TechConnect
Human Tech Index

HUMAN-TECHNOLOGY SKILLS COMPLEMENTARITY CONCEPTUAL FRAMEWORK II

Deliverable 2.2

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Abstract	This deliverable presents the synthesised insights from the observational case studies performed in Work Package 2 (WP2) of the TechConnect project and translates them into an analytically tractable Human-Technology Skills Complementarity framework that can inform both theory development and practical assessment. In this framework, *Human-Technology Skills Complementarity is* viewed as an empirically grounded, organisationally situated phenomenon where complementarity is achieved (or not) depending on systemic socio-technical relationships.

Keywords	Human-Technology complementarity, skills, practice, work, advanced digital technologies, socio-technical, intended affordance, actual affordance, affordance gap

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SEN	Sensitive, limited under the conditions of the Grant Agreement	
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* *R: Document, report (excluding the periodic and final reports)*

DEM: Demonstrator, pilot, prototype, plan designs

DEC: Websites, patent filing, press & media actions, videos, etc.

DATA: Data sets, microdata, etc

DMP: Data management plan

ETHICS: Deliverables related to ethics issues.

SECURITY: Deliverables related to security issues

OTHER: Software, technical diagram, algorithms, models, etc.

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EXECUTIVE SUMMARY

In this report we present an updated framework for Human-Technology Skills Complementarity. We do so by moving beyond "technology vs. skills" framings and by instead showing *how Human-Technology Skills Complementarity* is produced (or not) through the alignment of intended and actual affordances across task, role, team, department, and organisational levels.

In the TechConnect-project, 12 case studies have been performed. Each case centres around a particular advanced digital technology used by different groups of professionals in health care contexts. Drawing on an analysis of the cases studied, this report shows how affordance gaps emerge on various levels, and how these cascade and transform across levels. To manage these, and align intended and actual affordances, bridging work is performed in daily, organisational life. Depending on if this work is successful or not, Human-Technology complementarity might be low or high.

An important conclusion is that gaps that occur between intended and actual affordances are not necessarily solvable on the level where they first occurred. This points to the need to take a systems perspective on the implementation, adoption and use of advanced technologies.

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ABBREVIATIONS

CTF	Communications Task Force
DoA	Description of Action
ICT	Information and Communication Technology
WP	Work Package

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ABOUT TECHCONNECT

TechConnect is a €3 million initiative funded by the European Union, under the Horizon Europe framework with a consortium of 9 partners: Trinity College Dublin (TCD), Mälardalen University (MDU), Polytechnic University of Madrid (UPM), Universiteit Utrecht (UU), BluSpecs, Tallaght University Hospital (TUH), Västerås Hospital (RV), Hospital Ramon y Cajal (FIBIRYCIS) and University Medical Centre Utrecht (UMCU).

The TechConnect project aims to deepen the understanding of how advanced digital technologies impact human skills by focusing on Human-Technology Skills Complementarity. Through desk research, industry surveys, and case studies in healthcare, TechConnect explores how human skills and technology interact in real-world contexts. The project develops a systemic framework to address the gap between intended and actual technology use, offering practical guidelines for technology procurement, development, and training. By providing tools to enhance Human-Technology integration, TechConnect's ambition is to boost productivity and employment across industries, driving greater alignment between technology and human skills.

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1 Introduction

Often, digitalisation is framed as improving quality, safety, coordination and decision-making, while simultaneously reducing costs, administrative burdens and mundane work. Yet a substantial body of research in information systems, organisation studies, and public management shows that such promises are rarely realised through technology alone. Digital technologies become consequential through their entanglement with professional practice, accountability regimes, organisational routines, and infrastructural conditions, and these entanglements frequently generate outcomes that are mixed, uneven, and difficult to anticipate in advance (e.g., Cordella & Tempini, 2015; Orlikowski, 2007; Vial, 2019). For healthcare providers, the stakes are particularly high: when technologies become part of diagnostic work, documentation, triage, scheduling, sterile services, or coordination across units, small misalignments can scale into reliability concerns, new burdens, or contested shifts in professional discretion.

The TechConnect project begins from the observation that debates about whether advanced digital technologies "replace" or "augment" human labour often rest on thin empirical foundations and oversimplified assumptions about both skills and technology. The project's objective is explicit in pointing out that extant research tends to isolate technologies and individual skills from the organisational contexts in which the technologies and skills are brought into use. As a result, the relationships between Human–Technology Skills Complementarity in organisational contexts remains underdeveloped.

In response, TechConnect conceptually advances the notion of Human–Technology Skills Complementarity as *an organisationally situated phenomenon*. In the project, we examine not only how technologies are taken up in daily work and how work is reconfigured around these technologies, but also how organisations govern and support the Human-Technology arrangements that emerge to achieve the alignment between the functionality of technology and the skills of people. In other words, we see Human-Technology Skills Complementarity as emerging out of a set of systemic socio-technical relationships that emerge across the whole organisation.

A central conceptual move in TechConnect is thus to treat complementarity not as a single "fit" between a tool and an individual user, but as emerging in the context of a broader organisational system. Our assumption is that the whole organisational system matters for how and to what extent complementarity between humans and technologies emerges when human skills are mobilized in the performing of work with the support of technology. The affordances of a particular technology emerge as the technology is used to perform a particular task, as well as when someone with a particular role mobilizes it and when it comes to use in the joint work of a team, a department or even an organisation. As we shall see, to adopt a 'system view' on human-technology complementarity is important since the organisational consequences of digital technologies adoption are often indirect. For example, a tool that appears successful at the level

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of task completion may generate new requirement for coordination amongst the members at team level, new capacity constraints at the department level, and/or new governance tensions at the organisational level. Conversely, what looks like a “local” breakdown at the level of accomplishing a task may in practice be bridged by departmental routines, informal learning infrastructures, or boundary-spanning roles, often at the cost of new, largely invisible skill demands.

To operationalise the dynamics of Human-Technology Skills Complementarity as described above, we make a distinction between *intended affordances* and *actual affordances* and explore the gap between the two – *the affordance gap.* An affordance gap is the divergence between what a technology is expected to enable (intended affordances) and what it comes to enable in use (actual affordances). Our analytical assumption is that affordance gaps are not merely implementation “barriers”, but sites where the organisational and professional conditions of complementarity become visible. For instance, by mapping affordance gaps we will see where work is actually performed, where judgment is stretched, where coordination is re-patterned, and where new skills are required to keep service delivery reliable. To map and explain affordance gaps is thus a way to understanding how Human-Technology Skills Complementarity is brought about (or not); to understanding how skills are reshaped as a consequence of this; and what new types of skills are needed to ensure the smooth functioning of the organisation.

1.1 Purpose of this report

The purpose of this report is to present an updated, empirically grounded conceptual framework for Human-Technology Skills Complementarity. In the report, we synthesise the insights from the observational case studies of Work Package 2 (WP2) and translate them into an analytically tractable framework that can inform both theory development and practical assessment. The report is a result of Task 2.4, System analysis, where we have analysed the empirical material produced in previous tasks in WP2. Hence, the updated Human–Technology Skills Complementarity Framework presented at the end of this report is solidly grounded in empirically observed relationships between intended and actual technology use of a diverse range of advanced digital technology and across various professional groups, hospitals and countries. This way, D2.2 addresses the overarching question that motivates the overall TechConnect project: How can advanced digital technologies complement human skills in complex organisational settings, and what conditions enable such complementarity to be sustained rather than assumed?

1.2 Relations to other deliverables

The first Human-Technology Skills Complementarity Framework produced in the project (D1.1) established the core definition of Human-Technology Skills Complementarity as a "dynamic, multi-level synergy" and introduced the foundational distinction between "intended" and "actual" affordances across five levels (Task, Role, Team, Department, Organisation). This early model primarily served as a classification tool and a mapping of where affordances occur.

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The revised Human-Technology Skills Framework presented here significantly advances this by theorizing *how complementarity is achieved or lost, and by teasing out which skills are mobilized in this work.*

As will be described, the revised framework builds on the portfolio of 12 in-depth WP2-observational case studies conducted across healthcare organisations in Ireland, Sweden, Spain, and the Netherlands, documented in Deliverable 2.1. While the methodological details are presented later in this report, it is worth noting that the WP2-dataset documented in D2.1 constitutes a substantial comparative evidence base, built to support cross-case synthesis and, ultimately, the development of the Human–Tech skill Complementarity Index in D2.3.

Compared to D1.1 (Human-Technology Skills Framework I), which was based on a literature review, this deliverable thus provides a solid and empirically grounded conceptual foundation for a revised Human-Technology Skills Framework. Not only are we here able to produce a cross-case synthesis of affordance gaps and their variation across organisational levels, in line with the project's systems-thinking orientation, we are also able theorise the constitution of affordance gaps in a way that is faithful to the organisational realities of healthcare work, foregrounding the practices and material arrangements through which complementarity is made or unmade.

1.3 Target audience

The revised Human-Technology Skills Framework presented here is of high relevance to anyone interested in understanding why technologies sometimes seem to fail delivering what they were supposed to. This question occupies not only researchers in the areas of technology change, technology strategy and technology policy but in innovation, implementation studies and organisation and management studies. It is also a question – sometimes acutely experienced - for all stakeholders involved in selecting, procuring, implementing, introducing or adopting new technology, particularly in the area of health care, such as hospitals, health care trusts, unions for health care professionals and so on.

1.4 Structure of the report

The remainder of this text proceeds as follows. The next section develops the theoretical foundation for the work performed, grounding the project's conceptual approach in research on technology-in-use, affordances, sociomateriality, and organisational systems. The subsequent methodology section describes the WP2 case study portfolio and the empirical basis of the analysis, drawing on the shared project guidance and dataset documentation. The results section then synthesises cross-case patterns in affordance gaps by level and develops an analytic typology of gap types and constituting practices.

Finally, a revised Human–Technology Skills Framework is visualised, and the implications of this are articulated; clarifying how observed gap patterns map onto competence domains and what this suggests for organisational strategies aimed at strengthening complementarity in practice.

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2 Theoretical framework

Digitalisation is routinely framed through promises of efficiency, quality improvement, and transparency. Yet a large body of information systems, organisation studies and public sector research shows that these promises are neither self-fulfilling nor simply a matter of successful implementation (Barley, 2020; Vial, 2019). Digital technologies affect organisations and employees through their entanglement with work practices, professional norms, accountability arrangements, and organisational infrastructures (Barley, 2020; Cordella & Tempini, 2015; Orlikowski & Scott, 2008; Plesner et al., 2018). In settings where work is interdependent and safety-critical, even modest shifts in information flows, documentation routines, or decision support can reconfigure discretion, coordination, and what counts as competent performance (Petrakaki, 2018; Petrakaki & Kornelakis, 2016).

TechConnect approaches this terrain through the concept of *Human–Technology skill Complementarity*. The project claims that complementarity is not a stable state of a technology ("this system works well by radiologists") or of an occupational group ("nurses have the right skills"). Instead, this project regards complementarity as an emergent feature of sociotechnical arrangements. In other words, complementarity describes the alignment between human capabilities and technology capabilities which allows work to be performed well clinically, organisationally, and ethically, without displacing responsibility into opaque systems or shifting burdens into invisible coordination work. This framing is explicitly tied to the project's ambition to move beyond approaches that isolate technologies and human skills, and instead to develop a holistic account that can inform the development of Human–Technology Skill Complementarity Index in WP2.

2.1 Defining complementarity via affordance gaps

To conceptualise complementarity in a way that avoids both technological determinism and purely social explanations, the project builds on affordance theory. Originating in ecological psychology, *affordances* capture the action possibilities that emerge in the relation between an actor and an artefact, an idea that organisation and IS scholars have used to explain why the "same" technology can enable, constrain, or be repurposed differently across settings (Gibson, 1979; Hutchby, 2001; Leonardi, 2011). In contemporary organisation and information systems research, affordances are commonly treated as relational possibilities for action that arise in the encounter between human actors and artefacts, and that become consequential as they are taken up, stabilised, or resisted in practice (Barley, 2020; Leonardi, 2010; Leonardi & Barley, 2008). This relational constitution is crucial because "what a technology can do" is rarely reducible to functionality - it depends on configurations of access rights, interoperability, training arrangements, local routines, professional judgement, and the practical realities of work.

TechConnect distinguishes between the *intended affordances* and *actual affordances*. Intended affordances capture the expectations and rationales that are articulated in advance through procurement documents, business cases, training materials, vendor narratives,

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and managerial decisions. While expectations might be rearticulated in the process of technology implementation, intended affordances are more or less fixed through their articulations in procurement specifications, project documents and managerial discourse. Actual affordances capture what becomes possible in situated use (Suchman, 2007). This distinction is conceptually important because it keeps "aspirations" and "practices" in productive tension. In many digitalisation projects, organisational actors do not merely implement a finished artefact; they participate in constructing what the technology is for, what it is supposed to do, and what counts as legitimate use. The result is often that work is redesigned to fit the technology's presumed logic, not the other way around (Andersson et al., 2022).

The core of TechConnect's theorisation is the *affordance gap*: the divergence between intended and actual affordances. Affordance gaps matter because they are where complementarity fails to materialise as expected and where the organisational and professional consequences become visible. In healthcare, these gaps are rarely neutral. They have implications for patient safety, equity, clinician autonomy, accountability, and trust.

Importantly, TechConnect does not treat gaps as mere "barriers" or "implementation problems". Instead, gaps are theorised as constituted through sociomaterial arrangements. This builds on practice-based and sociomaterial scholarship that treats "the social" and "the material" as intertwined in the accomplishment of organisational life (Feldman & Orlikowski, 2011; Gherardi, 2010; Orlikowski & Scott, 2008). The implication is that an affordance gap is produced through the interplay of artefact materiality (interfaces, data structures, integration points), organisational arrangements (resourcing, governance, routines), and discursive framings (efficiency narratives, safety rationales, innovation tropes) that shape what actors can do and what they feel they are allowed to do.

We make this constitutive focus explicit by emphasising that understanding a gap requires attention to workarounds, accommodation practices, tacit knowledge, resistance and contestation, learning, and ethical/legal considerations. These are not "side issues", they are central mechanisms through which technologies and work practices are reconfigured, through which some misalignments are bridged, and through which others persist and become institutionalised.

2.2 A system thinking perspective on affordances

A distinctive theoretical contribution of TechConnect is to conceptualise affordance gaps in line with systems thinking. Examining Human-Technology Skills Complementarity at the level of individual tasks is necessary but insufficient, because key effects of digital technologies unfold through coordination, departmental routines, and organisational strategy. The project therefore conceptualises affordances and gaps as occurring within and between five interrelated levels: task, role, team, department, and organisation (see Figure 1).

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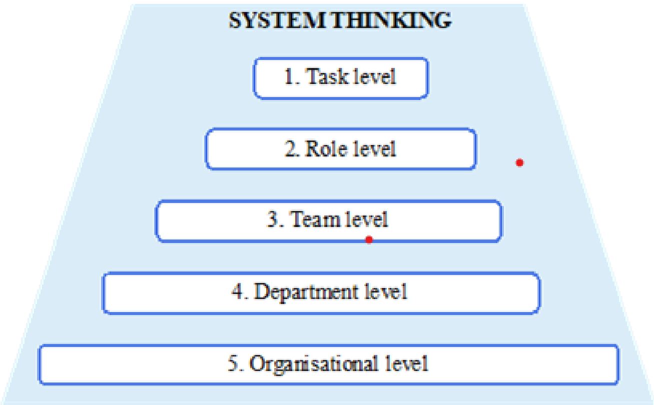
Figure 1. System thinking over five analytical levels of work



This moves parallels to a broader organisational insight: technologies shape organisations unevenly and often indirectly, by altering the distribution of work, the visibility of performance, and the conditions for collective coordination (Barley, 2020). Also, thinking about affordance gaps in this system, multi-level way matters because it highlights that complementarity is rarely "won" or "lost" at a single point. A system can appear complementary on one level in the organisation (a task becomes faster when being performed by or with an advanced digital technology) while producing misalignment on other levels (for example, if coordination costs increase, accountability becomes ambiguous, or if professional trust erodes).

Conversely, what looks like a task-level gap may be bridged through team-level practices or departmental accommodations at the cost of new skills development, new forms of invisible work, or increased dependence on particular actors. In other words, a systems view makes it possible to theorise complementarity as an emergent property of cross-level alignment rather than a local feature of, for example, interface design or training.

2.3 Bringing affordances and system thinking into the analysis

Applying the idea of affordances and affordance gaps to organisational systems allows us to not only see how affordance gaps emerge on different levels in the organisation but also to trace how they *travel* and *change shape* as digital technologies are introduced, adapted, and normalised in everyday work. In the TechConnect analysis, the five analytical levels are used as a practical way to "place" observations: where a gap is first experienced, where it is managed, and where its consequences become visible. A breakdown may be noticed in a specific task, but it is often conditioned by role expectations, team coordination patterns, departmental routines, and organisation-wide decisions about governance, integration, resourcing, and risk. This is why the same technology can appear to "work" in one part of the system while generating friction elsewhere. Our matrices are designed to make these movements legible across

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cases by mapping intended and actual affordances and then locating the gaps that arise, including where the work of bridging them happens and what that bridging work costs.

Bringing these ideas together, TechConnect treats Human-Technology Skills Complementarity as something that must be actively produced and maintained through organisational capability, not simply delivered by a technology or secured through individual upskilling. The affordance gap lens shows *where* intended value does not materialise and *what kind* of misalignment is at stake; the systems view shows *why* those misalignments persist, escalate, or get displaced across levels of work. In the next section we explain how we have operationalised this theoretical framework in our case studies analysis.

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3 Methodology

TechConnect is designed as a comparative programme of in-depth observational case studies in healthcare where the system thinking perspective described above has informed our methodological choices so that we, through the data, would be able to explore affordances on and across the whole organisational system. In practice, this means that WP2 has involved ethnographic observations and interviews (as a way to analyse actual affordance) with interviews and document collection focused on procurement and implementation rationales (as a way to analyse intended affordance). We have adopted an abductive approach (Dubois & Gadde, 2002) (often described as systematic combining), enabling iterative movement between empirical material and sensitising theoretical concepts.

3.1 Study setting and cases selection

As mentioned above, the case portfolio created in WP2 comprises 12 observational case studies conducted across four European healthcare partners in Ireland, Sweden, Spain, and the Netherlands (i.e., a deliberately heterogeneous set of national and organisational contexts). Each case centres on a specific technology-in-use in a clinical or operational setting (e.g. speech recognition, digital triage/chat, robot-assisted surgery, clinical dashboards, biobank platforms).

Case selection was purposive and structured to support *comparative inference* rather than statistical representativeness (Cavaye, 1996; Eisenhardt, 1989). Two design principles guided portfolio construction:

1. Occupational variation: Primary and secondary user groups were mapped using the European Skills, Competences, Qualifications and Occupations (ESCO) framework to ensure systematic attention to how technologies interact with different professional roles, jurisdictions, and skill configurations.
2. Technology variation: Technologies were grouped using "technology archetypes" (e.g. platform, connectivity, analytical insight generation, sensor-based data collection), supporting comparison across different digital technologies rather than treating "digitalisation" as a uniform phenomenon.

Together, these principles created a case portfolio suited to analysing how Human-Technology Skills Complementarity is shaped by occupational context, material characteristics of the technology, and the organisational system in which adoption unfolds.

3.2 Data sources and empirical scope

The WP2 dataset combines ethnographic and interview-based materials with relevant organisational and technical documentation. In total, the dataset comprises over 830,000 words of qualitative material. A more detailed description of the data sources and empirical scope can be found in D2.1, but, in brief, the corpus includes:

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- Participant observation and field notes documenting work practices, sequences of activity, interactional dynamics around technology, and situational conditions shaping use. The consolidated dataset includes 163 observation records totalling over 600 hours and 225,457 words.
- Formal semi-structured interviews with a broad set of organisational actors (frontline users, managers, procurement/implementation stakeholders, and technical support roles). The dataset includes 137 interviews totalling 209.61 hours and 544,493 words.
- Combined observation/interview entries (used in some sites to capture blended field encounters and in-situ interviewing) totalling 54 hours.
- Documents and artefacts, including technical specifications, training materials, strategic documents, implementation plans, procurement documentation, and evaluations, collected and logged to support analysis of intended affordances.
- Visual materials (e.g. photographs, diagrams) where ethically appropriate, primarily to support analysis of spatial arrangements, artefacts, and workflow configurations.

3.3 Fieldwork procedures and coordination

Fieldwork was conducted by seven researchers from four universities, with common protocols to support cross-case comparability while preserving the discretion needed for high-quality ethnographic work in dynamic clinical environments. The project developed joint Researcher Guidelines to emphasise building a shared ethnographic record through systematic and explicit observation practices, including detailed field notes (often with time stamps), descriptions of space and artefacts, accounts of interactions, and reflexive annotations on mood/affect and emergent interpretations. All researchers also underwent joint training before commencing fieldwork.

To maintain coherence across the twelve case studies in four countries with three case studies per country, researchers convened weekly during the fieldwork and the analysis phases to coordinate work. These meetings served both practical and analytical functions: addressing access constraints and ethical issues, calibrating what “counts” as relevant evidence for intended and actual affordances, and iteratively refining shared attentional foci in an abductive manner. Insights from these meetings also served to guide the analytical focus during the coding work.

3.4 Coding strategy and construction of the affordance gap matrices

The analysis builds on a structured coding and synthesis pipeline that links case-level analysis to cross-case theorising. Coding was performed in NVivo using a shared scheme with three orthogonal dimensions: affordance type (intended vs actual), affordance level (task, role, team, department, organisation), and topic (a structured set of thematic sensitising categories). Coding guidance defines *intended affordances* as pre-formulated ideas about technology use and utility

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(often found in procurement and implementation materials, managerial decisions, training and vendor materials), and *actual affordances* as in-situ use and experienced utility (often evidenced through observation, local evaluations, modifications, and staff accounts). Table 1 and Table 2 show the coding instructions for affordance type and level respectively. For a full account of how the coding was structured see Appendix 1 – Coding instructions

Table 1. Coding instructions for affordance type

Affordance type	Definition	May be found in, for example
Intended	Pre-formulated ideas and intentions about the usage and utility of technologies	Procurement documentation, implementation plans, project plans, managerial decisions, resource allocations, business case, training material, vendor material
Actual	In-situ actual usage and utility of technologies	Direct observation of technology use, organisational evaluations, signs or notes, technical modifications, frequency of use, staff experiences of use

Table 2. Coding instructions for levels

Level	Definition	Indicators
Task level	Occurring between tech and humans in relation to a particular task. Related to the changing of the performing of a particular task.	Related to the DOING of the task. For example, more or less human intense/staff required to perform a task; a task more or less time-consuming; the need for new/different practices to be developed on task-level; the need for humans learning new things, developing different competences; the diminishing of human interaction in the performing of a task.
Role level	Occurring between tech and humans in relation to the performing of a professional role. Related to changing the job of the professional more broadly (not simply a particular task).	Related to the PROFESSIONAL IDENTITY of the professionals and the PERFORMING OF THE PROFESSION. For example. the logic of the technology in relation to the professional; the language of the technology vs the language of the professional; the degree to which the tech threatens the professional identity.

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Team level	Occurring as tasks are performed with tech between professionals who collaborate in teams. Related to the changing the interaction of the team when they jointly perform a task.	Related to the COLLABORATION amongst people. For example, the degree or type of interaction amongst members of staff working together; the changing power-balance amongst people working together to deliver some sort of service to the patient.
Department level	Occurring in relation to the performing of department routines. Related to the changing in the delivery of the service provided by the department.	Related to the RESPONSIBILITIES of the department. For example, changes to department routines; changes to managing department responsibilities, changes to sick-leave rates; changes to number of staff needed.
Organisational level	Occurring in relation to the enactment of the organisational vision and goals in changing the mission of the organisation.	Related to the LOGIC of the vision of the organisation. For example, changes in emphasis on care, costs, time or data; changes to organizing principles such as managerialism vs collegialism.

3.4.1 Data coding process

Operationally, the analytical process proceeded through three stages:

(1) case-level summaries through affordance gap matrices in which each researcher responsible for coding material from a case were asked to, based on the completed coding of a case, fill out an analytical matrix that mapped intended and actual affordance across levels, what the gap was at each level and which practices that constituted the gaps.

(2) cross-case comparison in which the case specific matrices were compared, and patterns, regularities and descriptions were mapped and put together as analytical tables (see section 4 of this report).

(3) theorising/framework development in which the analytical results were put in relation to extant literature and the first conceptual framework and developed into section 5 of this report.

To move from rich, locally situated case accounts to a cross-case argument, we developed a shared case summary format that we call the affordance gap matrices. This pipeline makes the affordance gap matrices a key methodological bridge as they stabilise complex qualitative material into a comparable representation across cases without reducing analysis to frequency counts alone. NVivo matrix coding queries were helpful in cross-tabulating coding dimensions (e.g., intended vs actual by level and topic), supporting systematic comparison while preserving traceability back to empirical excerpts.

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Each case matrix consolidates the core empirical claims into a comparable format, specifying intended and actual affordances, the gap between them, and the practices and conditions through which the gap is constituted. The matrices are structured by the project's five levels of analysis, enabling comparison that keeps organisational dynamics in view rather than reducing findings to interface-level usability issues.

The matrices function as an analytic hinge. They preserve traceability to each case while making it possible to ask consistent comparative questions across heterogeneous technologies and settings. This supports the cross-case patterns reported below: which gaps recur at particular levels, where they concentrate, how they travel across levels, and what kinds of remedial levers are plausible at different parts of the organisational system. In this way, the results that follow do not treat cases as examples to be summarised, but as empirical instances through which more generalisable organisational mechanisms of (mis)alignment become visible.

3.4.1 Cross-case synthesis and theorisation

The cross-case synthesis is oriented toward two outputs: (1) a revised Human–Technology Skills Framework grounded in observed patterns of affordance gaps and their constitutive mechanisms, i.e. this deliverable, and (2) structured inputs to the Human-Technology Skills Complementarity Index (the following deliverable, D2.3). The cross-case logic is explicitly level-based: gaps are compared across task, role, team, department, and organisational levels, including attention to whether gaps are primarily material/technical at certain levels or more discursive/strategic at other levels, and whether gaps are bridged through emergent practice (e.g., workarounds, informal learning, local reconfigurations) or remain persistent.

3.5 Research ethics, consent, and data governance

Given the healthcare setting, we prioritised ethics and compliance throughout case onboarding. Ethical clearance and local approvals were required before observations and interviews commenced, and staff were informed about the study aims, scope, and implications of researcher presence in clinical work.

Participation was voluntary; interviewees received written information and provided written consent, with an explicit right to withdraw without providing a reason.

The scope of TechConnect is deliberately focused on staff roles involved in technology use, development, procurement, implementation, and maintenance. Patients were outside the scope of the study and were not interviewed or directly observed. Data protection procedures emphasised minimising sensitive personal data; interview transcripts and observation accounts were anonymised, with potentially sensitive content removed during anonymisation. Observation notes and interview transcripts were translated into English for shared cross-case analysis, while pseudonym lists were maintained locally. Only anonymised materials were uploaded to the shared secure repository, and researchers were instructed to securely destroy original handwritten notes after project delivery.

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4 Mapping affordance gaps, constituting practices, cross-level dynamics and bridging skills

This section reports the cross-case synthesis of where intended and actual affordances diverge, how those divergences are constituted in practice, and what they imply for sustaining complementarity over time. The findings are presented according to how the analysis has proceeded; first we describe affordance gaps as they appear per level (task, role, team, department, organisation). Based on this we present a typology of affordance gap types. Then we identify the constituting practices bridging the gaps and the cross-level dynamics, i.e. how affordance gaps are related across levels. Following on from these analytical steps, we are able specify which types of skills are required to perform the bridging work that is necessary to the different affordance gap types, and what the organisational outcomes are when these skills are brought to use.

The illustrative examples in this section are deliberately general and anonymised to protect the people, technologies and organisations where they were first studied: they are included to clarify the mechanisms evidenced in the matrices, not to identify or showcase particular cases.

4.1 Level-specific affordance gaps

Task-level gaps are commonly constituted by material/infrastructural issues related to integration of technology in the performing of particular tasks, usability, data quality, device management, and by the micro-adjustments required to 'make the system work' in real time. Across cases, intended efficiency gains are frequently undermined by the need for additional documentation, parallel systems, and reliability issues. To bridge the affordance gaps, bridging mechanisms are developed; often taking the form of workarounds, such as the development of paper lists, manual checks, or shadow spreadsheets, and the mobilization of tacit operational know-how.

In one case, a digital documentation tool was introduced to speed up clinical notetaking by converting speech to text and reducing reliance on manual transcription. In day-to-day use, the tool produced many small errors (medical terms, numbers, inflections) and occasionally misplaced text, with the consequence that clinicians spent substantial time correcting output and double-checking critical details. Because integration with existing record systems was partial, staff sometimes dictated into the tool's own text field and then manually copied or re-entered content elsewhere. Over time, users developed 'selective use' strategies (e.g., using the tool for longer notes but reverting to typing or other routines for short entries), which enabled them to perform the work but limited the intended efficiency gains.

A similar pattern occurred with a sensor-driven positioning/verification tool intended to improve precision and safety in a clinical procedure. Although the system provided numerical and visual feedback, staff experienced inconsistencies and missing cues, leading to distrust and routine manual double-checking. Workarounds included restarting sequences when critical confirmation steps were missed, using simple physical reference measurements, and adjusting patient set-up

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based on tacit know-how rather than system suggestions. Here, the intended automation of precision became an additional layer of work that required vigilance, troubleshooting, and judgment about when (not) to rely on system outputs.

Role-level gaps frequently manifest as shifts in responsibilities, changed accountability relations, and tensions around professional judgement. Technologies may redistribute coordination and 'data work' onto clinicians or administrative staff, create new intermediary roles (e.g. superusers), or require advocacy work to enrol patients and colleagues. Informal learning and role negotiation are recurrent gap bridging practices, but they can also generate inequities in workload and recognition.

A common role-level dynamic was the uneven adoption and shifting of administrative burden. A tool intended to 'free up' clinicians' time, for example, redistributed correction, formatting, and troubleshooting onto frontline staff. Some professional groups experienced this tool as a net burden and preferred the old, established routines, while others found the new technology beneficial for specific writing-intensive tasks. In the absence of structured training, local managers and a small number of experienced users emerged as an informal support group, creating dependencies and uneven competence across roles and seniority.

Another role-level dynamic involved the concentration of expertise in intermediary roles such as 'superusers' and technical specialists. Where vendor support or service agreements were limited, technical staff carried high responsibility for keeping equipment operational, often relying on specialised training and extensive overtime. Frontline clinicians, meanwhile, learned through prolonged on-the-job experience and informal peer support. The result was a fragile capability distribution: high dependence on a few individuals, long onboarding times for newcomers, and persistent variation in confidence and trust in automated functions.

Team-level gaps cluster around coordination and shared situational awareness. Digital tools can simultaneously make work performed by team members visible to the rest of the team, while also introducing friction amongst team members when assumptions about information completeness, timeliness, or responsibility do not align. Team-level affordance gaps are often discursive (interpretation, trust, accountability) and entangled with power dynamics (whose knowledge 'counts' and whose work expands – and whose doesn't).

In one case, a new digital contact channel was expected to strengthen team responsiveness and shared responsibility for incoming work. While teams did collaborate closely on high-risk or complex situations, everyday coordination became more segmented once dedicated 'channel shifts' were introduced (e.g., one person monitoring the channel while others focused on in-person work). Because the digital channel was not fully aligned with existing communication systems, staff had to juggle multiple interfaces, which increased the risk of duplicated work and made it harder to maintain a shared overview of who was handling what.

Another team-level example involved technologies whose performances depended on environmental conditions (noise, shared workspaces, device availability). Teams developed local

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conventions such as 'quiet zones', informal rules about when to use the tool, and peer coaching to help each other manage errors. These practices improved local usability but also revealed that 'successful use' relied on collective coordination and shared norms, not just individual competence or interface design.

Department-level gaps often centre on routinisation and capacity: staffing, scheduling, time allocation for learning and troubleshooting, and the fit between departmental workflows and the configuration of the technology. Where departments lack slack resources, intended benefits can translate into intensified work and 'implementation fatigue'. Departmental strategies that support bridging include allocating protected time for training, stabilising roles, and clarifying protocols.

In one case, a department introduced a digital scheduling and workflow tool intended to optimise capacity by learning task durations and flagging overbooked or underutilised lists. In practice, operational pressures (e.g., staffing shortages and downstream capacity constraints) meant that the system mainly afforded visibility rather than reliable actionability. Scheduling decisions still relied on phone calls, local spreadsheets, and informal negotiations across units. When the tool was expanded from a small pilot to a more complex environment, inconsistencies and workflow misfits led to a temporary pause and a return to parallel routines.

A related department-level pattern appeared in quality-control and tracking systems intended to standardise routines across instruments or mobile assets. While the technology enabled measurement and documentation, departments had to calibrate thresholds and protocols locally due to budget constraints, availability pressures, and divergent clinical expectations. Where dashboards were not sufficiently aggregated or actionable, staff supplemented the system with manual status categories and periodic review meetings. Some units bypassed formal request routes when these were slow, creating shadow channels and uneven standardisation.

Organisational gaps frequently involve benefit-realisation narratives (e.g. 'digitalisation', 'data-driven care') that, however, are weakly aligned with local practice realities. These gaps also involve governance arrangements that do not adequately support integration, data quality, and accountability. Organisational-level gaps are often hybrid: they combine discursive elements (strategic framing, legitimacy, professional values) with infrastructural decisions (platform strategy, procurement, interoperability). Persistent gaps are likely when organisational priorities emphasise adoption metrics over sustained capability building.

In one case, an organisation introduced a digital patient contact and remote-monitoring service with the strategic aim of increasing accessibility, reducing routine visits, and lowering reliance on phone-based coordination. While it improved reach, workload reductions did not materialise because the service was only partially integrated with other core systems, creating duplicated contacts and manual bridging work (e.g., staff re-entering information in other systems). Scaling was constrained by the absence of stable funding for maintenance and by limited staffing for monitoring and triage, leaving advanced functions planned rather than deployed.

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A second case concerned organisational adoption of advanced clinical technologies framed as a visible commitment to innovation and personalised, high-quality care. Local teams used these tools for sophisticated planning and decision support, but the organisation struggled to justify costs and standardise use in the absence of clear outcome metrics and agreed indications. Procurement choices also produced a heterogeneous technology environment, increasing training burden and reliance on a few experts: limited training licences further constrained diffusion. The result was symbolic alignment with strategy alongside uneven operational capability.

Across cases, some gaps are partially bridged through practice: staff develop local routines, informal training, and workarounds that stabilise technology use. However, such bridging is fragile and can conceal structural issues. Gaps tend to persist (in the sense that we don't find any bridging practices) when they are rooted in (a) infrastructural misfit and interoperability challenges, (b) unresolved governance around data quality and accountability, and (c) resource allocation that does not match the expanded 'invisible work'.

4.2 Typology of affordance gaps

To support cross-case comparison and skills mapping, we synthesise the affordance gap matrices as shown in the previous section into a working typology of affordance gaps (see Table 3). The purpose of the typology is pragmatic rather than taxonomic: it helps us name what kind of misalignment is at stake when intended affordances (e.g. efficiency, access, safety, standardisation) do not materialise as expected in practice. The typology functions as a comparative "lens" that keeps the systems perspective intact: the same local breakdown can be experienced as extra work (efficiency gap), contested judgement (identity gaps), coordination ambiguity (coordination gaps), weak governance/benefit realisation (strategic gaps), or infrastructural misfit (material/technical gaps)—and often as a combination. The categories are therefore not mutually exclusive, and single gaps frequently contain multiple dimensions. We use the typology to foreground the dominant mechanism(s) through which misalignment becomes consequential and through which bridging work (workarounds, informal learning, boundary spanning, etc.) is mobilised.

Table 3. Affordance gap typology

Gap type	Definition	Empirical examples
Efficiency gaps	Technologies intended to save time, reduce workload, or streamline processes, but in practice generate additional work (e.g., parallel documentation, new	**(1)** An AI-enabled documentation tool is introduced to speed up notetaking, but clinicians spend substantial time correcting outputs and "moving" text between systems; secretarial/peer quality checks

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	monitoring tasks, increased communication volume).	remain necessary, so work is duplicated rather than removed. (2) A patient-facing messaging/triage channel is expected to reduce phone calls but produces "double contacts" (message + call), constant chat inbox monitoring, and longer interactions when cases must be clarified or escalated.
Identity gaps	Technologies reshape professional scope, discretion, or accountability in ways that are contested or weakly supported (e.g., role drift, unclear boundaries between clinical and technical work, tensions around professional judgement).	(1) A decision-support or quality-control system produces outputs that become treated as quasi-authoritative; staff develop informal rules for when to override it, but responsibility for errors becomes ambiguous ("is it my judgement or the system's?"). (2) New systems create informal "hybrid" roles (superusers/translation brokers) who end up doing troubleshooting, training, and vendor/IT liaison work alongside clinical duties—often without clear recognition, protected time, or a stable role definition.
Coordination gaps	Technologies expected to improve collaboration and shared situational awareness instead create ambiguity around responsibility, interpretation, handover, and communication channels.	(1) A shared dashboard is meant to provide real-time overview, but teams disagree about who updates/validates data; handovers become contested when information is incomplete or delayed, prompting parallel "shadow" coordination tools (whiteboards/spreadsheets). (2) Digital referral/messaging makes cross-unit coordination possible but also multiplies channels and routing work; staff spend time chasing responses and translating information between professional groups, often reverting to phone calls for urgent alignment.

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Strategic gaps	Organisational narratives and governance (e.g., “digital-first”, “data-driven care”) are insufficiently aligned with local conditions, resources, and professional logics; issues often involve benefit realisation, prioritisation, standards and quality thresholds.	(1) A “digital access” initiative is rolled out with strong expectations of efficiency and reach, but without matching staffing models, escalation pathways, or clarity on what counts as acceptable response times; adoption metrics look good while workload and stress increase on the ground. (2) Platform/procurement strategies aim for standardisation, but legacy heterogeneity persists; departments absorb integration and change costs, leading to fragmentation, implementation fatigue, and a sense that “digitalisation” is something done *to* them rather than *with* them.
Material/technical gaps	Gaps primarily constituted by material properties of systems/infrastructures: interoperability, reliability, usability, configuration, data quality, device constraints.	(1) Interoperability constraints mean a platform cannot exchange data cleanly with core systems; staff compensate through manual exporting, copy/paste routines, and re-entry—creating data-quality risks and undermining trust in the “single source of truth.” (2) A sensor-based measurement tool is introduced to improve precision and safety but produces inconsistent readings or lacks key accessibility/usability features; staff restart systems, use manual measurement “tricks,” and rely on tacit judgement to decide when to trust the numbers.

Across the cases, affordance gaps almost never sit neatly at one “level” of work. A problem that looks local—an annoying extra step, a workaround, a missing function—often traces back to earlier choices about procurement, integration, staffing, training, or how success was defined in the rollout. And the other direction matters just as much: when the same small breakdowns keep happening, they start to add up into queues, rework, uneven competence, and eventually questions for managers about risk, accountability, and whether the system is delivering what was promised.

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Just as importantly, gaps tend to *change form* as they move. A technical limitation can quickly become a coordination headache because people have to reorganise handovers and double-check information. A "timesaving" promise can turn into a role problem when staff end up monitoring, documenting, and troubleshooting instead of doing their core work. And when coordination remains unclear for long enough, it often becomes a governance issue about standards, responsibility, and what counts as acceptable performance. This is why fixing a gap in one place can sometimes just push the work somewhere else rather than remove the underlying problem. Taking measures to "solving" a gap on one level may thus shift it elsewhere rather than eliminate it. In our framework, we conceptualise this as displacement into invisible work, or "low complementarity."

4.3 Constituting practices

Affordance gaps are not only "problems" or shortfalls relative to intended affordances; they are also accomplished and stabilised through situated practices, as illustrated in Table 4 below. In the table, the "constituting practices" column is where the socio-material mechanics become most visible: how people make technologies workable, how gaps are temporarily bridged (or displaced into invisible work), and how new skill demands and organisational dependencies emerge in the process. *These practices therefore function as comparative mechanisms across heterogeneous cases, helping us explain why the same kind of technology can produce very different outcomes depending on local routines, infrastructures, and governance arrangements*.

Table 4. Constituting practices of affordance gaps

Constituting practice	Definition	Empirical examples
Workarounds	Local, improvised or routinised "patches" that compensate for missing functionality, unreliable flows, or workflow misfit—often sustaining continuity while creating new risks (e.g., version control, accountability drift).	(1) Staff maintain parallel artefacts (paper lists, ad hoc logs, manual "status" categories) because the system lacks search/filtering, prioritisation, or reliable overview—then reconcile back into the formal system later. (2) When outputs are error-prone or non-integrated, users routinely copy/paste between interfaces, re-enter data, restart sequences, or perform manual double-checks/measurements to ensure safety and correctness.

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Tacit knowledge mobilisation	The situated know-how needed to interpret, compensate for, and safely act on partial or ambiguous system outputs—often learned through experience rather than formal training.	(1) Users develop a practical sense of *when to trust* the system (and when to override it), including interpreting signals that "look right" versus those that require manual verification or escalation. (2) Staff learn local "routing competence": how to push cases through bottlenecks, translate categories to fit system logic, and sequence tasks to avoid lockouts or downstream errors—knowledge that is rarely written down but crucial for flow.
Resistance and contestation	Pushback, critique, or negotiation around technology use and its implications—often grounded in patient safety, workload, professional autonomy, or perceived misalignment between design assumptions and practice.	(1) Clinicians selectively avoid or downgrade use of a tool (e.g., reverting to established routines for complex cases) because they judge system outputs as unreliable or because the new channel creates uncontrolled demand/duplication. (2) Teams and middle managers contest configuration choices and responsibility boundaries (e.g., who must validate data, what quality thresholds are acceptable, which role "owns" troubleshooting), raising issues to IT/vendor/leadership or renegotiating protocols locally.
Emotional responses	Affective reactions (stress, frustration, relief, resignation) that shape willingness to engage, capacity to learn, and the "temperature" of coordination—often acting as an early warning signal of misfit.	(1) Frustration and fatigue grow when technologies introduce extra steps under chronic time pressure (e.g., repeated manual corrections, slow registration, queue juggling), reducing experimentation and increasing reliance on shortcuts. (2) Relief and regained control appear when a tool provides a shared reference point or more objective visibility—yet this can coexist with stress if the tool adds

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		monitoring burdens or increases accountability pressure.
Informal learning	Peer-to-peer training, superuser support, ad hoc experimentation and "tips-and-tricks" that fill gaps left by formal rollout—strengthening local capability but often producing uneven competence and key-person dependencies.	(1) Informal trainers emerge (enthusiasts, unit managers, experienced staff) who coach colleagues, share templates/checklists, and stabilise workarounds into a "normal way of working," especially when official training is brief or absent. (2) Capability becomes uneven across shifts and roles: newcomers learn by shadowing and trial-and-error; a small group becomes essential for troubleshooting and vendor/IT liaison, making routines brittle when those individuals are absent.

As the table illustrates, local workarounds (paper lists, manual double-checking, shadow spreadsheets) commonly compensate for missing functionality, inadequate training or unreliable data flows. While they may sustain service continuity, they can also create new risks (version control, accountability) and hide systemic issues. Effective use frequently depends on experiential knowledge: knowing when to trust system outputs, how to interpret partial information, and how to route cases through 'the system' given local constraints. Tacit know-how becomes a critical complement to formal training.

Resistance is often rational rather than 'anti-technology': it can express concerns about patient safety, workload, or professional autonomy. It can also reflect experiences from previous implementations of new technologies, or of implementation fatigue. Contestation also appears in negotiations with vendors, ICT units, and management regarding configuration and responsibility. However, this is not to say that resistance does not also occur simply as a desire to sustain existing skills, practices, professional boundaries and power relations. Emotions (stress, frustration, relief) are not incidental: they shape adoption trajectories and learning willingness and can signal misalignments between technology demands and lived work conditions. Peer learning and ad hoc training—often organised by superusers or enthusiasts—frequently fill gaps left by formal rollout. Informal learning can be a strength but may also make capabilities uneven across staff and shifts. The introduction of new technologies can also disturb existing informal learning and support arrangements.

4.4 Bridging work and mapping gap types to skill domains

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When affordance gaps occur, attempts are made to close them through what we call *bridging work*. It is by looking closely at the practices and features of bridging work that we can tease out which skills are needed to make humans and technologies complement each other in actual organisational life and what must change for that bridging to become *sustained mitigation* and "good complementarity" rather than compensatory "low complementarity."

Here, *skills* are not treated as individual attributes that can simply be "added" through training; they become effective only when organisational arrangements—roles, routines, infrastructures, governance, and time—enable them to be enacted reliably. Table 5 below should therefore be read as a translation device that links dominant affordance gap types to (i) the skill types that become salient in practice, and (ii) the organisational outcomes that may emerge when these skill types are enacted in practice, and that are needed to institutionalise the bridging of the affordance gaps.

Table 5. Types of skills required to perform the necessary bridging work in relation to different affordance gap-types, and organisational outcomes

Dominant affordance gap-type	Bridging Work	Types of skills	Organisational outcomes & enabling conditions
Efficiency gaps	Re-sequencing routines; exception-handling; safe improvisation; prioritising and time-boxing digital queues; identifying and reducing rework; documenting "good enough" fixes	Adaptive work reconfiguration competence (primary) + Reflective learning & improvement competence (secondary) + Affective regulation & sustainable work competence (secondary)	Workflow redesign to remove duplication; protected time/slack during transition; measure displacement (rework, double contacts, manual checks); formalise safe workaround protocols or eliminate root causes; capacity planning aligned with new work
Identity gaps	Documenting judgement and overrides; boundary negotiation; escalation/consultation practices; articulating concerns about autonomy/safety; managing hybrid tasks	Strategic translation & governance competence (primary) + Interprofessional coordination competence (secondary) + Affective regulation & sustainable work competence (secondary)	Clarify accountability and decision rights; explicit override/escalation pathways; recognised broker/superuser roles with protected time; governance for safety-critical judgement; structured arenas for

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	(clinical/technical/administrative)		contestation so tensions become learning not silent refusal
Coordination gaps	Closed-loop communication; handover scripting; triage and routing; maintaining shared situational awareness; channel selection and prioritisation; resolving interpretation disputes	Interprofessional coordination competence (primary) + Digital systems & data competence (secondary) + Reflective learning & improvement competence (secondary)	Routinise coordination (ownership for data updates, handover rules, escalation thresholds); reduce channel proliferation or define channel rules; align staffing/shift patterns with coordination load; cross-unit forums where dependencies are strong
Strategic gaps	Translating local workability into requirements; benefit-realisation sensemaking; negotiating standards/thresholds; prioritising investments; aligning metrics with practice realities; vendor/IT dialogue competence	Strategic translation & governance competence (primary) + Reflective learning & improvement competence (secondary) + Interprofessional coordination competence (secondary)	Govern for workability not rollout: feedback loops from frontline signals into strategy; KPIs that don't reward superficial adoption; fund infrastructuring (integration, support, data stewardship); clear decision rights for iteration; vendor governance that supports reconfiguration over time
Material/ technical gaps	Troubleshooting; recognising failure modes; data provenance checking; safe fallback routines; interpreting uncertain outputs; configuration use (templates/ fields/filters); incident reporting	Digital systems & data competence (primary) + Adaptive work reconfiguration competence (secondary) + Reflective learning & improvement competence (secondary)	Treat reliability/integration as first-class work: interoperability and data quality governance; configuration authority close to practice; device availability/maintenance routines; incident/near-miss learning loops; service agreements matched to criticality; training on limits

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			and safe workarounds (not only features)

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5 Human–Technology Skills Framework II

Having outlined the results of the analysis in section 4 through the steps of describing affordance gap types; identifying constituting practices that bridge the gaps; the cross-level dynamics; and – finally – the skills' types required to perform the bridging work necessary, in this section we synthesise the findings into a revised Human-Technology Skills Framework (see Figure 2).

Moving beyond the descriptive mapping that was the core of the first Human-Technology Skills Framework (D1.1), the conceptual framework presented here focuses explicitly on the affordance gaps, and divergences between intended and actual use. Thereby, it redefines the relationship between levels, conceptualising these not just as a hierarchy within the organisation, but as a system of constituting practices (such as workarounds, boundary spanning, and informal learning). As described above, these practices constitute what we call "bridging work" since they are needed to actively bridge affordance gaps. Where the initial framework of D1.1 conceptualized Human-Technology Skills Complementarity as a goal or "synergy", the revised framework presented here treats it as a fragile, emergent accomplishment that depends on specific bridging mechanisms mobilized to prevent the displacement of burden into "invisible work" or "bad complementarity".

Figure 2 illustrates the project's conceptual framework, visualizing Human–Tech Skill Complementarity not as a static fit between a user and a tool, but as an emergent property of a broader organisational system.

System Dynamics (Top Block): At the core of the framework is a recursive system of five levels: Task, Role, Team, Department, and Organisation. These levels are mutually constitutive; organisational strategies shape task possibilities, while local task realities bubble up to influence team and departmental routines. It is within these system dynamics that the "rules of the game" for technology use are established.

Affordance Alignment (Centre): The framework posits that complementarity depends on the alignment between Intended Affordances (the design expectations and rationales) and Actual Affordances (the situated utility achieved in practice). The vertical arrows cascading from the system dynamics block indicate that this alignment is heavily filtered and shaped by the organisational environment—it is not purely technical.

Divergent Pathways (Bottom Branches): The degree of alignment produces two trajectories along a continuum of complementarity:

- Low Complementarity (Misalignment): When affordance gaps persist, the system defaults to "bridging work" (e.g., workarounds, shadow systems) and compensatory labour. This results in lost value and unintended skill demands (e.g., invisible data cleaning) rather than productive capacity.
- High Complementarity (Alignment): When the system supports alignment, the result is "emergent value" and a genuine fit between human skills and technological capabilities,

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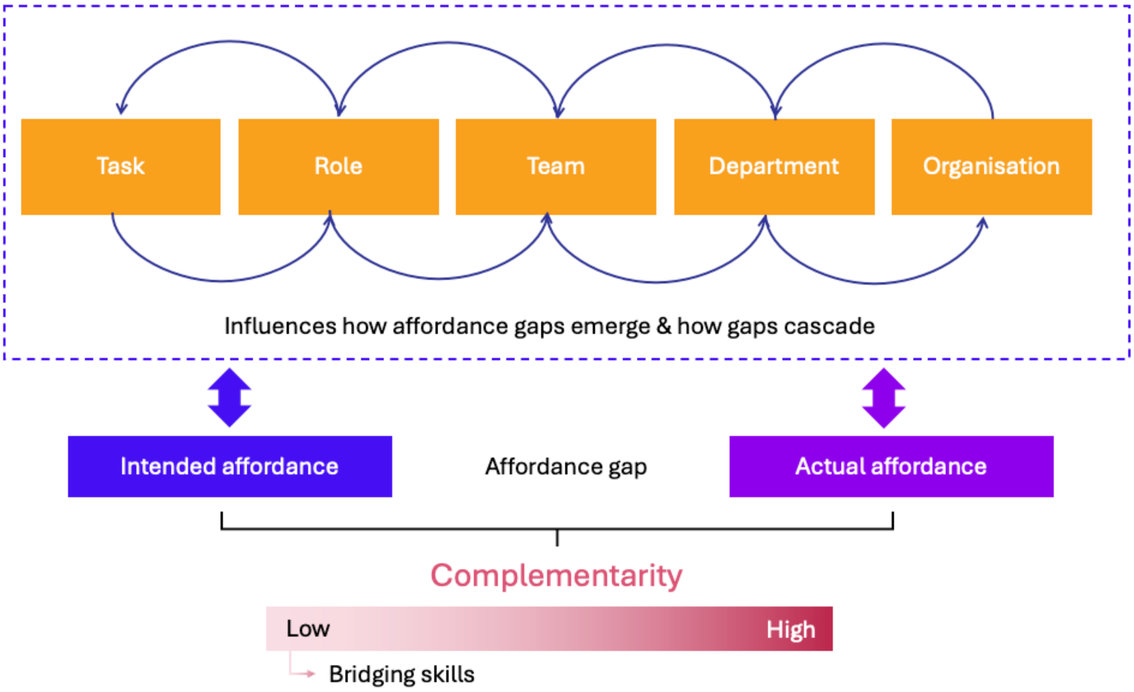
allowing for sustainable work practices and allowing professional judgement and organisational routines to function without being displaced by compensatory labour.

Figure 2. Human-Technology Skills Complementarity Framework II



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6 Conclusions and practical implications

This deliverable set out to move beyond “human skills vs technology” framings by showing *how* Human-Technology skills Complementarity is produced (or undermined) through the alignment of intended and actual affordances across task, role, team, department, and organisational levels. The results and revised framework converge on a clear message: complementarity is rarely decided by a single interface feature or a single training session; it is a fragile, cross-level accomplishment that depends on whether organisations recognise, resource, and govern the *bridging work* that inevitably arises when technologies meet healthcare work as performed in daily life.

Two key actionable insights emerge from this:

First, in the bridging work performed, different skill-types are continuously mobilized by staff to close affordance gap: skills of improvisation, self-management as well as of practical wisdom and prudence.

This points to the importance of human professionality, expertise and experience, also in contexts where work becomes increasingly digitalised. Our studies show that affordance gaps are systematic rather than exceptional. They recur across heterogeneous technologies because they emerge from recurring socio-material mechanisms: partial integration and data fragility; redistributed “invisible work” and administrative burden; contested judgement and accountability; and coordination frictions amplified by staffing pressure and multi-channel workflows. These mechanisms also explain why gaps often cascade: what begins as a material/technical limitation at the task level can become a coordination problem at the team level, a role/accountability contestation at the role level, and eventually a governance and benefit-realisation issue at departmental and organisational levels. The importance of humans cannot be underestimated.

Second, persistent affordance gaps are rarely solvable at the same level where they are first experienced or identified.

When frontline teams compensate through workarounds and tacit know-how, services may continue to function, but often by shifting costs into invisible labour, key-person dependencies, uneven capability, and heightened stress (“low complementarity”). Conversely, when organisations convert gap signals into cross-level alignment work—investment in integration, routinisation, governance, protected learning time, and boundary-spanning roles—bridging practices become less heroic and more sustainable (“high complementarity”).

For organisations to be successful in digitalising operations the implementation of digital technologies should not only be seen as a matter of training the users but one of creating a context in which conditions are enabled through which the responses to bridge affordance gaps are institutionalized. Only by creating such conditions will the organisation gain the full value of the adopted technology.

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APPENDIX I – system analysis: coding instructions and scheme

This appendix documents the analytical approach, coding structure, and coordination procedures used in Task 2.4, including the operational guidance provided to research teams during implementation.

The system analysis (T2.4) is a task in WP2 that is supposed to result in a new/revised Human-Technology Skills framework (D2.2). More specifically, this framework will build on the reporting of the affordance gap between intended and actual affordances in the different cases of the TechConnect-project. To produce this, we will be performing analyses on the empirical material produced in all the case studies of the project.

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1 Analytical approach

Our analytical approach for analysing the case studies will be abductive (Dubois & Gadde, 2002). An abductive approach to qualitative case studies, particularly when employing ethnographic methods, offers a dynamic and iterative mode of theorizing that contrasts with both inductive and deductive reasoning. As Dubois and Gadde (2002) argue, the abductive approach allows researchers to move back and forth between empirical observations and theoretical constructs, enabling a continuous refinement of both data and theory. This approach is especially valuable in ethnographic research, such as the one used for the TechConnect case studies, where rich, contextualized data emerge from prolonged engagement with the field. Rather than starting with a fixed theoretical framework or allowing theory to emerge solely from data, abduction encourages a "systematic combining" process in which the empirical world and theoretical insights co-evolve. This makes it possible to generate novel understandings of organizational phenomena that are deeply grounded in practice while also being theoretically informed.

In ethnographic case studies, abductive reasoning facilitates the development of what Dubois and Gadde term a "matching" process between the evolving results from the case study and the theoretical framework. This process is not linear but recursive, involving recurring iterations between the narratives of the case, the conceptual framework, and the empirical field. The researcher's role becomes one of navigating amongst these elements and negotiating between them, thereby often revising initial assumptions and theoretical lenses as new insights emerge in the process. This makes abductive analysis particularly suited for studying complex, situated practices within organizations, where meanings and actions are often fluid and context dependent.

Translating this to the context of the TechConnect-project, we will perform the analysis influenced by theory by drawing on the work of, for example, Stephen Barley (2020), who argues that technology affects organisations in several dimensions (tasks, roles, teams, and organisations), and by empirics, by being open to new insights that have emerged during fieldwork (expressed, for example, in our Monday meetings) and by going back to the data (interview transcripts, observation notes and collected documents).

In practice this means that our analysis will draw on the Researcher Guidelines (D1.3, Annex 2), which were formed based on literature and on the theorising in which the TechConnect research group has engaged jointly during the weekly Monday fieldwork meetings.

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2 Theoretical background

To fully understand technological affordances at different organizational levels, it is essential to systematically code for a range of topics that capture both the intended and actual dynamics of technology in practice. The coding of managerial intentions and stakeholder expectations allows us to trace the strategic and sociocultural narratives that underpin technology procurement and introduction, revealing how organizational leaders and other actors envision and legitimize technological change (Barley, 2020; Leonardi et al., 2012; Orlikowski, 1992). By examining the frequency of use and use-in-practice, we will gain empirical insight into how technology becomes embedded in everyday routines, which affordances are realized through human-technology interaction, and how human agency interacts with material artefacts in situ (Feldman & Orlikowski, 2011; Gherardi, 2012).

Furthermore, topics such as workarounds and novel usage are crucial for identifying affordance gaps and emergent practices, highlighting how users creatively adapt or innovate with technology beyond its original design assumptions (Barley, 2020; Suchman, 2007). Staff appreciation provides a window into the affective and attitudinal dimensions of technology adoption, which can significantly influence acceptance and use at both individual and collective levels (Mol, 2008). Accommodating practices and technical accommodation, meanwhile, illuminate how work practices and technical infrastructures are reconfigured to integrate technology, emphasizing the dynamic interplay between social and material arrangements (Andersson et al., 2021; Orlikowski, 2008; Suchman, 2012).

Additional topics such as resistance and contestation, tacit knowledge and informal practices, material constraints and enablers, learning and skills development, and ethical and legal considerations, further enrich the analysis. These dimensions expose tensions, invisible work, infrastructural conditions, learning processes, normative frameworks, and the evolving nature of affordances, all of which are central to a nuanced, sociomaterial understanding of technology in organizations (Gherardi, 2010, 2012; Mol, 2008; Orlikowski, 1992).

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3 The coding work

3.1 Time plan and data

Between mid-October and end of December 2025, each Academic team will be responsible for coding all data from the three case studies performed in the hospital in their country. "All data" refers to interview transcripts, observation notes, documents, and – if relevant and possible – also visuals, such as photos taken or drawings made during fieldwork.

3.2 Software and data security

The coding will be performed in NVivo. Please note that we will not work with NVivo's Collaboration Cloud. Instead, all researchers will use local licenses for the coding. Consequently, each individual researcher is responsible for ensuring that the hardware used is kept secure, and that data is managed according to the Data Management Plan.

After completing the coding for each case, the complete file should be uploaded to SUNET in the correct case study folder.

3.3 Coding

In practice, the coding work means going through all data (observation notes, interview transcripts, documents and potentially visuals) for each case, looking for indicators in line with the coding scheme outlined in tables 1-3.

The coding scheme uses three aspects that the empirical material should be coded from: Intended or actual affordance, Affordance levels, and Topic. In tables 1-2 below we provide a definition of intended/actual affordances and provide illustrations of where they may be found in the material, and what indicators could be. Table 3 provides the topics and a brief description of each topic along with a suggestion of how they most probably will be coded.

Please note that the suggested codes are not exhaustive and there might be combinations of affordance type, affordance level and topic that are not anticipated in the table. In the end, it is each researcher that is doing the coding that assesses what is the most appropriate way to code a string of empirical material.

Table 1. Affordance types

Affordance type	Definition	May be found in, for example
Intended	Pre-formulated ideas and intentions about the usage and utility of technologies	Procurement documentation, implementation plans, project plans, managerial decisions, resource allocations, business case, training material, vendor material

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Actual	In-situ actual usage and utility of technologies	Direct observation of technology use, organisational evaluations, signs or notes, technical modifications, frequency of use, staff experiences of use

Table 2. Affordance levels

Level	Definition	Indicators
TASK LEVEL	Occurring between tech and humans in relation to a particular task. Related to the changing of the performing of a particular task.	Related to the DOING of the task. For example, more or less human intense/staff required to perform a task; a task more or less time-consuming; the need for new/different practices to be developed on task-level; the need for humans learning new things, developing different competences; the diminishing of human interaction in the performing of a task.
ROLE LEVEL	Occurring between tech and humans in relation to the performing of a professional role. Related to changing the job of the professional more broadly (not simply a particular task).	Related to the PROFESSIONAL IDENTITY of the professionals and the PERFORMING OF THE PROFESSION. For example. the logic of the technology in relation to the professional; the language of the technology vs the language of the professional; the degree to which the tech threatens the professional identity.
TEAM LEVEL	Occurring as tasks are performed with tech between professionals who collaborate in teams. Related to the changing the interaction of the team when they jointly perform a task.	Related to the COLLABORATION amongst people. For example, the degree or type of interaction amongst members of staff working together; the changing power-balance amongst people working together to deliver some sort of service to the patient.
DEPARTMENT LEVEL	Occurring in relation to the performing of department routines. Related to the changing in the delivery of the service	Related to the RESPONSIBILITIES of the department. For example, changes to department routines; changes to managing department responsibilities, changes to

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	provided by the department.	sick-leave rates; changes to number of staff needed.
ORGANISATIONAL LEVEL	Occurring in relation to the enactment of the organisational vision and goals in changing the mission of the organisation.	Related to the LOGIC of the vision of the organisation. For example, changes in emphasis on care, costs, time or data; changes to organizing principles such as managerialism vs collegialism.

Table 3. Topic and coding scheme

Topic	Description	Codes	Possible data sources
Managerial intentions	Managerial intentions/expectations/hopes related to how a specific task could be performed differently; to how professional groups may work differently; to how the department will be organised; to the vision and strategy of the organisation or new core capabilities of the organisation.	Intended Managerial intentions Task/Role/Team/Dept/Org	Ethnographic and/or semi-structured interviews Organisational documents
Stakeholder expectations	Expectations/predictions/hopes/fears of stakeholders (including outside groups, professionals, unions, administrative staff, media) of how the technology will change work tasks, professional roles, department organisation or capabilities	Intended Stakeholder expectations Task/Role/Team/Dept/Org	Ethnographic and/or semi-structured interviews Organisational documents Other documentation

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Policy and Regulatory Framing	How legal, ethical, or policy frameworks shape the intended use of the technology. These might include restrictions on use due to legal or ethical concerns or even attempts to change regulations to allow use.	Intended Policy Framing Dept/Org	Ethnographic and/or semi-structured interviews Organisational documents Other documentation
Design Assumptions	Assumptions embedded in the design of the technology about users, tasks, or organizational context. What assumptions do designers seem to have made about the skills of the user, context of use etc?	Intended Design Assumptions Task/Role	Ethnographic and/or semi-structured interviews Organisational documents Other documentation
Anticipated Risks and Mitigations	Risks foreseen during planning and how they are intended to be managed.	Intended Risk Management Team/Dept/Org	Ethnographic and/or semi-structured interviews Organisational documents Other documentation
Frequency of use	How often the technology is used	Actual Frequency Task	Participant-observation
Use-in-practice	Descriptions of actual usage of the technology in-situ. Can include instances in which the technology has been put to use in a novel way.	Actual Use Task/Role/Team/Dept/Org	Participant-observation Ethnographic and/or semi-structured interviews

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Tacit Knowledge and Informal Practices	Instances where technology use depends on or affects tacit knowledge or informal routines.	Actual Tacit Practices Task/Role	Participant-observation Ethnographic and/or semi-structured interviews
Workarounds	Instances in which workarounds are used in order to make the technology useful or fit with work practices	Actual Workarounds Task/Role/Team	Participant-observation Ethnographic and/or semi-structured interviews
Emotional expressions	Verbal or non-verbal expressions of affective responses. Such as frustration, anxiety, enthusiasm, confusion, relief, or pride related to the use, implementation, or presence of the technology. This includes spontaneous emotional reactions, mood shifts, or affective atmospheres observed or described in relation to the technology.	Actual Emotional Expressions Task/Role	
Appreciation	Indications or expressions of positive opinions of the technology. Focuses on positive evaluations of technology (e.g., "This tool is great"), often more cognitive or attitudinal.	Actual Appreciation Role/Team	Participant-observation Ethnographic and/or semi-structured interviews
Contestation	Expressions of negative opinions, resistance, critique, or questioning of the technology or its implementation	Actual Resistance Role/Team/Dept	Participant-observation Ethnographic and/or semi-structured interviews

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Organisational enablers	Changes in formal work practices, organisational arrangements that are made in order to accommodate the new technology. Instances where 'workarounds' have become accepted practice.	Actual Org enablers Role/Team/Dept	Participant-observation Ethnographic and/or semi-structured interviews
Organisational constraints	Instances when established or legacy practices or organisational arrangements constrain the full use of the technology	Actual Org constraints Role/Team/Dept	Participant-observation Ethnographic and/or semi-structured interviews
Material enablers	Technical or material arrangements necessary for the technology to be used. E.g. Back-end technical systems, new infrastructure, etc.	Actual Material enablers Task/Role/Team	Participant-observation Ethnographic and/or semi-structured interviews Organisational documents
Material Constraints	Technical, physical or infrastructural conditions that hinder or constrain technology use	Actual Material constraints Task/Role/Team	Participant-observation Ethnographic and/or semi-structured interviews Organisational documents
Learning and Skill Development	Indications of learning processes or competence development related to technology use	Intended/Actual Learning Task/Role/Team	Participant-observation Ethnographic and/or semi-

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			structured interviews Organisational documents
Ethical and Legal Considerations	Ethical dilemmas, privacy concerns, or legal issues related to technology use.	Actual Legal Task/Role/Team/Dept/Org	Participant-observation Ethnographic and/or semi-structured interviews Organisational documents

3.4 Step-by-step instructions

We suggest that you get acquainted with NVivo before you start coding, for example by looking at on-line tutorials, if you haven't worked in this software before.

Simply put, this is what you do in NVivo to code the empirical material:

(1) Import a document to NVivo and open it there.

(2) Start reading the document and look for instances that says something about topics in table 3. When you find instances of a topic, right-click and choose "Codes". If it's the first time you identify the topic in the material, create a New Code.

   a. In the beginning it might be helpful to have the coding scheme open on a second screen or printed so you can reference it while looking at the material.

(3) Please note for each instance in the data that you code, you need to create codes not only for the topic, but for intended/actual affordances, and for the levels (as indicated in table. Instances of material can be coded as multiple nodes. We also at this stage will only work with first level codes.

(4) In some instances, categories like 'intention' may be difficult to identify directly but can still be 'read off' reliably from other observed phenomena (Uhlin and Ivory, 2005).

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