a portfolio of their activities during the fellowship to demonstrate progression towards objectives listed in their personal development plan. The portfolio should include but is not limited to: record of learning, personal reflections, certificates, and code repository. This portfolio will contribute evidence to the supervisor's reports.