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The Design and Evaluation of a Clinical Process Mapping Methodology (CPMM) to Support Information Systems (IS) Innovation in a Healthcare Context

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Abstract

This paper discusses the development, and assesses the appropriateness, of a Clinical Process Mapping Methodology (CPMM) to support information systems (ISs) innovation in acute hospitals. It is based on an ongoing longitudinal study in acute academic teaching hospitals in Ireland. The key rationale underpinning the research was that any attempt to develop ISs to support or change clinical work, must be based on a sophisticated, holistic and granular understanding of existing practices. Drawing on the insights gleaned through this observational study, an initial CPMM was developed by adapting elements from existing modelling languages to fit the clinical context in question.

Our observations highlight the complex, collaborative and contingent nature of clinical practice, and the important mediating role played by technical and non-technical artefacts. This complexity would caution against viewing modelling as a panacea, which can be used to map the world in an objective or unproblematic manner. While modelling can be very helpful for facilitating new perspectives on work, and for facilitating productive collective sensemaking processes, it should be borne in mind that all models are purposeful, and necessarily partial, representations of the 'real' world. This underlines the importance of using any modelling approach in a discriminating and reflective way.

Keywords: Electronic Patient Record (EPR), Clinical, Process, Socio-Technical, Mapping, Sensemaking, Process Management

1 Introduction

Underestimating the complexity of clinical practice is a significant concern within the field of Medical Informatics and e-health in general. This problem influences the design, development and deployment of Information Systems (ISs) in a range of predictable and unpredictable ways.

In an Irish context, the development of ISs for the clinical environment is a central objective of current government strategy (Scolaí 2003). Pride of place among the proposed range of information systems is the development of a national Electronic Patient Record system (EPR's) (NHIS, 2004). An EPR system can have a combination of off-line and web-enabled functions and the proposed benefits of such a system are very alluring. For example, one U.S. study claimed an integrated national EPR could prevent 500,000 medical errors, and save \$9.7 billion annually (Agarwal, 2005). Moreover, this strategy is not unique to Ireland and its similarity to current UK initiatives is striking (see Jones, 2004).

There exists a dichotomy on the most appropriate approach to system development. Senior national management view the issue of standardisation as central to their goal of a national integrated EPR system. Local management however are suspicious of the 'one size fits all approach' and are adamant that local variance must be accommodated in any new IS. As a result of notable large scale IS project failures, including one in the health service, more organic and collaborative approaches to designing systems to support clinical practices are growing in popularity.

The principle concern of this paper is to discuss a recent attempt to design a Clinical Process Mapping Methodology (CPMM) which could be used to specify an EPR at an appropriate level of granularity, and more poignantly, to outline the appropriateness of such an approach. The rationale is based on the premise that designers and developers need to advance approaches that draw them closer to the practices in question, well in advance of deciding which processes can be supported on-line and indeed by information systems in general. While generic administrative processes might be readily identified and mapped, more nuanced clinical knowledge work practices present a much more significant challenge.

This paper is structured as follows. In Section Two, we explain our approach to examining clinical processes and practices and (Section Three) to utilising this methodology in the context of process modelling. This is followed, in Section Four, by an outline of our attempt at designing a CPMM. The paper concludes, in Section Five, with a discussion on the appropriateness of process mapping within e-health based on the result of initial testing with clinicians¹.

2 Research Method

Ethnographic methods were used to explore the detail of micro-level clinical practices, and on the basis of this observational activity, an attempt was made to specify broader and more generic chains of work processes. This type of observational research presents a number of difficulties, not least, its resource

¹ The term 'Clinical' includes doctors and nurses. For the purpose of this study, the activities of administrative staff were also observed.

intensive nature. In what follows, we explain and justify our choice of methodological approach.

The success, or otherwise, of any given technology depends on how it is appropriated by users and becomes embedded in the social and organisational context in question. Consequently, any mature attempt to understand the likely implications of a specific information system (IS) implementation must be based on a sophisticated understanding of the context in question, and the institutionalised work practices and social relations that constitute it. Our approach, then, embraced a user orientated socio-technical philosophy, emphasising the importance of developing a thorough understanding of the practices within which IT applications will be embedded as the starting point for design, development and deployment activities (Kling and Scacchi 1982; Berg 1999).

This philosophy points to the shortcomings of using more detached quantitative survey methods for the development of such an understanding (Berg 1999; Anderson and Aydin 2005), emphasising instead the need for intensive, ongoing engagement with the research context. A further difficulty with the use of these more detached research methods is the problem of discriminating between what people 'say' they do and what they 'actually' do. Hence, our approach was particularly sensitive to observing the enacted world of work, which helped uncover work practices that clinicians 'forgot' to describe and also verified 'general claims' made about system use and the practices surrounding their use.

Ethnographic methods are widely recognised and employed by IS researchers (Berg 1999; Hanseth and Lundberg 2001; Ellingsen and Monteiro 2003; Timmermans and Berg 2003; Boonstra and Boddy et. al. 2004). This paper is based on an on-going study conducted at two large acute teaching hospitals. In Hospital A we focused on Neurology. In Hospital B we focused on Elderly Medicine.

In each hospital we shadowed the clinical team as they performed their day-patient, out-patient and ward-round associated activities. In Elderly Medicine the ward-round patients were located on one specific ward but this was not the case for the Neurology patients. Consequently, the Neurology ward-round covered a number of different wards and resulted in us spending a significant amount of time in the Intensive Care Unit (ICU) of Hospital A.

We examined the clinical practices of both doctors and nurses (particularly specialist nurses). Our sources of data included secondary document analysis, primary interviews (semi structured and unstructured), informal discussions and observation. This approach allowed us to cross-validate, triangulate and formulate questions for further investigation. The main observations were conducted over a four-week period, and involved about 120 hours of clinician observation. Some observation work also took place prior to, and subsequent to, this period. Semi-structured interviews were conducted with seven senior managers, two administrators and 12 clinicians. Interviews ranged from half an hour to three hours, with a number of informants interviewed more than once. In all cases we took hand-written notes, some of which were supplemented by the use of an audio

recording device. In total, the project consumed approximately 650 hours of effort.

Overall, then, the selected research approach facilitated the development of a very granular understanding of clinical practice in the specialities studied, which informed the design of an initial CPMM. The following section introduces the notion of process modelling, while the initial CPMM design is outlined in Section Four.

3 Introduction to Process Modelling

Process Modelling is a specific kind of conceptual modelling. While conceptual models have been one of the key research topics in the IS field since the early 1970s (Wand 2002), interest in the area has increased recently as Service Oriented Architectures (SOA) (Ruiz, Valderas et. al. 2005; Werth, Leyking et al. 2006) and Model Driven Architectures (MDA) (Klepp, Warmer et al. 2003; Thomas 2004; OMG 2003) have risen to prominence.

Conceptual modelling can serve a large variety of different purposes (Wand 2002) and involves the application of the principle of abstraction (Frank 1999). Specific purposes include facilitating communication between users and software developers, supporting software developers' understanding of a certain domain, and documenting requirements for further design processes (Kung and Solvberg 1986).

In process modelling, conceptual models are developed in an attempt to describe an interrelated set of processes within a specific organisational context. According to Becker and Kahn, a process is defined as “a completely closed, timely and logical sequence of activities which are required to work on a process-oriented business object” (2003 p.4). Typical business objects in the context of hospitals would include patient records, prescriptions and/or appointments.

In applying models in ISs development processes, it is vital that the specific domain and its modelling requirements are accounted for (Weber 2003; Goldstein and Storey 1990; Prietula and March 1991; Batra and Marakas 1995; Hitchman 1995; Maier 1996). Moreover, all stakeholders should be involved in the overall modelling project.

Within the models, the view on processes should not be limited to one perspective. To achieve acceptance, the individual work practices and information needs of the clinicians should be taken into account when designing “as-is” and possible future “to-be” models. Therefore, complexity and diversity need to be reflected in the models. Their application for various future purposes, calls for extensibility of all models. In the following we describe our approach to model clinical processes.

4 A Clinical Process Mapping Methodology (CPMM)

A key success factor for the development and application of process models in a hospital context is the integration of all relevant stakeholders in every stage of the

modelling process. To this end an approach to managing the development and application of a CPMM, which emphasises the importance of incorporating a plurality of perspectives, is essential (see figure 1).

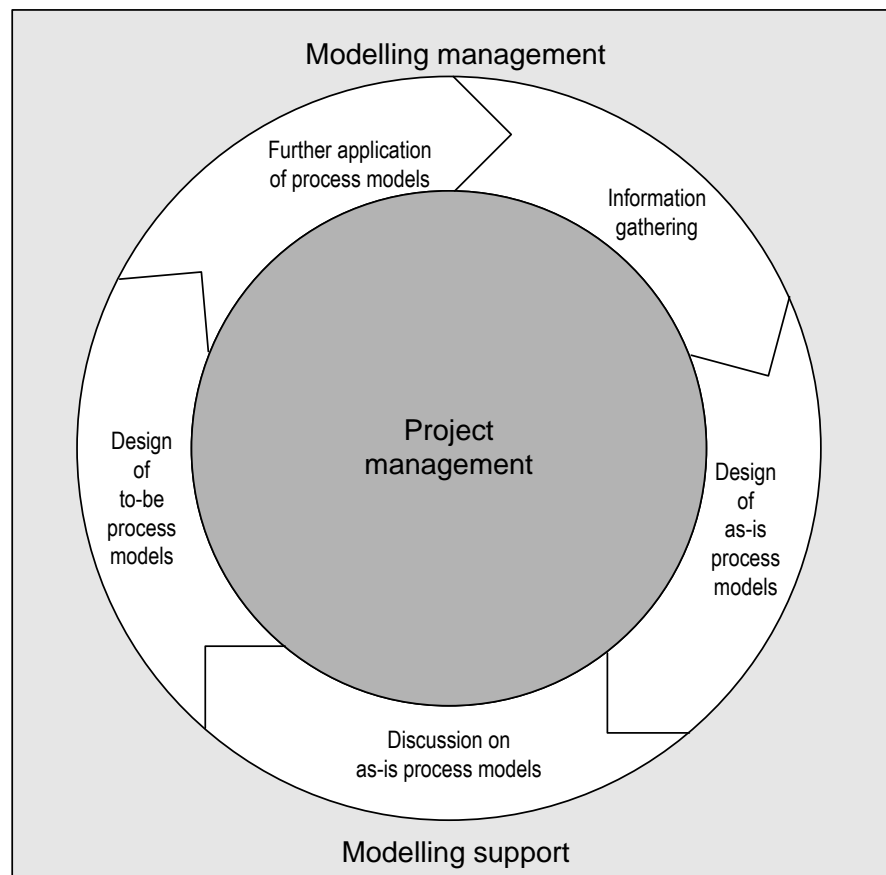


Figure 1: Stages of the CPPM approach

Based on the observation and interviews, as-is models were designed by the research team for both areas. They served as a basis for discussion with all stakeholders. The results of these discussions lead to the design new to-be models, to be applied in further application contexts.

Design of Process Models

An event-driven modelling language was adapted for the acute hospital context. This language provides a graphical view of processes through the design of process chains. In order to document the specific underlying work-practices, the process chains are supported by the process glossary and the process descriptions (see figure 2).

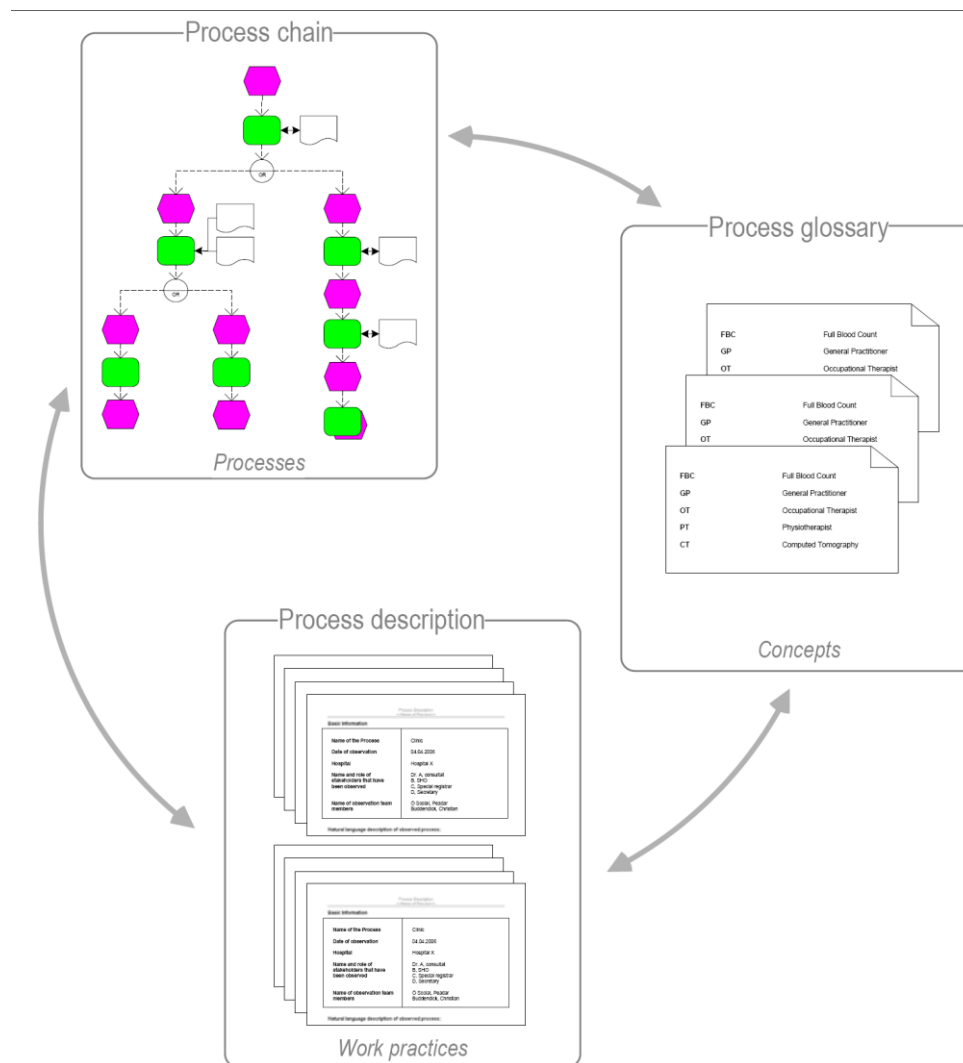


Figure 2: Constitutive elements of a process model in the context of hospitals

The following section describes, in more detail, each element of a process model in the context of acute hospitals.

Process Chains

Process chains can be modelled in the semi-formal language of Event-Driven Process Chains (EPC) (Scheer 1998). This language aims to facilitate the development of a common understanding and collective discussion about processes. EPCs are especially suitable for the design of an information system because they deliver an integrated view of processes (activities, events, and their interconnections), organisational units, and the IT and non-IT resources employed in a process. In contrast to other modelling approaches, this integrated view of processes enables the identification of interdependencies, technologies, tasks, and responsibilities. Modelling EPCs can be supported by a variety of CASE-Tools.

Moreover, EPCs facilitate the direct linking of events and activities. This enabled us to signify the interconnection between the fulfilment of a certain task, its preconditions, and its outcome. EPCs are directed graphs which use three basic elements, Events-Activities-Logical Connectors, for modelling the control flow.

Events depict flow-relevant states of the process. The example of a CT scan (Computed Tomography) can be used for illustrative purposes. As a starting event, a patient with an order form for a CT arrives in the CT department. This starting event indicates that a CT activity should be conducted. The CT picture is a resource produced by this activity. The availability of this new resource for further activities is modelled by the following event. This event can trigger further activities, for example printing the picture.

Activities are active nodes and transfer input and output data/ information. They are executed by resources and can indicate further process flows. Examples of activities are the scheduling of a clinic on a certain day or performing a memory test (MT) or a full blood count (FBC). Activities are triggered by events. The outcome of an activity is one or more events. For example, the ordered FBC will trigger the conducting of an FBC, the result (as an event) is the available FBC result, which can be processed in another activity (e.g. a consultant setting up a test). In the graphs, they are identified by rectangles with soft rounded corners.

Logical Connectors are used to model splitting (outbound connectors), or joining (inbound connectors), points in process models. Three different connectors are available in the EPC: Conjunction (AND-connector), Disjunction (XOR-connector) and Adjunction (OR-connector).

Due to the specific requirements of the hospital domain, and the intended application purpose of the models, the basic EPCs need to be customised for modelling clinical processes. To specifically deal with the complexity and diversity of this domain two more elements can be introduced: process signposts and abstract activities. Process Signposts, as elements of the extended EPC, indicate an interface between different processes in a hospital. For example, this concept can be applied in the outpatient clinic process to indicate that when a blood test is ordered, the process “blood testing” is triggered. Abstract Activities allow the integration of different levels of abstraction in process chains. An abstract activity indicates that a sub process is element of the displayed process, where the sub process describes some events and activities in a more detailed way. This construct is especially suitable to reuse sub processes in different processes, e.g. to integrate the process CT-Scanning in different clinics. Graphically these constructs are regular activities black point adjusted by a black point in the upper right corner.

Based on our observations, many of the following resources would appear to be relevant: human resources (specified and unspecified) [yellow oval], data [blue Entity type] and application systems [reed square], paper based documents [icon for document] and other resources [blue oval]. These resources can be attached to activities by a directional allocation edge.

Symbols for annotations were also developed. This is particularly important for modelling individual information needs. We used these annotations to indicate a specific individual information need, an underlying work-practice, or other specific comments on elements of the EPC. Annotations for information needs can be attached to resources, whereas annotations for underlying work practices can only be attached to activities. Annotations for specific comments can be

attached to every element of the EPC. All annotations are numbered sequentially, linked to a process description, and explained in detail.

Process Glossaries

Process Glossaries specify all terms and abbreviations associated with a specific process. It is essential in terms of facilitating a discussion amongst all stakeholders about a certain process. Based on the process description and the process chains, all relevant terms and abbreviations that need to be explained are extracted and integrated in the glossary. The glossary is formatted within a table. Key terms can also be explained in the glossary (e.g. a “Parkinson test”). The glossary can be implemented as a Microsoft Word document. This offers the potential of hyper-linking to other documents (e.g. to a scan of the Parkinson test document), or to process descriptions and process chains.

Process Descriptions

Process Descriptions are a basic part of the modelling language and consists of two elements:

1) Basic information in the form of a table. 2) A natural language description of the observed process. For each observed process a specific process description was provided. The process description builds the basis for the elaboration of activities and events, as well as process variants and underlying work practices. Based on the observations and the interviews specific process descriptions have been designed by aggregating the different outcomes. Within the process description individual work practices of clinicians are especially focussed on.

Hospital-Specific Elements of the CPMM

An example of a process chain for Neurology Outpatient Clinic is displayed in figure 3.

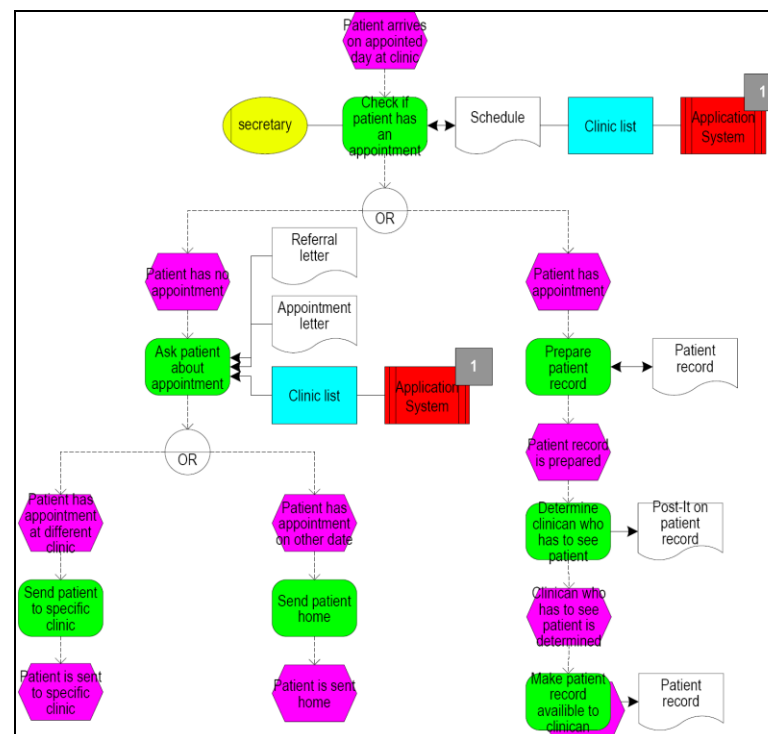


Figure 3: One of the Process Chains in Neurology

The process chain displays that the secretary has to check first, when a patient arrives, whether he has an appointment at that date or not. Therefore the secretary looks at here schedule, a printed version of the clinic list, which can be accessed in the specific application system in each hospital. Two different cases can be distinguished regarding patients that don't appear on this list: the patient can either have an appointment on a different date or at a different clinic. The secretary will send the patient either to his clinic or home in order to come back on the appointed date. In case the patient has an appointment at this specific clinic, the secretary fetches his paper based patient record and prepares it for the clinician who will see this patient. The information to determine who will see the patient can be found in the patient record if the patient has been in the clinic before. When the patient is a first time visitor, a consultant will take care of the patient. The information which clinician will treat the patient is written on a post it and attached on the front of the patient record. With this post-it on it the secretary makes the patient record available to the clinician, for example by putting it on a specific shell, where all patient records for patients to been seen by a clinician are stored.

The following points summarise the main site-specific elements of the methodology that were designed on the basis of our ethnographic engagement with the research sites:

- The methodology allows one to explicitly note the material form of clinical information artefacts.
- The methodology is not limited to a set of symbols for mapping. It also incorporates an approach to facilitate the development and discussion of the models.
- Processes are not solely described by process chains. In addition, work practices and information needs are mapped by means of process descriptions. Furthermore, a process glossary is constructed in order to facilitate a common understanding among all stakeholders.
- In addition to the standardised elements of an EPC, we developed two site-specific elements: Process Signposts and Abstract Activities. The section on resources is also hospital-specific. For example, a symbol for modelling certain paper-based documents is incorporated in the language.
- Site-specific annotations were designed to model information needs and work practices. These annotations identify possible limitations within the process maps, and they enable a cooperative discussion on how far different work practices should be supported by an EPR specification.

The above sections serve as a basic overview of the main elements of the CPMM. However, a principle concern of this paper is an assessment of our approach, which is discussed in the following section.

5 Discussion and Conclusion

If used appropriately, this kind of approach offers a means of facilitating the process of specifying an EPR system for acute hospitals in a manner that attempts to recognise and support the complexity of clinical work practices. At the very least, process models emphasise the interactive and unfolding nature of healthcare work (Berg and Toussaint 2003). In particular, it allows us to model a broad range

of work processes without preconceptions as to which of these may be supported (or, indeed, partially or completely automated) by e-enabled information systems.

Indeed, a striking feature of our observations of hospital life was the diversity of different (non-electronic) technologies that appear to play a central role in co-ordinating clinical work (e.g. paper charts, telephones, beepers etc.). Decisions can then be subsequently made about which (if any) clinical processes/practices need to be supported by different kinds of technology, and the extent to which these can and should be integrated.

Moreover, this initial design phase highlighted a number of potential benefits of using a CPMM. For instance, the models/maps provided a useful way of revealing the complexity of a clinical environment and its constituent practices. In both research sites the clinicians appeared to find the maps useful and the language intuitive. The maps provided a way of reflecting on the processes and sparked many useful on-site discussion which proved fruitful in addressing a variety of IS related issues and a number of misconceptions between the IS team and clinicians.

Notwithstanding those positive indications, the time constraints within which this study was conducted, and its limited scope (i.e. the fact that it was confined to specific functions within two clinical departments), are two important issues that should be borne in mind. In particular, the amount of time required to develop a sophisticated understanding of complex clinical work practices, and the extent of the possible divergence in practices across departments and locations, should not be underestimated. Furthermore, while mapping descriptions are useful, it should not be forgotten that they are necessarily underspecified and ... “[a]ny concrete work activity only unfolds ‘in the doing’, in constant interaction with the contingent circumstances that make up the situation in which it is located” (p.92 Berg 1999). All models are limited in that they provide a purposeful, and necessarily partial, perspective on a complex social/organisational ‘reality’.

Consequently, it is imperative not to mistake the model for the ‘reality’ that it purports to represent. One of the key benefits of process modelling appears to be the understanding gained through participation in the process as opposed to the model produced. To further develop this methodology it is necessary to engage in a comprehensive process of refinement and negotiation across other hospitals and other medical specialities. Research questions in this area should focus on the following issues:

Does this methodology and associated models support a useful discussion on EPR specification and design? It is important to note that, while initial feedback from clinicians was encouraging, the methodology has not yet been tested ‘in anger’.

Issues of particular interest include the extent and quality of clinician engagement that the method facilitates, and the ease with which good quality initial specifications for ICT support might be developed. Future questions should also address how appropriate the method is in other application areas, and how easy will it be for an IS team to appropriate the method and apply it in a mature manner within their everyday work practices?

Our initial results point to a value in the design of process maps and descriptions, which facilitate an understanding of clinical processes and practices at a level of granularity, that is largely absent. We believe this initial CPMM presents a basis from which to examine clinical processes and identify a range of clinical information needs, and we are encouraged by the initial support and feedback from clinicians. The results from the initial verification process indicate that the emphasis should be on the collective sense-making processes that such modelling activities facilitate. It is this 'methodology-in-use' that is crucial to the facilitation of meaningful forms of communication and collaboration across a broad range of clinical areas. Consequently, the skill, judgement and experience of those using the methodology will be crucial to any successful deployment.

To conclude, then, this CPMM offers a promising approach to overcoming some of the reported difficulties associated with system specification within clinical settings. It has the potential to create an environment of mutual understanding and shared responsibility for system design, development and deployment. Used appropriately, the CPMM can facilitate helpful forms of individual and collective reflection, and provide a focus for meaningful and actionable dialogue between clinicians and IS professionals. Moreover, this CPMM represents an innovative approach to the development of an initial Electronic Patient Record specification that will be sensitive to the complexity and diversity of clinical practice.

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