Applied Interdisciplinary Theory in Health Informatics
P. Scott et al. (Eds.)

doi:10.3233/SHTI190123

The NASSS Framework – A Synthesis of Multiple Theories of Technology Implementation

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Abstract. Technologies are often viewed as the route to better, safer and more efficient care, but technology projects rarely deliver all the benefits expected of them. Based on a literature review and empirical case studies, we developed a framework (NASSS) for studying the non-adoption, abandonment and challenges to scale-up, spread and sustainability of technology-supported change efforts in health and social care. Such projects meet problems usually because they are too complex – and because the complexity is sub-optimally handled. NASSS consists of six domains – the illness or condition, the technology, the value proposition, the individuals intended to adopt the technology, the organisation(s) and the wider system – along with a seventh domain that considers how all these evolve over time. The NASSS framework incorporates a number of other theories and analytic approaches described elsewhere in this book. It is not intended to offer a predictive or formulaic solution to technology adoption. Rather, NASSS should be used to generate a rich and situated narrative of the multiple influences on a complex project; to identify parts of the project where complexity might be reduced; and to consider how individuals and organisations might be supported to handle the remaining complexities better.

Keywords. NASSS framework; complexity of innovations; diffusion of innovation; value proposition; scale-up

Learning objectives

After reading this chapter the reader will be able to:

1. Articulate various individual theories of technology adoption and implementation within a multi-level integrated framework.
2. Draw different theories together to explain the multiple and complex challenges to the adoption, scale-up, spread and sustainability of technology-supported programmes in healthcare.
3. Design an evaluation of a health informatics intervention based on the NASSS framework.

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1. Introduction to the NASSS framework

1.1. Origins and overview of the NASSS framework

Most research into technological innovations has focused on technology development and mapping patterns of adoption, with little attention paid to the systematic study of the *non-adoption* of promising technologies. This chapter introduces an evidence-based framework (abbreviated NASSS) for studying the **n**on-adoption and **a**bandonment of technologies by individuals and the challenges to **s**cale-up, **s**pread and **s**ustainability of such technologies in health and care organizations. The NASSS framework was developed using two parallel processes: a narrative systematic review of theory-informed frameworks for analysing and evaluating technology-supported change programs in health and social care [1], and empirical testing and iterative refining of the NASSS domains using a diverse sample of technology implementation projects, written up as rich mixed-method case studies followed up for (at the time of writing) three years [2].

The NASSS framework is shown in Figure 1. It consists of seven domains, each of which may be simple (few components, predictable), complicated (many components but still largely predictable) or complex (many components interacting in a dynamic and unpredictable way). The more complexity there is in the system, the less likely the technology is to achieve sustained adoption across the system (and the more likely it is to be abandoned). The different sub-domains in the NASSS framework (right-hand panel in Figure 1) can be applied adaptively to produce a nuanced narrative that reveals the different kinds of complexity in the unfolding programme.

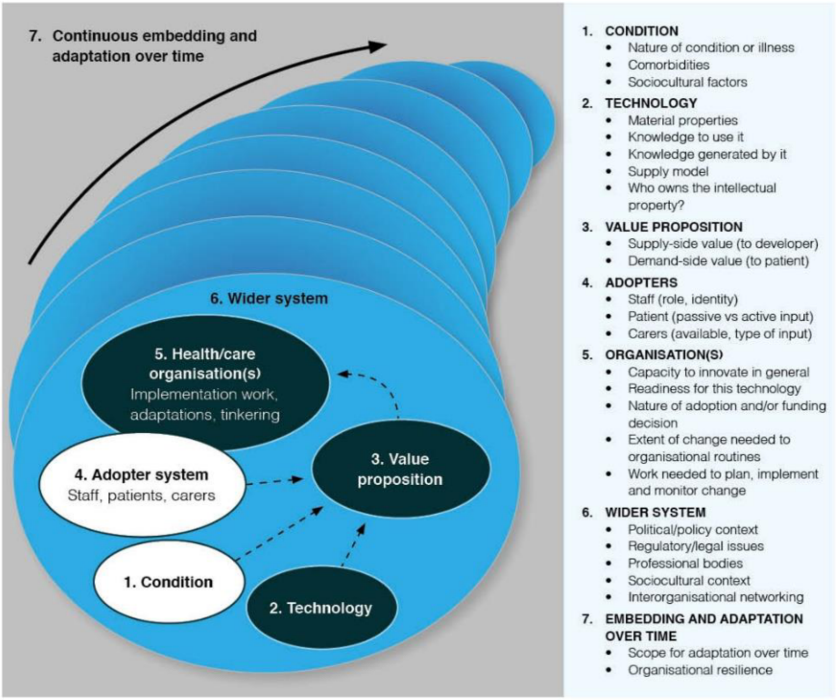

Figure 1: The NASSS framework for studying non-adoption and abandonment of technologies by individuals and the challenges to scale-up, spread and sustainability of such technologies in health and care organisations (adapted from Greenhalgh et al [1])

The NASSS framework is not a theory on its own. It is a map of possible areas of complexity to take into account when planning, analysing or writing up a project or initiative involving a technology. In addition to an over-arching theory of system complexity (which can be thought of as a 'grand theory' – that is, one at a very high level of abstraction and generality), each domain in the NASSS framework may be informed by one or more focused ('middle-range') theories, many of which are explained in more detail elsewhere in this book. Below, we introduce the over-arching theory of complex adaptive systems which informs the NASSS framework as a whole, followed by examples of relevant underpinning theory(ies) for each individual NASSS domain.

1.2. The importance of complexity

Complexity has been defined by Cohn et al as "*a dynamic and constantly emerging set of processes and objects that not only interact with each other, but come to be defined by those interactions*" (page 40) [3]. Complex [adaptive] systems are characterised by fuzzy boundaries; their interacting agents operate according to internal rules that cannot always be predicted; such systems interact, adapt and co-evolve with other systems [1, 4, 5]. Whilst it is fashionable in healthcare circles to talk about complex interventions, it is important to recognise that complexity is a feature not just of an intervention but of the system(s) into which the intervention is introduced [6, 7]. Indeed, even when an intervention (such as a technology) is simple (defined as having one active component and unchanging) rather than complex (defined as having multiple interacting components and perhaps also evolving over time), the *system* will almost invariably need to adapt in some way to accommodate it [6, 7]. Typically, a planned technological intervention (such as a patient-facing portal to access a health provider) and its context (e.g. a deprived rural community with unreliable broadband coverage) will be inter-related and reciprocally interacting.

Complex systems have many other features that are relevant to the study of technologies in a health care context. It is simply not possible to predict with certainty what will be the outputs if X is the input. Health systems are rapidly changing (the baseline against which the implementation is being evaluated is rarely static). Technologies may be more or less reliable in different contexts (software, as we all know, has a tendency to crash or develop bugs when interfaced with other software). Work-as-imagined (the guideline or standard operating procedure) necessarily differs from work-as-done [4]. Human actions may be variously constrained (both materially and socio-culturally).

In complex systems, therefore, decisions must often be made on the basis of incomplete, contested or only partially relevant data. Furthermore, certainty not only eludes us *now*, it will continue to elude us as the project progresses and we will have to learn to work with *uncertainty*. Indeed, the conclusion "more research is needed" often needs to be replaced with "more pragmatism is needed". In such systems, human agents use their creativity and generate pragmatic solutions that make sense locally – at least for a while, until circumstances change, when they must adapt again. When researching complex systems, we need to surface and celebrate (rather than ignore or sanitise) all the articulations, workarounds, muddling-through and emergent activity that keep the show on the road.

A complex systems perspective holds that the planning, analysis and writing up of a technology project should be much more than a linear account of a particular goal and the extent to which it was met. It should be a richly-described case study (which may contain quantitative as well as qualitative data) of how human actors made it happen *despite* all the uncertainties, contingencies, inconsistencies, material challenges and micropolitical hiccups – and how the goals changed (perhaps quite appropriately) as the project unfolded and contextual influences changed [8].

1.3. Domains of the NASSS framework

Against this background of complexity in health systems, let us now consider the different domains of the NASSS framework, shown in Figure 1, and the different kinds of complexity that can occur. Broadly speaking, such complexity can be logistical (relating to the scale, scope and different inter-related sub-systems involved) or socio-political (relating to personal, interpersonal or inter-organisational issues such as differences in values or conflicts of interest).

Domain 1 in the NASSS framework is the condition (perhaps an illness, such as diabetes, or risk state, such as increased tendency to falls). The human body is of course a complex system, as is the family and community in which the sick person is cared for. The most obvious theoretical influences on this domain are biomedical and epidemiological theories of disease (which often but not always allow prediction of how the condition and its co-morbidities will progress over time) and pharmacological theories of how drugs work and interact. In addition, a number of theories of *illness* (that is, disease as experienced by the patient) are relevant here. Sociological framings depict illness as a unique personal (and family) experience which may involve stigma, biographical disruption, loss of status, reduced income and a heroic struggle to retain dignity, rebuild identity and live a moral life in the face of adversity [9, 10]. Political economy framings depict illness as the result of poverty or maldistribution of power in society (for example, Julian Tudor Hart's Inverse Care Law states that people most in need of health care are least likely to seek it or receive it) [11].

Complexity in Domain 1 may occur, for example, when the condition is metabolically volatile (e.g. sepsis), inherently unstable (e.g. alcohol dependency), poorly described or understood (e.g. a newly described syndrome), associated with multiple co-morbidities and polypharmacy (for example, in older people) or influenced by socio-economic or cultural factors (including poverty and material circumstances; limited access to healthcare; low health literacy, system literacy or digital literacy; cultural traditions and norms; social exclusion). For an overview of the kinds of complexity that affect the condition or illness, see this review [12].

Domain 2 is the technology, for which a number of underpinning theories covered in separate chapters elsewhere in this text book may be relevant, including socio-technical systems theories[2], technology adoption theories[3], normalisation process theory[4] and user-centred design theories[5]. In our own empirical work applying NASSS to patient-facing technologies (e.g. designed to support self-care in the home), we have drawn particularly on Jeanette Pols' theory interpretation of actor-network theory, which

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[2] See Chapter 7, "Distributed Cognition: understanding complex sociotechnical informatics" and Chapter 8, "Using Actor-Network Theory to study health information technology interventions".

[3] See Chapter 6, "Technology Acceptance Models in health informatics: TAM and UTAUT".

[4] See Chapter 15, "Implementing and embedding health informatics systems – understanding organisational behaviour change using Normalization Process Theory (NPT)".

[5] See Chapter 5, "Linking Activity Theory with User Centred Design: a human computer interaction framework for the design and evaluation of mHealth interventions".

focuses on how particular technologies bring particular kinds of knowledge into play and render other kinds of knowledge less visible [13].

Complexity in Domain 2, therefore, may relate to the material properties and functionality of the technology itself (especially its dependability and speed of operation); to the knowledge needed to use it (hence, to how easily staff and patients can be trained); or to the knowledge it brings into play and how much that knowledge is likely to be trusted or contested. It may also relate to the technology supply model (e.g. to what extent is the technology substitutable?) and to the intellectual property (IP) it generates (how easy is it to say who 'owns' the IP?).

Domain 3 is the value proposition – both supply-side (value to the developer and/or healthcare system) and demand-side (value to the patient and/or insurer). Relevant to Domain 3 are various theories of value generation. Here, we describe one: transaction costs theory, which was developed to explain the governance implications of costs that constitute friction or a barrier to otherwise desirable economic or social exchange [14, 15]. The level of transaction costs on any given patient-provider interface is influenced by technology; and can be measured in terms of the number and duration of steps involved in patient pathways and clinical workflows [16, 17]. Transaction costs include search and information costs, bargaining and payment costs, or monitoring and enforcement costs. From the perspective of a consumer transaction costs are all costs incurred by the consumer that are not transferred to the seller (e.g. the time spent obtaining information on the good or service, and on prices and potential alternatives, legal fees, and the costs of establishing credibility as a buyer). From the perspective of a producer, transaction costs are all costs which the producer would not incur were they selling the good to themselves (e.g. time spent waiting while people examine the good or service, agent and advertising fees, and the costs of establishing credibility as a seller) [18].

In the software-platform revolution that began 20 years ago with the launch of eBay, and continues with Uber and Airbnb, Munger argues that "entrepreneurs have for the first time been able to specialise in selling not more stuff, but reductions in transaction costs for access to existing stuff" (page x) [19]. These platforms reduce transaction costs by providing "(1) information about identity and location [of potential transacting partners]; (2) a way of making payment that both parties can trust; and (3) a way of outsourcing trust on performance of the terms of the contract" (page 393) [19]. Often, the primary value of a technology is reduction in transaction costs; reducing frictions on the patient-provider interface – for example, patient-facing digital health innovations such as video consultations, and apps designed to support self-care in the home or help patients to locate, pay for, and rate laboratory services in their vicinity. But by reducing transaction costs, a technology may also add value by creating/maximising the capacity of a system to deliver services (on the supply side) or by creating/maximising opportunities for population access to services (on the demand side).

Complexity in Domain 3 thus relates to difficulties in formulating a plausible business case for developing the technology or to verifying the assumptions about how value will be generated [20, 21]. A simple value proposition offers a clear business case for investors *and* evidence that patients and the health service will benefit. In a complex situation, the business case for developing the product is implausible, or rests on unverifiable assumptions, and/or the results of health technology assessment studies are unavailable or contested. In addition, a business case may be complex when it is unclear or unpredictable how the innovation will re-distribute transaction costs among stakeholders, and how this may change over time – for example, video consultations may reduce transaction costs for patients (e.g. direct and indirect costs of travel) but increase transaction costs for the health system (e.g. costs of installing the videoconferencing equipment); conversely, a self-monitoring app may increase transaction costs for patients (e.g. forgone income due to time spent on monitoring by the patient or their family) but reduce transaction costs for the health system (e.g. less expense on staff time for patient monitoring).

Domain 4 is the adopter system: the staff, patients and carers who will be expected to use the technology (but who may refuse to use it or find they are unable to use it). Relevant theories here include theories of how people learn to use technology (one example is Bandura's social learning theory, which emphasises on-the-job learning and the importance of respected role models [22]). But non-use of a technology is rarely solely due to lack of knowledge or skill. We may also need to invoke sociological theories of why professionals resist new technologies, (see for example Greenhalgh, Stones and Swinglehurst's adaptation of Giddens' structuration theory to explore professional resistance to nationally mandated software programmes [23]). Complexity in Domain 4 occurs not only when using the technology requires knowledge or skills the user does not have but also when the roles and practices assumed by the technology threaten deeply held values or norms – for example, when a staff member is expected to do something she feels is against her professional code of conduct or work in a way that provides what she feels is a lower standard of care.

In relation to adoption of technologies by patients, May's burden of treatment theory (like transaction costs theory) proposes that shifting the work of care from clinician to patient places new demands on the sick, hence may be disempowering rather than empowering [24]. Such work may include taking readings and entering data (e.g. in many telehealth applications), making judgements (e.g. about what is an emergency or whom to contact in a crisis) or adjusting medication (for example, in response to a treatment titration algorithm).

Domain 5 is the healthcare organisation(s). The theoretical underpinning of this domain was summarised in an earlier paper, 'Diffusion of Innovations in Health Service Organizations' [25], which included an extensive systematic review of the characteristics of organisations that support innovation. These included theories of organisational *structure and climate* (for example, the well-documented findings that well-led organisations with flat hierarchies, devolved decision-making, slack resources and a risk-taking climate find it easier to innovate than those lacking these features), theories of *absorptive capacity* (preconditions for capturing knowledge from outside the organisation and disseminating it internally), theories of organisational *readiness* (especially the notion of innovation-system fit and the potential 'wrecking power' of strategically-placed opponents) and various theories of assimilation and implementation. In addition, theories of incremental versus disruptive change are relevant ('disruptive innovation' of the rip-and-replace school succeeds far less often than a more incremental approach to change [26]). Finally, May's normalisation process theory[6] unpacks the work of implementing a technology in an organisation, including *coherence work* (the work that people do to make sense of a practice), *cognitive participation* (work to enrol and engage other people in relation to that practice), *collective action* (work to enact the new practice), and *reflexive monitoring* (the work involved in evaluating the impact of the technology) [27].

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[6] See Chapter 15, "Implementing and embedding health informatics systems – understanding organisational behaviour change using Normalization Process Theory (NPT)".

Complexity in Domain 5, then, may relate to the organisation's general capacity to innovate (such as leadership, clinician-managerial relationships, absorptive capacity for new knowledge and availability of slack resources); its readiness for this particular technology (tension for change, balance of supporters and opponents); the nature of the adoption and funding decision (more complex if it depends on inter-organisational agreements and speculative cross-system savings); potential disruption to existing routines (the less there is, the simpler it will be); or the extent of work needed to implement the changes (including ensuring staff buy-in, delivering the change and evaluating the change).

Domain 6 is the wider system. There are many potentially relevant theories that suggest how external social, political, technological and economic context may affect the uptake of innovations. One example is Richard Scott's neo-institutional theory, which proposes that innovation and change in healthcare organisations is heavily influenced (and may be slowed down) by three broad types of social forces or "institutional pillars": regulative (laws, regulations and contracts which stipulate what *must* happen), normative (professional and societal expectations about what *should* happen) and cultural-cognitive (taken-for-granted scripts and mental models about what generally *does* happen). Each pillar offers a different rationale for legitimising human action or inaction, by virtue of being (respectively) legally sanctioned, morally (e.g. professionally) authorised, or culturally supported. The wider system also embraces the networks that exist between organisations and theories of how networking and knowledge-sharing between organisations can significantly increase the uptake and embedding of innovations within them [25].

Complexity in Domain 6 may relate to negative perceptions of the innovation or specific blocks to its introduction from policymakers, regulatory or professional bodies, or the general public [8]. It may also indicate limited scope for networking activities among organisations (for example via quality improvement collaboratives), which are known to improve organisations' capacity to innovative.

Domain 7 is continuous embedding and adaptation over time (of both the technology and the service or organisation). Relevant theory here includes Everett Rogers' consistent finding that 'potential for reinvention' is a key determinant of successful adoption of an innovation [28], and also to the notion of organisational resilience [29], which has been defined as *"the intrinsic ability of a system to adjust its functioning prior to, during, or following changes and disturbances so that it can sustain required operations, even after a major mishap or in the presence of continued stress"* (page 1) [30]. Complexity in Domain 7 may thus relate to the technology's lack of potential to adapt to changing context or to the organization's lack of resilience.

2. Usage of NASSS framework in health informatics: A case study of a telehealth system for heart failure *(SUPPORT-HF)*

Empirical studies by our own team [2, 31] and others (as yet unpublished) have demonstrated the value of the NASSS framework for constructing a rich narrative of an unfolding technology-supported change programme and identifying the various interacting uncertainties and interdependencies that need to be contained and managed if the programme is to succeed.

An example from our empirical dataset is a home-based telehealth system for heart failure, known as SUPPORT-HF, which provided remote data on patients' blood pressure, blood oxygen levels and heart rate and rhythm [32]. When aggregated over time, these data could alert clinicians to impending deterioration, prompting a phone call, an invitation to clinic or a home visit.

The technology was adopted patchily (even by participating sites in a randomised controlled trial, all of whom had initially agreed to participate), and the service model which it supported was not straightforward enough to implement in community or hospital-based heart failure clinics. Below, we consider the different kinds of complexity in the SUPPORT-HF study and how the different NASSS domains can help in analysing this complex case.

The condition: Heart failure affects 1–4% of the adult population; it is commoner in ethnic minorities and people from socio-economically poor backgrounds, and its prevalence increases with age (the average age of first diagnosis of heart failure patient is 76) [33]. It has multiple causes and complex pathophysiology; heart failure that results from an isolated defect in a part of the heart (e.g. a leaky valve) is now much less common than heart failure linked to general deconditioning in an obese person who also has high blood pressure and diabetes. On average, four to five comorbidities add to symptom and treatment burden and influence prognosis. Co-existing frailty, depression and cognitive impairment are common. The course of the condition is highly variable but it can lead to rapid deterioration and/or sudden death. Heart failure frequently causes extreme fatigue and may cause confusion; patients typically describe themselves as bewildered and frightened.

The technology: The SUPPORT-HF technology consisted of standardised instruments for biomarker monitoring (weight, blood pressure, heart rate) along with a tablet computer (which had been developed using a co-design methodology) into which patients entered data for remote transfer to a monitoring centre. Participants in both arms of the trial received the technology and automated feedback messages (e.g. if results went outside pre-set parameters). In the intervention arm, the patient's family physician was alerted to out-of-range results and offered suggestions for changes in therapy, whereas in the control arm, results were made available on a Web portal for the patient's physician to access if they chose to.

The value proposition: Because the technology had been developed as a research initiative, the value chain was somewhat speculative. The assumption was that using telehealth would enable the hard-pressed community heart failure nurses to take on a higher case load (from 35-50 patients per nurse to an estimated 200 patients per nurse). This was thought to be possible because of reduced travel time for nurses (who did a lot of their work by home visiting) and the assumption that processing remote data (blood pressure, heart rate and rhythm, body weight) would be a quicker way to monitor the course of a patient's heart failure than undertaking regular clinical examinations of the patient. However, for various reasons, the trial was slow to recruit (in some but not all sites) and many patients were either not entered into the study (because the care package was considered clinically inappropriate) or because they were unable or unwilling to undertake the monitoring, or because broadband was unavailable. Thus, at the time of writing, the anticipated economies of scale in relation to nurse caseload have not yet been realised (and may have been over-optimistic). Another as-yet unknown transaction cost of the telehealth model is the cost of supporting and maintaining the technology in patients' homes.

The intended adopters: Staff at the different SUPPORT-HF sites engaged variably with the study, sometimes leading to slower than predicted recruitment. Some heart failure nurses were extremely keen but others engaged only superficially with the trial protocol and recruited few patients, citing previous poor experiences with telehealth, concern that a remote monitoring service would threaten their jobs, or a belief that patients 'deserved better'. The implied role change for the specialist heart failure nurse was potentially far-reaching. Instead of spending her time seeing patients in clinic or visiting them at home, nurses would now be spending a proportion of their time sitting in a data processing centre looking at on-screen data and trends. Furthermore, one driver for the introduction of the telehealth programme was a rapidly rising incidence of heart failure (and, because of improved care, patients were surviving many years after diagnosis). One cardiologist spoke of a health economic model in which the case load for each nurse would increase from 35 to 200 patients. Whilst some nurses embraced this vision enthusiastically, others strongly resisted it on the grounds that a dramatic reduction in direct patient-facing activity meant that they were no longer *being* heart failure nurses.

Patients expressed a wide range of views about remote biomarker monitoring in the SUPPORT-HF study; some took an active interest in their readings, engaged enthusiastically with the feedback they received, and found this monitoring reassuring. Others found the experience confusing and burdensome; they did not know (and did not wish to learn) what the numbers meant. In some cases, a research nurse who knew the patients well provided (unofficial) telephone support to maintain engagement.

The organisations: Participating sites in the SUPPORT-HF study were generally semi-autonomous cardiology units based in large district general or teaching hospitals. With few exceptions, leadership and managerial relations were good and (because of research support funding for the trial) there was sufficient financial slack to support introduction of the technology. As a research initiative, the SUPPORT-HF technology was not integrated into mainstream services, but we tentatively predict that because of the major knock-on implications for work routines (especially in relation to community heart failure nurses), this technology will be experienced as 'disruptive' and hence prove difficult to mainstream after the 'proof of concept' phase ends. One further external factor is the complexity of heart failure services, which typically span general practice, community clinics and hospital services – each of which has a different funding stream and different patient caseload. A telehealth-supported service in one of these sectors may need to interface with other sectors in the same locality that do not support (and perhaps do not trust) telehealth.

The wider system: The SUPPORT-HF study unfolded at a time when there was a strong policy push for telehealth initiatives in general and for initiatives to reduce outpatient attendance in particular. But whilst the policy environment was positive, our data showed that in some sites up to half the eligible patients could not be randomised because of the variability of broadband speed outside the main cities. The extent of inter-organisational networking among participating departments in the SUPPORT-HF study was limited as this was not an explicit component of the trial intervention; we suggest that if this technology is introduced as a business-as-usual intervention post-trial, networking and knowledge-sharing among organisations should be supported (either via a virtual link or occasional face to face meetings).

Evolution and adaptation over time: The tablet technology used for SUPPORT-HF included some limited scope for adaptation and customisation, but our qualitative data suggested that both staff and patients wished to adapt it further (either to accommodate individual needs and preferences or to adjust to external factors such as a changing technical infrastructure in the participating service). We are somewhat pessimistic about this particular technology's potential for surviving into the future, but the same service could be delivered on a substituted technology.

In summary, the main complexities in the SUPPORT-HF example are the condition itself (heart failure is serious, unpredictable, heterogeneous, associated with multiple comorbidities and occurs more commonly in patients who are poor and from minority ethnic groups), untested assumptions in the value proposition (such as predicted uptake and the cost of processing remote data), the intended adopters (neither staff nor patients view the technology with unqualified enthusiasm, and a key staff group may perceive a threat to their scope of practice and job security), and the disruptive implications of the technology for organisational (and especially inter-organisational) routines. Furthermore, lack of broadband access in rural and remote parts of the UK currently preclude this technological model as a solution in the very geographical regions where it could potentially be most useful.

3. Discussion

The NASSS framework has been developed relatively recently; whilst many teams around the world are currently exploring its potential, published studies of its application are limited. Indeed, we are still at the stage of formulating hypotheses which we encourage others to test. At the most broad-brush level, for example, we hypothesise that:

- when most or all of the NASSS domains can be classified as *simple*, the programme is likely to be easy to implement and to be achieved on time and within budget;
- when many domains are classified as *complicated*, the programme will be achievable but it will be difficult and likely exceed its timescale and budget;
- when multiple domains are *complex*, the chances of the programme succeeding at all are limited.

The reality is that almost no technology projects in health and social care are simple. Therefore, to maximise a programme's chances of success, efforts must be made to reduce complexity in as many NASSS domains as possible. That said, the temptation to address an oversimplified, abstracted version of the problem (in any domain) should be resisted. Bounded rationality (delineating the problem as a simple set of algorithmic decisions and defining various complicating factors as out of scope, for example) is sometimes a necessary tactic for policymakers – but it is unlikely to work in practice.

Rather than oversimplifying, we suggest that the approach to the problem should incorporate acknowledging and exploring complexity in all its richness across the multiple domains of the NASSS framework – including the condition or illness, the technology, the value proposition, the intended adopters, the organisation(s), the wider context and likely evolution of the technology and the programme-in-context over time. Next, seek to identify any sub-domains in which this complexity might be reduced. This is likely to mean scaling back on the kinds of illness or condition for which the technology is claimed to be useful; reducing the technology's interconnections (and other complex features); sharpening the value proposition; reducing the demands made on staff and patients, and proactively addressing national regulatory and policy barriers. In each of these areas for potential complexity reduction, specific theories (some of which are described above) may be relevant.

Because complexity tends to be inherent in healthcare programmes, the key challenge is often to develop ways of 'running with' complexity rather than seeking to eliminate it. The literature on complex systems suggests a number of strategies for running with complexity, including: strengthen programme leadership (and consider how to draw on distributed leadership to complement overall programme leadership); co-develop and sustain a clear and compelling vision for the programme while at the same time tolerating multi-stakeholder perspectives; identify and talk about uncertainty especially when it cannot be resolved; develop individuals and support the adaptive actions they take when implementing the programme at the front line; create incentives for delivering on broad objectives (but leave the detail to front-line staff) and provide them with slack resources (e.g. an accessible draw-down budget to use as appropriate); build relationships and manage stakeholder conflict; control programme growth (e.g. minimise scope creep); co-design pathways and work routines with intended end-users; acknowledge and respond to emergence, appreciating that unintended consequences will occur; and seek to better understand and work with the policy or regulatory context.

In conclusion, we live in a world that is saturated with technology, yet the pervasive problems of non-adoption, abandonment and failure of scale-up, spread and sustainability of technology programmes show no signs of abating. Time after time, the strategic focus is drawn narrowly to the technology and actors are seduced by over-enthusiastic sales pitch and distracted by simplistic models and metaphors (e.g. 'tipping point'). The dynamic socio-technical system into which new technologies and care practices must become embedded is overlooked or ignored – yet understanding and navigating its multiple interacting domains are key to programme success.

Teaching questions for reflection

1. How would you define complexity?
2. What are the features of a complex adaptive system?
3. Using your own example of a health informatics project, identify key areas of complexity in the following domains: the condition or illness, the technology, the value proposition, the intended adopters, the organisation(s), the wider context and the embedding and adaptation of the technology and the programme-in-context over time.
4. Using your own example, consider how these areas of complexity could be either reduced or managed.

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