Evidence-Based Health Informatics
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Evidence-based Health Informatics Frameworks for Applied Use

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Abstract. Health Informatics frameworks have been created surrounding the implementation, optimization, adoption, use and evaluation of health information technology including electronic health record systems and medical devices. In this contribution, established health informatics frameworks are presented. Important considerations for each framework are its purpose, component parts, rigor of development, the level of testing and validation its undergone, and its limitations. In order to understand how to use a framework effectively, it's often necessary to seek additional explanation via literature, documentation, and discussions with the developers.

Keywords. Medical informatics, frameworks, models theoretical, evaluation studies as a topic, qualitative research, implementation science.

1. Introduction

Academic disciplines create frameworks that characterize, describe, guide, analyze, and evaluate phenomena and processes. For example, the field of management, according to a 2015 Harvard Business Review article, has created 81 frameworks for management strategy between 1958 and 2013 [1]. Some of the more familiar examples include Gap Analysis (1965), SWOT (Strengths, Weaknesses, Opportunities, Threats) Analysis (1969), and Disruptive Innovation (1999) [1]. Nursing has created many frameworks such as the Nursing Process Model (1961) [2], Modeling & Role Modeling (1983) [3], and Nursing as Informed Caring for the Well-Being of Others (1993) [4]. In health informatics, frameworks have been created surrounding the implementation, optimization, adoption, use and evaluation of health information technology including electronic health record systems (EHR) and medical devices.

A common question is what exactly is a framework? Is it the same thing as a theory, a theoretical or conceptual model, a theoretical framework, or something

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distinct? At first glance across terms, definitions, and disciplines, U.S. Supreme Court Justice Potter Stewart's famous 1964 words on "obscenity" seems to apply: It's difficult to pinpoint the definition, but "I know it when I see it" [5]. What is agreed upon is that these varying terms are often used interchangeably, a practice which "has created confusion among scholars and practitioners [6]" [7, 8].

In his 2015 article "Making sense of implementation theories, models, and frameworks" [8], Per Nilsen provided a selective review of key theories, models, and frameworks used in implementation science. Implementation science encompasses and applies to health information technology, but it is defined more broadly than in health informatics, as the "scientific study of methods to promote the systematic uptake of research findings and other EBPs (evidence-based practices) into routine practice to improve the quality and effectiveness of health services and care" [8]. Certainly, these are the goals of evidence-based informatics research and evaluation studies, and informatics-based, evidence-driven health IT implementations.

Nilsen acknowledges that the terms theory, model, and framework are often used interchangeably, and explains that theories tend to be viewed, across disciplines, in terms of high-, mid-, and low-levels – "an abstraction continuum." However, he attempts to delineate the terms, and defines theories as "a set of analytical principles or statements designed to structure our observations, understanding, and explanation of the world … usually comprising "definitions of variables, a domain where the theory applies, a set of relationships between the variables, and specific predictions" [8]. Nilsen says that models often involve a deliberate simplification of a phenomena or its aspects, have value "without having completely accurate representations of reality," and can be described as "theories with a more narrowly defined scope of explanation; a model is descriptive while a theory is explanatory as well as descriptive" with some predictive capacity [8].

Frameworks, however, do not provide explanations, but "describe empirical phenomena by fitting them into categories. Frameworks usually denote a structure, overview, outline, system, or plan, consisting of various descriptive categories, e.g. concepts, constructs, or variables, and the relations between them that are presumed to account for a phenomena" [8]. Nilsen adds that models and frameworks in implementation science do not specify the mechanisms of change. "They are typically more like checklists of factors relevant to various aspects of implementation, frameworks often have a descriptive purpose by pointing to factors believed or found to influence implementation outcomes." [8]. Nilsen' proposes three overarching aims of all theoretical approaches in implementation science, and five categories of approaches to achieve these aims [8] (See table 1).

In the next section, we present two health informatics frameworks for discussion purposes. The first, DiCoT-CL, is used for guiding implementation, evaluation, and use-optimization of medical devices, and the sociotechnical systems in which they are used. According to Nielsen's five categories, DiCoT-CL is a process model or framework, of the action sub-type. The second framework, the Clinical Adoption Framework, is an evaluation framework used to evaluate health IT adoption, particularly electronic health record system (EHR) adoption, in healthcare organizations from a sociotechnical perspective. For each of these frameworks, its purpose, component parts and development, testing and validation, limitations, and a basic explanation for how the framework is employed are discussed.

Table 1. Nilsen's Three Overarching Aims of All Theoretical Approaches and Five Categories of Theories, Models, and Frameworks Used In Implementation Science.

Category	Description
AIM 1	Describing and/or guiding the process of translating research into practice (process models)
Process Models	Specify steps (stages, phases) in the process of translating research into practice, including the implementation and use of research. The aim of process models is to describe and/or guide the process of translating research into practice. An action model is a type of process model that provides practical guidance in the planning and execution of implementation endeavors and/or implementation strategies to facilitate implementation. Note that the terms "model" and "framework" are both used, but the former appears to be the most common
AIM 2	Understanding and/or explaining what influences implementation outcomes (determinant frameworks, classic theories, implementation theories)
Determinant Frameworks	Specify types (also known as classes or domains) of determinants and individual determinants, which act as barriers and enablers (independent variables) that influence implementation outcomes (dependent variables). Some frameworks also specify relationships between some types of determinants. The overarching aim is to understand and/or explain influences on implementation outcomes, e.g. predicting outcomes or interpreting outcomes retrospectively
Classic Theories	Theories that originate from fields external to implementation science, e.g. psychology, sociology and organizational theory, which can be applied to provide understanding and/or explanation of aspects of implementation
Implementation Theories	Theories that have been developed by implementation researchers (from scratch or by adapting existing theories and concepts) to provide understanding and/or explanation of aspects of implementation
AIM 3	Evaluating implementation (evaluation frameworks)
Evaluation Frameworks	Specify aspects of implementation that could be evaluated to determine implementation success

2. Health Informatics Framework Example 1: DiCoT Concentric Layers Framework (DiCoT-CL)

2.1. Purpose of the DiCoT Concentric Layers Framework (DiCoT-CL)

Evaluating medical devices and a health IT in context is challenging. Technology is influenced by and influences the workflows, social settings, organizational contexts it is embedded within; also artefacts and equipment around it can impact its effectiveness and use. Further, it can be influenced by training, procurement, policy and technical configuration decisions that happen far away from its actual use. The DiCoT Concentric Layers framework (DiCoT-CL) [9] is a framework for investigating these issues.

DiCoT was a precursor to the DiCoT-CL framework. DiCoT (Distributed Cognition for Teamwork) [10, 11] facilitates the use of Distributed Cognition for analyzing sociotechnical systems. Distributed Cognition [12] focuses on the transformation and propagation of information in sociotechnical systems. The DiCoT

Concentric Layers framework (DiCoT-CL) [9] builds on DiCoT by focusing on how technology is coupled to different layers of sociotechnical context. DiCoT and DiCoT-CL help analysts investigate the underlying information architecture of a sociotechnical system, within which a technology is embedded.

DiCoT and DiCoT-CL have four proposed outputs: an understanding of the basic mechanics of the system, opportunity for deeper conceptual insight into the system, recognition of incremental design considerations, and more revolutionary design considerations [13]. For DiCoT-CL, Furniss et al. [9] argue that further insights can be gained by looking within and between the concentric layers of the sociotechnical system. Also, the framework can help provide micro-level insight (e.g. specific issues at the interface) and macro-level insight (e.g. problems with the way the device was configured when it was purchased months or years previously). The ultimate purpose of DiCoT-CL is to identify issues and make recommendations for improving the technology and the sociotechnical system it is embedded within.

2.2. Component Parts and Development of the DiCoT-CL Framework

The beginning of DiCoT stems from Furniss' master's thesis in 2004: *Codifying Distributed Cognition: A case study of emergency medical dispatch*. The output of this research was an analysis of the London Ambulance Service control room using Distributed Cognition [11] and the DiCoT method [10]. Distributed Cognition is promising for the design and evaluation of technology in practice. However, it has not been adopted as widely as one might expect. Some believe that this is due in part to a lack of an off-the-shelf method and analytical support. DiCoT helps to fill this gap. Furniss and Blandford (who supervised the earlier thesis) have continued work on DiCoT together and separately with master's and doctoral students, and involving external research teams. Of particular note is Rajkomar's 2014 PhD thesis summarized in [14]. He proposed further details on how tasks are distributed over time and how this impacts distributed cognition [15]. DiCoT has also been applied in intensive care [16] and medical equipment library design [17].

The critical breakthrough for creating DiCoT came from combining the theoretical literature on Distributed Cognition with the methodological structure and advice from Contextual Design [18]. The idea of analyzing the sociotechnical system through creating interdependent models of the context came from Contextual Design, but the models were adapted to suit the themes that occurred in Distributed Cognition.

DiCoT has five main models: the information flow model, the artefact model, the physical model, the social model, and the evolutionary model. Each model has associated principles that have been distilled from the Distributed Cognition literature. These principles guide analysts to reflect on aspects of Distributed Cognition in data gathering and analysis. Questions that arise through reflection might include, for example, the following: Is there an "information buffer" that holds information for later use? What processes filter and change information? Is "situation awareness" good and why? How does the 'physical arrangement of equipment' impact information processing?

DiCoT-CL [9] was developed relatively recently by Furniss, Blandford, and others. It adds concentric layers to the original DiCoT framework, so that layers of sociotechnical system can be analyzed around a technology, e.g. a device and user at the center, then the device's use at the bedside, then its use at the ward level, then at the hospital level. Furniss performed an analysis of the design and use of a modern in-

patient blood glucose meter [19]. The focus on evaluating this medical device made it apparent that it was coupled to different layers of context. Conceptually this resonated with Grudin's [20] view of the computer reaching out. Furniss et al. apply this idea to conceptualize the medical device reaching out from interface issues between the device and the user, to issues at the bedside, to team issues at the ward level, to management issues at the hospital level [9]. DiCoT-CL adds concentric layers to DiCoT's five models. Figure 1 shows the different layers around the user-device interaction at the center, how each layer is divided into five segments, and where features of a sociotechnical system appear in the framework.

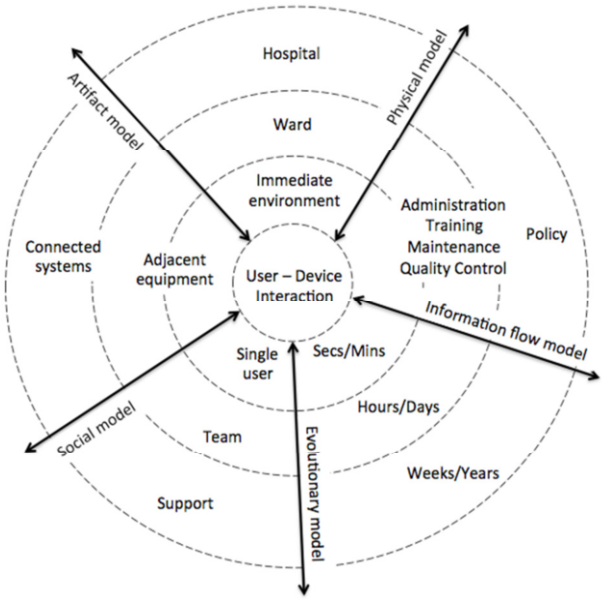

Figure 1. The DiCoT Concentric Layers (DiCoT-CL) Framework.

There are different centric layers around the user-device interaction, which is at its core. Each pie-shaped segment represents a different model. From the top, moving clockwise round, we have the physical model, the information flow model, the evolutionary model, the social model and the artefact model (reproduced from [9]).

DiCoT and DiCoT-CL have been built up through successive case studies. These case studies have mainly involved fieldwork, in which the design and use of technology has been evaluated in context, using observations and interview data. In each case study, the analyst who applies the framework often not only reflects on the results, but also on the applicability of the framework. Sometimes there is reason to add to the framework, e.g. an extra theme and more principles (e.g. [15]), and sometimes the emerging data and theory suggest new forms for the framework, such as the addition of concentric layers in DiCoT-CL.

2.3. Testing and Validation of the DiCoT-CL Framework

Development and testing of the framework has been iterative. Berndt et al. [21] report a case study that compares the learning and application of Contextual Design with DiCoT in the same setting, i.e. information flow in anaesthesia. Their results suggested that Contextual Design was easier to learn, but DiCoT encouraged deeper insights in this complex setting. Others have used DiCoT successfully in different contexts. For example, it has been used to analyze the work of agile software development teams [22], and the processing of patients within a hospital [23]. DiCoT-CL is a new development and has only been used in one case study [9, 19]. Further case studies will be developed to test the addition of the concentric layers to DiCoT. Future work will review original DiCoT principles to ensure they are well-structured and comprehensive, develop the social and evolutionary models, and provide training materials for the framework.

2.4. Example of How to Apply the DiCoT-CL Framework

When first engaging with complex sociotechnical systems, it is easy to get overwhelmed with information, particularly when new to the system. DiCoT helps to guide the analyst on where to focus data collection. The following example describes how to apply the framework in the field via an example evaluation of a modern inpatient blood glucose meter in an oncology ward [9]. This walkthrough is broken into three stages, and employing the framework will depend on familiarity with these stages.

In the first stage, the author [DF] shadowed a nurse to see what she did in relation to the blood glucose meter. She picked up the blood glucose meter reader, retrieved a case with its other paraphernalia inside, and started to do a quality-control check. The author noted down the detailed steps of this process and the equipment used as best he could in field notes, while asking questions at opportune times. This stage revealed preliminary task steps for an information flow model and notes on equipment use for the artefact model. The author then followed the nurse to do a blood glucose meter reading with a patient, and similarly, made careful observations and notes. Finally, over successive observations, the author observed, asked questions, and gathered more information and filled in these partial models and descriptions.

As a beginner one can work through the five DiCoT models to develop a description and schematic diagrams, e.g. an information flow diagram, a sketch of the device's interface, and the layout of equipment around a patient's bed, while reflecting on how this configuration of the system impacts its effectiveness and whether it could be improved. These models are developed iteratively. Through each iteration, describing the system via the models reveals gaps in understanding. Sketches will generate new questions. Further observations will reveal new issues, and the principles will encourage the analyst to think in different ways. DiCoT-CL will reveal areas where data is lacking. As the complexity of the picture builds up, intricate dependencies emerge between the models, which challenge the idea of a decomposition into separate models as in the first stage.

For example, an observation of a healthcare assistant lending a student nurse his or her personal barcode to use the blood glucose meter touches on the social, artefact, and information flow model. So, in which component model does this go? It doesn't really matter at first. What matters more is that this part of the process is noted and included

somewhere to start with; the models collectively build a picture rather than any one standing alone.

Once the analyst has more of a grasp of the framework in the context, she or he can refine and formalize the models. For example, DiCoT-CL revealed that the author had not applied the information flow model at the ward level, but what did this mean for the glucometer evaluation? Healthcare assistants had been observed writing bed numbers they had to attend to on tissue paper and cardboard trays as part of a blood glucose meter 'round'– and this seemed to belong within the information flow model. This highlighted that the device only supported single glucose readings; it did not support the user in doing multiple readings across the ward; such functionality could be a future design consideration. Here a reflective conversation between the data, the models, the principles, and within and between layers of DiCoT-CL can help drive new insights. Tensions between the data and the framework could also lead to its development, as noted in [15] above.

2.5. Limitations of the DiCoT-CL Framework

DiCoT-CL emphasizes the complex connections that a device or technology has with the context in which it is embedded. Therefore, there is some tension between emphasizing the context-dependent nature of a device within a specific context, and trying to evaluate its performance across different contexts. When evaluating technology across contexts the significant context-dependent features that impact the design and use of a device need to be recognized and managed.

3. Health Informatics Framework Example 2: Clinical Adoption Framework (CAF)

3.1. Purpose of the Clinical Adoption Framework (CAF)

The Clinical Adoption Framework (CAF) is a conceptual framework used to evaluate health IT adoption in healthcare organizations from a sociotechnical perspective [24].[2] The CAF represents health IT adoption as having three interrelated dimensions at the micro, meso, and macro levels. At each level, there is a feedback loop that can lead to further changes from the effects of the initial adoption. There is also a feedback loop across levels such that the adoption and effects at one level can influence the other levels. A basic premise of the CAF is that health IT adoption and its effects are not deterministic because they are dependent on the dynamic interplay of the factors within and across the three dimensions over time. Figure 2 shows CAF (source: http://ehealth.uvic.ca/methodology/models/CAF.php).

[2] See also: B. Kaplan, Evaluation of people and organizational Issues – Sociotechnical ethnographic evaluation, in: E. Ammenwerth, M. Rigby (eds.), Evidence-Based Health Informatics, Stud Health Technol Inform 222, IOS Press, Amsterdam, 2016.

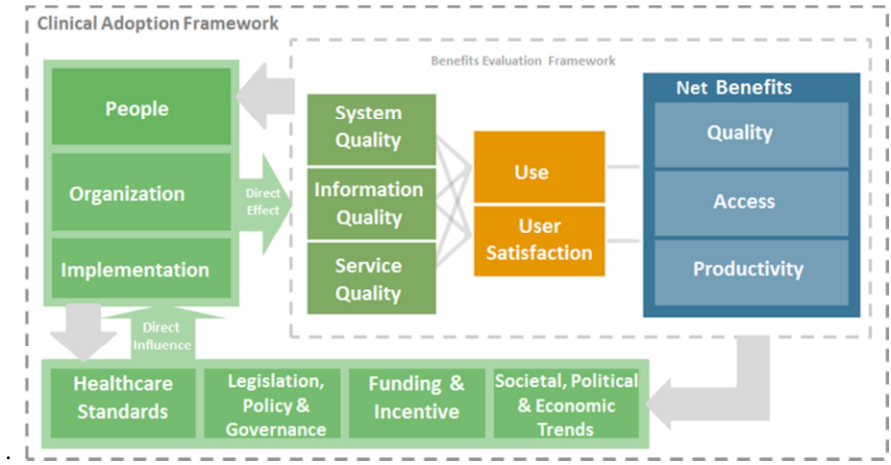

Figure 2. Clinical Adoption Framework.

3.2. Component Parts and Development of the Clinical Adoption Framework

The CAF is an extension of the Infoway Benefits Evaluation (BE) Framework that takes into account the contextual factors which influence health IT adoption. The BE Framework was created by Lau, Hagens & Muttitt (2007) to describe health IT adoption at the micro level by focusing on the health IT quality, its use and satisfaction, and net benefits [25], for Canada Health Infoway, a non-profit organization funded by the Canadian governments to accelerate the deployment of interoperable electronic health record systems (EHR) and ehealth solutions.

The BE Framework is an adaptation of the well-known Information Systems (IS) Success Model created by DeLone & McLean (2003) for business organizations [26]. One shortcoming of the IS Success Model is that it does not address the socio-organizational aspects. To account for these contextual factors, the CAF incorporated the meso and macro level dimensions with key measures from the Information Technology Interaction Model by Silver, Markus, & Beath (1995), the Unified Theory of Acceptance and Use of Technology Model by Venkatesh (2003), the Organizational Change Management Model by Kotter (1995) and the Health IT Risk Assessment Model by Pare, Sicotte, Jaana, & Girouard (2008) [27, 28, 29, 30]. The micro, meso, and macro dimensions of the CAF, the categories of measures in each of these dimensions, and an explanation of to what these measures refer are briefly described below in Table 2. Detailed explanation of the dimensions and measures are in Lau, Price, & Keshavjee (2009) [24].

Table 2. Dimension Levels and Measures of the Clinical Adoption Framework.

Dimension Level	Categories of Measures in the Dimension	Explanation of Measures
Micro	Quality of health IT	Accuracy, completeness and timeliness of the information, performance and security of the system, and responsiveness of the support services
	Use of health IT	Intended/actual health IT usage, user competency, and satisfaction in usefulness and ease of use
	Net benefits of health IT	Care quality in safety, appropriateness and effectiveness, access to care through provider/patient participation and service availability, and productivity in care coordination, efficiency and net cost
Meso	People	Individuals/groups, their characteristics and expectations, and roles and responsibilities related to health IT adoption
	Organization	The fit between health IT and the organization's strategy, culture, infrastructures, processes, and value.
	Implementation	Implementation refers to health IT adoption stages, project-management approaches, and extent of health IT-practice fit
Macro	Governance	Roles of governing bodies, legislations, and advocacy groups on health IT
	Funding	Remunerations, payments and incentives that influence health IT adoption
	Standards	health IT, organizational performance, and professional practice standards in place
	Trends	Public expectations, and socioeconomic and political influence on health IT

3.3. Testing and Validation of the Clinical Adoption Framework

The CAF underwent three testing/validation steps during its initial development. In the first of these, in 2009, Infoway held a *consultation session* with 23 health IT practitioners from across Canada to invite feedback on the CAF. The practitioners responded to whether the framework made sense, if concepts were missing or needed revisions, as well as their interest and effort needed to apply the framework in their organization. Based on the feedback, revisions were made to streamline the framework into its current form (Charlebois 2009) [31].

In the second, Oh (2009) [32] compared the CAF measures against 16 *published survey instruments*. They included 13 instruments from the Health IT Survey Compendium section of the Agency for Healthcare Research & Quality (AHRQ) Health IT website (AHRQ, 2010) [33] and three from Canada Health Infoway. Of the 16 instruments examined, only the Infoway System and Use Assessment Survey items mapped to all 20 micro-level measures. At the meso level the 16 instruments mapped between 0 and 11/12 of the measures. At the macro level they mapped poorly from 0 to 5/12 measures. No question items were found missing from the CAF which suggested it was sufficiently comprehensive for all aspects of HIT.

In the third, in a *meta-review* of 50 systematic reviews of health IT evaluation studies published in 1995-2008, Lau, Price, Kuziemsky & Gardner (2010) [34] mapped most of the evaluation measures from the published reviews to the micro-level of the CAF. They also identified measures that did not fit the micro level and created new categories which were patient/provider, implementation, incentive, policy/legislation, change improvement and interoperability. These factors mapped nicely under the meso and macro dimensions of the CAF.

The testing/validation results showed CAF has face validity as a multi-dimensional scheme. Therefore, CAF can be used to describe, understand and evaluate health IT adoption and its effects in healthcare organizations. Since its publication in 2009, the CAF has been applied, adapted, or mentioned in over 30 health IT related studies.

3.4. Example of How to Apply the Clinical Adoption Framework

The following example is to further demonstrate how the framework could be applied. The CAF was applied in a six-month post-implementation study of an electronic health record system (EHR) in two ambulatory clinics managed by a health region in a Canadian province [35]. The implementation of the EHR in these clinics represented the initial phase of a long-term plan by the health region to adopt EHRs in all of its ambulatory clinics throughout the region. The purpose of the study was to evaluate the impact of EHR adoption on the organization in order to guide subsequent implementation effort.

Four university researchers conducted the study over six weeks. They used a rapid evaluation method to examine selected micro and meso components of the CAF. The selected CAF components were deemed relevant and feasible by the researchers and clinic/IT executives given the stage of EHR adoption effort at the time. At the micro level, CAF components covered the EHR system, information and service quality, EHR usage and user satisfaction, and net benefit in terms of EHR-supported care coordination and efficiency were examined. In particular, system quality covered EHR functionality and usability; information quality covered EHR data accuracy, completeness and consistency; service quality covered EHR staff knowledge and responsiveness; and usage covered actual EHR use and its perceived usefulness. At the meso level, CAF components covered people, organization and implementation aspects for the clinics involved were examined. People covered clinic and EHR staff roles, expectations and experiences. Organization covered EHR-health IT infrastructure, strategy and process. Implementation covered EHR deployment process and EHR-practice fit.

The rapid evaluation method is a pragmatic field evaluation approach developed by the researchers as part of their eHealth evaluation research program. The method consisted of an EHR adoption survey, user assessment, usability/workflow analysis, document review, project risk assessment, data quality review, and group reflection [36]. Data collection took place over four weeks that included concurrent review of project documents and EHR data. EHR support staff organized interviews, assembled relevant documents, and extracted EHR data for the researchers. Notes taken during the interview, usability/workflow and focus group sessions were summarized and analyzed for common themes. The evaluation report was finalized in the last two weeks of the study

Forty-three participants took part in the study that included clinicians and support staff from the two clinics, EHR support staff and health region executives involved with the project. Over four weeks the researchers completed 12 EHR adoption surveys, 14 usability/workflow sessions, 13 user assessment interviews, 11 project risk assessment interviews, 3 focus group sessions, and reviewed 65 project documents and 3 months of EHR data.

The study found that clinic staff perceived benefits in EHR-supported care coordination and efficiency, despite challenges stemming from early suboptimal deployment decisions surrounding EHR configurations, user training, clinic workflow,

data quality assurance, and data exchange with the regional EHR, which negatively impacted clinical work. For example, during the study, clinicians had to work with fragmented charts because some clinical documents were stored in the regional EHR, which required separate logins. The EHR had no mechanism to indicate whether a document was available or where it could be found. As a result, clinicians had to create workarounds that led to inconsistent EHR use. The researchers emphasized that the study represented only one point-in-time after the EHR was implemented in the clinics. Therefore, the attitude of the clinic staff toward the EHR could change over time if and when the identified issues were resolved. Overall, the CAF had proved useful in making sense of ways that EHR could add value to the organization.

3.5. Limitations of the Clinical Adoption Framework

The CAF is a complex scheme with multiple dimensions, categories, and measures that can be difficult to understand and apply in practice. More work is needed to explain and refine the respective components in ways that are relevant to practitioners involved with health IT adoption and evaluation. Second, there is little guidance available on how one should apply the CAF when studying health IT adoption. Having a how-to guide on the types of study methods and measures that can be used to examine health IT in a specific setting could facilitate its uptake in practice. Third, the CAF is new and has only been applied in a limited number of evaluation studies thus far. To be credible more studies are needed to demonstrate its validity and utility across different settings.

4. Conclusion

In the practice of evidence-based health informatics, the development of a framework, as well as its use in a live setting for real-world purposes must be conducted rigorously. A mix of expert consensus and some empirical observations rather than theory may be the basis for a new framework. Or vice versa. However, the important questions are what sort of expertise and how many experts were involved in its development? How many direct observations were made, in how many iterations, and in how many settings? Were validated theories or process models employed in the development of its components, as it was iteratively developed? How mature is the framework: How many times has it been put to the test in the field to guide the process that it purports to describe? Or, has it been used retrospectively to evaluate the completeness and/or success of that process? What were the outcomes of these efforts?

By their nature frameworks can be rigorously developed, yet how to employ them – where to start and what to do – is not always clear-cut without additional explanation or guidance materials. In addition to reading available literature and documentation, a suggestion is to contact the framework's developers. Request a discussion about the purpose of the framework and its parts to ensure that it is useful for the intended purpose, in the context in which it is to be applied, and how to use it effectively.

Recommended further readings

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2. Holden RJ, Carayon P, Gurses AP, Hoonakker P, Hundt AS, Ozok AA, et al. SEIPS 2.0: A human factors framework for studying and improving the work of healthcare professionals and patients, *Ergonomics* **56**(11), (2013), 1669-86. Note: A framework that represents work system structure, process, and outcomes. Used to evaluate specific existing work systems, plan work system (re)design, and structure research data collection and analysis.
3. V.L. Patel, T.G. Kannampallil, R.R. Kaufman (Eds.) *Cognitive Informatics for Biomedicine: Human Computer Interaction in Healthcare*, Springer, Switzerland, 2015. Note: Addresses gaps on the applicability of theories, models, and evaluation frameworks of human computer interaction (HCI) and human factors for research in biomedical informatics.

Food for thought

1. Which classic theories are employed in development of the frameworks presented?
2. Could any of the frameworks presented here be considered Implementation Theories according to Nilsen's definition? Why?
3. Are you familiar with other health IT frameworks? For what purpose are they used, and how would you classify them according Nilsen's five categories? Why?

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