Faithful to the Earth*: Reporting Experiences of Artifact-Centered Design in Healthcare

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Abstract In this paper we report about two design experiences in the domain of healthcare information technology that shed light on the advantages of getting rid of complex and abstract representations of hospital work and of concentrating on the artifacts that practitioners habitually use in their daily practice. We ground our approach in the recent literature on the often unintended shortcomings exhibited by healthcare information systems and propose a lightweight method to support the phases of requirement elicitation and functional design. We then discuss the main requirements expressed in our recent research activity and provide examples of how to address them in terms of modular and artifact-centered design solutions.

Background and Motivations

In this paper we report on two design experiences that we had in two different hospital settings: a Medical Oncology and Haematology Unit (MOHU) and a Medically Assisted Procreation Unit (MAPU) in a large hospital in Northern Italy. The task we were assigned to as requirement analysts was slightly different for either settings: the MOHU was involved in a process of digitization of its paper-based drug ordering system; this was based on a very well structured paper-based patient record that supported the management of approximately 15,000 hospitalizations yearly and that had been progressively and collaboratively optimized by both doctors of the MOHU and druggists from the hospital pharmacy. The MAPU, one of the most efficient units of the country with approximately 3,500 admissions yearly, was in the process of adopting a new Electronic Patient Record; this was supposed to substitute a simple, but very effective, homemade database that had been designed by the head doctor himself and had been used for 12 years in the unit

*Friedrich W. Nietzsche, Thus Spoke Zarathustra, Prologue, 3 (*bleibt der Erde treu*).

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with general success. Both experiences motivated us in focusing on the delicate task that business and system analysts face when they are involved in the development of a software application that is intended to support healthcare practitioners in hospitals, e.g., an Electronic Patient Record (EPR) or any other collaborative healthcare information technology.

Healthcare Information Technology (HIT [1]) is an umbrella expression that includes widely different solutions, ranging from bar coding, picture archiving systems, order-communication systems, medication systems and EPRs, which often integrate several of these technologies. With respect to other organizational domains, system analysis towards the deployment of new HIT is a very delicate task, also because this usually implies the full replacement of a multi-purpose, multi-user, composite "folder" of paper-based documents, reports, charts and forms that, as a whole, has evolved over the last century to a degree of success in supporting clinical work that no HIT to date has been able to match [2]. In fact, it is now well recognized that HIT can make hospital work easier as well as harder [3], smarter as well as unsafer [4], cheaper as well as costlier [5], slower as well as faster [6], in short: better as well as worse [7]. In any case, HIT has the power to change care provision and hospital work in ways that are not always free from critical and unintended consequences [8]. In fact, despite the hype that usually surrounds the initiatives of HIT deployment, its promises for a safer, more efficient and effective healthcare have so far fallen short of expectations [9]. In the spirit of Illich [10] a new term has been recently introduced, namely technological iatrogenesis (or e-iatrogenesis), to describe the technology-induced harm to patients caused by the introduction of superimposing HIT systems that disrupt practices and trouble care providers in complex healthcare settings [11]. A mischievous observer could annotate that in the last 5 years researchers have been courageous to see the HIT King naked. It has been reported that roughly 75% of all large IT projects in health care fail [12]. In this paper we will not try to re-formulate the ever-valid question of Grudin [13] and examine "why HIT applications fail". Rather, we found it interesting that one of the main problems identified by Grudin with multi-user applications, i.e., what Norman would rephrase as simply "bad design" [14], has been restudied by sociological studies in the HIT domain claiming that a devious obstacle to the full success of EPRs are the *models* on which EPRs are based [15]. In fact, abstract models are an easy suspect, since to our personal experience as analysts in some of the largest IT projects in our region, roughly 100% of large IT projects are initiated on the basis of complex abstract models delivered in the phases of business modeling and requirements analysis. Yet, for the healthcare domain, suspicions could be better-grounded than for other organizational domains.

Generally, the importance of abstraction and modeling in software development is well recognized: abstract models facilitate the interaction with users in eliciting requirements and embedding them in the design [16] since they allow to conceive of programs in terms of user-centered functionalities, rather than the mere capabilities of the computing environment [17]. On the other hand, as candidly and wittily expressed in the Spolsky's Law ("All non-trivial abstractions, to some degree, are leaky" [18]), models can be ambiguous, incomplete, internally inconsistent, prone to fast obsolescence or just plain wrong. More suggestively, in the CSCW domain Robinson and Bannon wondered if complex and abstract models, by which work processes are represented, information needs and functionalities would not just end up by contributing in "automating a fiction": "The language of work is abstracted in a language of representation, useful to analysts. This is transformed again into an abstract formalism, chosen for its usefulness to the system implementers. The resulting system is then imposed on workers/users, taking a critical perspective, and changes the nature of the work that the representation was built on. This is a cycle that has clear potential for catastrophic change via a positive feedback loop" [19, p. 223]. Also in the organizational literature, the point is made that "Embedding fully-fledged and logically refined models in [*…computer-based*] tools […] is not necessary – worse, they would more likely than not obstruct the work they are intended to 'support'".[1] In particular in the domain of HIT, sociological contributions suggest that the models underlying the EPR design contain a rationalistic projection of hospital work, which does not match how health practitioners actually work in a ward. Accordingly, to fill the gap between theory and clinical practice, researchers from the ICT communities who are more sensitive to the sociological debate (e.g., CHI and CSCW) have recently proposed methods for user needs analysis and requirement specification that call for a design process that is more collaborative [20,21] and involves users as well as human factor specialists [22]. Yet, other researchers question if the very objects of abstraction in healthcare, i.e., medical knowledge and clinical practice, can be modeled at all, irrespectively of whether HIT models are used in the closest collaboration with health practitioners [2].

But even so, if "logically refined models are not necessary", we address the following research question: *what could be an alternative and appropriate design approach to HIT*? To this aim, we share with Berg and Toussaint the point that models have to be "repositioned" in the HIT development process starting from the observation that documents and forms in regular paper-based records are only parts of a socio-technical environment where physicians, nurses, patients, organizational routines, all play their role in constituting memory of interventions and coordinating work [23]; in this view, artifacts need only to "cover their part", i.e., hold inscriptions and allow their manipulation, while their electronic counterparts do not need to embed any explicit and entity-based model to reflect and bridle the intelligent behavior that healthcare practitioners bring to the scene (or, better yet, let *emerge*) by using the record. Thus, determined to unearth the hidden "wisdom of artifacts" and persuaded that "doctors do not (want to) play the model game", we have applied a method that derives the information structures and conceptual operations of an EPR, by avoiding the construction of abstract models representing either work processes, information flows between actors, distribution of responsibilities (i.e., roles) or the mutual relationships between tasks, roles and data. Rather, we

[1] Technology in working order. Studies of work, interaction, and technology (Eds: Button G), Routledge, London, 1993, cited in [2].

have tried to examine “what the record does” [23], how its internal structure works in sequencing the work of health practitioners – as a workflow system avant-la-lettre [23] – how its fields and boxes act as reminders and ordering systems [24] of relevant information, how its affordances succeed in evoking pertinent knowledge in the minds of practitioners. This approach leads to adopting a real bottom-up approach that recognizes that artifacts used in healthcare are usually the result of a long-lasting, collective, experiential and almost unconscious design process, which is made up of attempts to improve how physicians document their decisions, represent illness trajectories [25], retrieve facts and interpretations, or cooperate with their colleagues [26]. In the next section, we explain what we mean about artifact-centered and bottom-up approach and provide some detail of the informal method we employed in our last field study. Then, in Section Reconciling Requirements and Artifacts, we will interpret the main requirements we collected in our research activity in the hospital domain in light of the artifact-centered approach, and we will report how this led us to conceive a framework we propose for the design of innovative EPRs and document systems in organizational settings. Section Summing Things Up discusses and summarizes the main findings of our research.

From Entities, Back to Artifacts

According to Silverston [28], there are two general approaches to the understanding of a domain and to the conception of its supportive software systems: the so called top-down and bottom-up approaches. They can be used combined or in some sort of integrated manner, but due to their profound differences, each approach polarizes system design in ways that are substantially irreducible.

In the top-down approach the design process starts by specifying an abstract model of the global system and what information flows take place within and outside the system. In the organizational domain, the model necessary has to include the users’ milieu, and to this aim, it is (hopefully) built by interacting with the so called “domain experts” or “key users”. On the basis of the experts’ accounts and their good resolutions to improve practices, top-down designers get a picture of how practitioners should produce and consume data, and then formalize that picture into a list of necessarily pigeonholed and often very fine-grainedly defined entities, which the application (e.g., the EPR) will represent in its internal state and whose mutual interactions it will support by corresponding functionalities. To bear witness to the success of the top-down approach, it is sufficient to say that the methods proposed in the 1970s to both support data modelling [29] and structured programming [30] are by far the most widely and pervasively used in everyday requirement analysis and design. In regard to data modelling, for instance, designers follow the top-down tenet whenever they take conceptual entity-relationship models, and thorough a series of normalization techniques [31], they build the logical model of software applications and identify the main tables and constraints of the data base underlying these applications, as well as the main functionalities to access and manipulate their data. In this view, top-down approaches can also be called entity-centered approaches, since their main objective is to identify what (types of) entities are involved in a work setting (with either an active or passive role), to translate these entities into computational counterparts (i.e., classes and objects) and to design (and implement) interactions between these entities so that their "proxies" in the field of work (that is, the human users of the computational system) can manage and perform parceled tasks more efficiently.

This, in our opinion, outlines the first and foremost difference with bottom-up approaches in the analysis of collaborative domains as we intend them. In fact, we refer to bottom-up approaches (in system design[2]) to denote those methods that first of all, focus on the concrete artifacts that are used within a work arrangement to specify their requirements and capabilities; and that then, build a system of digital counterparts of the artifacts, which are augmented to some respect in the assumption that the complex behavior of the overall system will emerge out of interactions among its components and between components and the environment. Since in this approach artifacts are both the starting point and the final result of the digitization project, for us to say bottom-up is equivalent to say "artifact-centered". An artifact-centered approach is a method that is aimed at understanding, for each single artifact used in a work arrangement, its structure; its scope (i.e., what it is about) and aim (i.e., what it is used for); the duties and expectations its users have about it; how it works (i.e., its functions and operations), and how it can be (computationally) improved in supporting duties and in satisfying expectations; in short, we mean an artifact-centered method as aimed at (i) understanding the artifact's current and intended role within the *web of artifacts* [32] and resources that practitioners can use in their daily practice to get things done; and (ii) translating this understanding into precise functionalities that embedded in the artifacts and associated with precise uses or contexts of use, either enable, promote or augment human behaviors that *fit* into their work practices [53]. For all these reasons, despite the name, such an approach does not focus only on the *materiality* of artifacts, but rather on the "artifacts in use", i.e., on those objects that, intended to reify processes and their articulation, have come to congeal experiences, conventions and practices of participated and situated collaboration into "thingness" [52]. As other approaches that are more overtly user-centered (e.g., [27]), ours also observes and focuses on what users do, and how; but it also differs in that it focuses on *what* users use, and how, without relying much on users' accounts of work or on any representation (either mental or iconic) of their practices that cannot be traced back to some activity on artifacts. In other words, this approach is user-centered in that it addresses *their*

[2]We are then not referring to the general meaning that "bottom-up" has in strategies that are mentioned in methodologies of either relational schemas drafting, model integration or procedural programming; in these contexts strategies are called bottom-up in that they, respectively, integrate small portions of a conceptual model into a bigger/more abstract one, or support the construction of complex software applications from smaller modules (as it is common in Object-Oriented programming).

(emphasis intended) actual tools but it is also artifact-centered since it tries to minimize design misunderstandings coming from either unfocused observations of (too) complex behaviors, polarized descriptions of work (since users can be even more biased than ICT designers in narrating their own work or they can be just wrong in good faith) or too abstract and polished representations of work (since any explicit representation is only about the "thing", it is *not* the thing).

Obviously, no approach can be deemed perfect per se: both entity- and artifact-centered approaches can indeed present known shortcomings. Integrated approaches that take both into (some) account are probably the best choice in most cases, *once* designers have understood what the main pitfalls to avoid are and what they are prepared to trade off for the success of the project. For instance, artifact-centered approaches can "complicate" information retrieval that is performed outside the tasks that usually operate on artifacts; the same holds true in regard to post-hoc data organization according to grouping criteria that are orthogonal with respect to the artifact structure; also information sharing with external information systems can be complex to achieve in strict artifact-centered approaches. These limitations are mainly due to the fact that data structures and values in artifact-centered design can be hardly abstracted from their local context of use (i.e., the artifacts containing them) and that standard-compliant data models can be hardly subsumed when data definition and semantics is driven according to actual and locally agreed artifacts. In other words, strong points of this approach towards technologies that are smoothly included in a local and peculiar setting can play against the compatibility of these technologies with other standard systems, unless additional effort is paid toward the development of proper wrappers and extractors of the artifacts' content.

On the other hand, entity-based approaches lay ICT projects open to other risks. In regard to standardization, model reconciliation in healthcare and the adoption of common classifications towards better integration are still a highly debatable issue (e.g., [33,34]). Model-based approaches usually lead to embed entities' fixed characteristics and the associated business rules (i.e., what to do with data, what they are for) into the data models and the application logic, respectively; this can make even small changes in either entities, information flows or processes unfeasible, since changing the underlying model would require large changes in the underlying database and in the application logic of information systems. Moreover, top-down approaches are usually accomplished on a dialectical and speculative level: that is, designers reconstruct the relevant entities involved in work practices on the basis of narrations told by relatively few key-users, which often unawares tend to depict practices as they *should* be performed rather than how they *actually* are. For this reason, the reliability of entity-based data models can be jeopardized whenever important entity types are not identified, are incorrectly characterized (e.g., in terms of attributes and their formats), or just change some of their aspects over time [35].

It's All a Matter of "Observance"

In order to enable the development of an EPR at the MOHU and MAPU, we organized our analysis in three steps: for convenience we can call them

– Artifact reconstruction
– Mapping between artifacts and functionalities
– Mapping between content and behaviors

The intended goal of the first step was to get the structure of the artifacts and the type, attributes and main characteristics of the information they contain. To this aim, we proceeded using a list of open questions that supported both the interviews with key representatives and the observations we undertook in the hospital units (see Fig. 1). At the end of this first step, we identified all the relevant artifacts used in the ward; in particular, through questions no. 1 and 2 we agreed with the practitioners on meaningful ways to partition the artifacts into "building blocks", i.e., portions that group together inscriptions and fields that pertain to specific aspects of patient health and care. For each of these portions we also specified its "local" schema, i.e., data types, conventional value ranges, intrinsic constraints and access rights (cf. question no.3).

In order to balance an objective but still external approach with a subjective and informal view "from within", we administered an anonymous and brief questionnaire in which all doctors and nurses were asked to informally assess on a five-point scale the frequency of use and the perceived "importance" of each artifact identified. This provided a coarse feedback on what artifacts could be simply abandoned or integrated in others in the digitization process and also on what would be a

1) What sections can be detected in the artifact? What fields and inscriptions can be grouped together as pertaining to the same aspect of the patient's health and care process?

2) What are the constraints (if any) regarding the artifact sections/fields in terms of either type, value range or mutual consistency (with other sections/fields of possibly other artifacts)?

3) Who can write what in the above detected sections? More generally, what role(s) can use the artifact (either by reading or writing)?

[...]

12) Does the artifact contain data that must be replicated into some other artifact, or data that can be used for some aggregate or summary report (e.g., a weekly or monthly report)? Conversely, is some field of the artifact supposed to contain entries that are either duplicated or directly derived [34] from other artifacts?

13) What are the relevant conditions (on data or their absence) that practitioners must be aware of, or alerted/reminded/warned about, also according to the context (e.g., according to what time it is, or if an exam report has become available)? What practitioners should do in virtue of awareness of these condition?

14) Can the artifact be annotated by practitioners or contain explicit references to other artifacts/documents/media (e.g., exam reports, digital images).

Fig. 1 Excerpts from the check-list used for the artifact reconstruction. The full list is available at http://www.gl-iss.org/woad/checklist.htm priority (and, at the same time, delicate) objective for digital replacement; for instance, from the survey, we found evidence that one shared artifact between nurses and physicians was particularly important for their mutual collaboration, i.e., the Drug Order Form; further inquiring into user habits for this artifact helped us understand that constraints regarding authorized access and writing rights should be flexible enough to allow for occasional rule infringements. Moreover, we received confirmation that the artifacts that were less structured and more independent from schedulable tasks for either professional categories (i.e., the Doctors' Diary DD and Nurses' Notes NN) were instead the most important ones which were most often used in daily practice. For its role in providing cues and starting points for further discussions, the survey also helped us in gaining trust from the "shop floor" staff in that they perceived that their opinions, even if highly qualitative, were taken into consideration by the "ICT guys".

The second step was aimed at understanding what actors do with their records, whereas just 'reading' and 'writing' is certainly restrictive. In this step, we then built a mapping between each meaningful portion of each artifact and any behavior we found applicable from a set of elementary operations that were inferred from direct observations of artifact use (see Fig. 2). We speak of behaviors since these involve users (not only the computer system) and can be seen as the goal-oriented execution of sequences of elementary operations upon artifacts within a work context. The output of the second step is then a set of associations between each artifact and all the operations that users could (potentially) need to make either *about*, *upon* or *by means of* that artifact. To draw an analogy with the design of regular graphical user interfaces, it is as if we had the entries of the context menu for each screen (or frame) of a prospective application.

From the list reported in Fig. 2, it is clear that some of the behaviors more easily than others can be automatized in an information technology without the direct intervention or supervision of users (e.g., operations no. i, ii, vi, vii, viii, ix, x). Moreover, from the perspective of system design, operations can be combined in more complex procedures, which are possibly transparent to users; for instance, the affordance of a button by which users can open an artifact directly from another can be associated with the execution of the sequence `consolidate`, `retrieve` and `open`; a button at the bottom of a page by which the user can "save the page" with the sequence `write` and `consolidate`. Usual operations on the artifact's content

i) **create** (an artifact)	viii) **transmit** (*artifact/portion*)
ii) **retrieve** (artifact)	ix) **print** (*artifact/portion*)
iii) **open/read** (artifact)	x) **consolidate** (*artifact/portion*)
iv) **write** (portion)	xi) **annotate** (*artifact/portion*)
v) **select** (artifact/portion)	xii) **attach** (*artifact/portion*)
vi) **copy** (portion)	xiii) **cache** (*artifact*)
vii) **correct** (artifact/portion)	xiv) **store** (*artifact*)

Fig. 2 Elementary operations in artifact use. Detailed descriptions for each operation are available at http://www.gl-iss.org/woad/operations.htm

like “cut” and “paste” are combinations of `select, copy, write` (a blank) and `select, write` respectively. All things considered then, we see the identification of the associations between the artifacts (or, better yet, their parts) and what users may want to do with them (or may want the artifacts to do for them automatically), as a list of functionalities that are neutral with respect to how the electronic counterparts of the artifacts will exhibit them.

The third step of the method takes this list of functionalities as input and aims to identify an association between patterns of prospective content and the timely triggering of proper sequences of operations: these “associations” can be seen as a sort of *relations* between particular conditions upon both content and context (e.g., what time it is), and behaviors to exhibit in that particular case. Consequently, as output this step produces a list of modular and self-bounded if-then “bunches” of application logic that either triggers timely reminders and alerts, enables commands and operations at the GUI level or executes specific automatic tasks. For instance, a simple “workflow rule” after completing a form would be expressed (in any convenient language) in these terms: *if* ‘each portion of the form is filled in’ and ‘the user `consolidates` the form’, *then* ‘the system `transmits` the form to the Lab and (`creates/retrieves` and) `opens` an other specific artifact’. We will see more examples of conditional rules like this in Section Design to the Test of Ward Life.

Reconciling Requirements and Artifacts

In our field analysis, we employed the method described in Section It’s All a Matter of “Observance” the same way as we presented it, i.e., as a simple checklist not to neglect any relevant aspect of artifact use that could have an impact on the design of the EPR. Since the method has been developed almost ‘on the fly’ while it was experienced, it is not to be taken too strictly. Moreover, this method would have been of little value for us if we had not been able to interpret its outputs, i.e. the schema specification, artifact association with elementary functionalities/behaviors, and the rules for their automatical activation and promotion (respectively), in the light of the general requirements that we had come to identify in our research in the hospital domain (see, e.g., [36–38]).

During our observational studies, we saw doctors and nurses express the same request in many different but converging ways: i.e., the request for a tool capable of evolving with their practice, a tool to work *with* and *through* to pursue their professional goals, e.g. timely and accurate diagnosis, appropriate treatment, effective care. Conversely, in our informal conversations with doctors they all dreaded a tool that was customized once and for all, according to an abstract idea of their work, to work *on* and *for*. But how can this very general request be reflected in precise system requirements for successful HIT?

The analysis task undertaken at the MOHU allowed us to formalize 149 functional requirements and 250 information requirements; the analysis at MAPU detected 168 functional requirements and 1,694 information requirements of 29 different charts. Despite the relatively big numbers here involved, most of these requirements can be traced back to three main dimensions: Support, Autonomy, Flexibility. These dimensions stand for functionalities that, respectively, (i) support the use of information for both clinical activities and "secondary" activities (e.g., management, resource planning, billing, clinical research); (ii) preserve and enhance practitioners' autonomy and creativity; (iii) uphold the informality and flexibility typical of paper-based record keeping. In what follows, we discuss these three dimensions in some details.

Support (or, "fly me to the moon") This is a common-place requirement. Since HIT is Information Technology, and medicine is an information-intensive discipline, it is no wonder that health practitioners ask HIT to support them in producing and consuming better information in better ways. Notwithstanding, a tool conceived for the administrative side of hospital work (e.g., management) can turn out to be a double-edged tool for other ambits (e.g., care). Doctors and nurses are very aware that their primary job is to identify and solve health problems, to assist and cure patients; they often advocate the introduction of HIT in their setting by mentioning reports (e.g., [39]) that back up their own experience, claiming that in modern hospitals every hour of patient care requires up to 1 h of *paper*work. Too much. This translates into the often-heard requirement of health practitioners to relieve them of the burden of secretarial and administrative tasks and to give them back time to concentrate on the many clinical works that are invisible to formal registration (e.g., sentimental, negotiative, interactional, safety work [40]). In our field studies, we collected a series of requests that regarded operations performed on the artifacts that doctors envisioned could be accomplished by the EPR alone: e.g., to control whether charts were completely filled in and "go after" the defaulters; to create re-supply orders according to cancellations in the stock book; to arrange the scheduling of tasks and orders according to the availability reported in the daily schedule; to plan shifts and leaves according to workloads reported in the monthly schedule; to wrap up reports and accounts for local departments and regional agencies. Paradoxically (but only apparently), doctors would be the first ones to be surprised if designers proposed to talk about how EPRs could support them in the *care* of their patients. This ends up as a subtle lesson: doctors are not "asking for the moon" but, rather to "thrust (or better yet, unballast) their rockets" to reach it. Adopting an artifact-centered approach allows then to focus on the practitioners's real needs exactly where they originate (cf. step one of the method) and to address them with a composite palette of artifact-centered operations (cf. step two), which the system must be able to timely call and assemble together (cf. step three), quite like a scrupulous head nurse would do, but faster and completely error-free.

Autonomy (or, "oh, don't bother opening a ticket for that") Since no technology is (or remains for long) perfect, especially in a demanding and dynamic domain like hospital work is [41], several times practitioners expressed to us the need to be able to fine-tune and tailor HIT to their demands autonomously, i.e., without the direct involvement of either the HIT supplier or ICT professionals after the official release of the application, unless for failures or problems. This was mainly due to two overt reasons plus one which is more tacit. First, to obtain any kind of improvement or minor adjustment for a complex application (as EPRs are) usually takes a lot of time and bureaucracy. Second, it can be costly, since after-sales support usually only covers standard corrective maintenance, and any request for improvement is seen by HIT suppliers as a new business opportunity when not a pain. Third, doctors and nurses, since they are the closest users of the EPR, know all too well that their needs change over time, that they can fail to externalize them and that ICT professionals usually just do not get the point or insist on claiming that the small changes doctors solicit actually imply major interventions to the application. A do-it-yourself approach would be welcome by both professional categories as a panacea. But there is a subtle divide between fine-tuning, which usually designers interpret as the ability to configure predefined parameters, and tailoring an application to changing and extemporaneous demands, as requested by practitioners. More precisely, practitioners advocated the capability:

1. To modify the artifacts' *affordance*, in the widest meaning of the word, i.e., in terms of either how the interface looks like or what it allows users to do, on the basis of the continuous feedback from the field of work. This point regards the fact that when the patient record is made of paper-based forms and documents, doctors can tweak templates by themselves with programs that are widely known and require no particular ICT skill, such as regular word processors to, e.g., add a row to a table, move a field, insert a key or note, change an inscription. Obviously, for these modifications to become official and adopted in all the wards that have requested them, they must also be validated by the hospital management, and this can be more difficult than just changing the doc template. Yet we stress the importance of providing the practitioners with some capacity to "tweak" the interface: many of the practitioners we interacted with in our researches were in some way involved in the design of their paper-based patient record, or in its progressive tuning over the years; for some of them it was something as easy as printing drafts of templates and handing them out in the ward for validation. Others were also involved in official task forces organized by the top management to optimize how records had to look like also at the regional level. We believe that this involvement in co-building their own tools helped these practitioners in becoming more conscious users and more prepared interlocutors for both discussing and exploiting innovations in their work. The artifact-centered approach we described in Section It's All a Matter of "Observance" facilitates the parcellization of the interface into reusable "building blocks" (cf. questions no. 1–3 in Fig. 1), and thus it conceptually opens the doors to a solution where users can arrange their blocks into full-fledged forms, similar to users of a friendly DBMS who can build their own masks to the DB in a direct and visual way.
2. To formulate queries over the data stored in the patient record, both for managerial purposes and especially for research-oriented needs. This point regards how doctors formulate scientific hypotheses repeatedly as they see new cases (e.g., the idea to investigate the correlation between the odds of a negative outcome and the presence of a potential risk factor can flash more likely while discussing

a case presenting that risk factor). In these situations, practitioners found it natural to get a list of all the patients that in their records had a particular value in a specific field, i.e., to conceive conditions on clinical data where they were used to fill in these data. In other words, we observed how they preferred to reason more in terms of "fields" from forms and charts than in terms of entity attributes. Moreover, they formulated this extemporaneous kind of research questions with a frequency that would be unmanageable even if they just had to refer to the employees of the IT department to launch a standard query over the corporate database. Consequently, being autonomous in formulating queries calls for a technology that enables practitioners to build their data-centered queries in a visual manner, e.g., by picking fields from the artifacts they use more often and defining local inclusion and exclusion criteria on the values they can contain.

3. To create simple alerts and reminders that could be defined upon either data or particular recurring events, as well as to modify and disable those that for any reasons are not perceived as useful any longer. As in the case of record retrieval by field-based queries, we noticed that practitioners tended to associate these kinds of alerts and reminders with single fields and with contextual information that could be easily retrieved from the application (e.g., time, arrivals of messages and documents). This kind of local and conventional knowledge on how artifacts make sense in recurring situations is specifically addressed by the third step of our method where relationships between context and functionalities promoting awareness are made explicit. Once this knowledge has been externalized (also on the basis of question no. 13 in Fig. 1), the autonomy requirement for this calls for a solution whose complexity lays between that of reactive and computable components that are developed directly by end-users [43] and that of articulated parametric structures that, conceived at design time with the highest degree of flexibility, are then configured by the practitioners to build triggers on the basis of local conventions and extemporaneous needs [49].

Flexibility (or, "if it ain't written, there is a reason!") It is now common for researchers in healthcare to acknowledge that health practitioners can be "bad users" of HIT for very good reasons [44]. As also reported in [45], many practitioners confirmed to us that they feel uneasy in using a computer during health encounters, that it has the power to distract them from the point, that computers at the bedside can alienate the patient or worse yet, spoil the personal relationship between her and the care providers. Regarding urgent care, moreover, we also observed what has been reported in [46], i.e., that nurses tend to refuse to follow data-entry rules requiring physician pre-authorization, and that physicians often indulge in working around cumbersome procedures that they feel could hamper their actions. We also observed nurses in frantic day-hospital settings bypassing the precept to use personal credentials to log in to the system, doctors in intensive care unit refuse to open the application in the "right" sequence to get a specific page and to fill in orders with the intended level of granularity and precision: "nurses would understand all the same" was their usual justification. But flexibility does not necessarily means disorder, or anarchy. It is the *opportunity* to enjoy structured order entry and well-timed confirmations when work proceeds as smoothly as routine; as well as to improvise and cope with unexpected problems. It is the likelihood of finding a useful piece of information in multiple places instead of having to remember where it could be stored. Paradoxically, this latter requirement is clear when HIT admirers exalt the information mobility allowed by portable devices and the concurrent access to the same datum by multiple users where they are. Yet we were invited by practitioners to think of this requirement also in terms of the inner structure of the record itself. As reported in regard to the phenomenon of positive redundancy, practitioners appreciate being able to insert and view the same datum in multiple places: in fact, they explained to us that they could have to record the same datum during different activities (and hence while having different charts to handle) as well as to consult a datum while engaged in tasks that, in name, would not refer to it. This valuable insight from the field motivated us to pay particular attention to what answers practitioners may give to question no. 12 reported in Fig. 1.

Also informality is another way of seeing flexibility in action. Paper-based forms and charts often host extemporaneous inscriptions and informal annotations (e.g., underlinings, marks and marginalia). Practitioners add them to formal artifacts for several reasons [47] but especially to enrich their records so that relevant information, they said, could "leap out" at their colleagues as well at themselves in the next shifts. This operation of enriching artifacts with something that can not be reduced to any official "datum" or to any pre-established information need is then accomplished in an informal and asynchronous way that is substantially unpredictable at design time; for this reason, the logic underlying the provision of this kind of meta-information can be also correlated with the third point discussed about practitioners' autonomy. By recognizing the important role of this informal stratification of inscriptions that artifacts naturally support and on the basis of what we could collect from question no. 14 (Fig. 1) about the annotate operation (xi in Fig. 2), we were brought by practitioners to concentrate on this functionality: that the system's GUI could host, as well as proactively convey, what we previously called awareness promoting information [37] to indicate its subsidiary nature with respect to both the functional level (it is just some graphical or textual cue intended to promote a human capability) and the cognitive level (it regards "awareness", that is a human and intimate state of mind).

In summary, our experiences in HIT design and adoption have provided us with sufficient evidence that the dimensions of support, autonomy and flexibility must be taken seriously into account in order to minimize the odds of falling short of meeting the needs and (even tacit) expectations of care providers. In terms of the method we employed, we can recognize that the step of schema reconstruction is especially devoted to collecting knowledge to address claims of increased autonomy and flexibility, while the design of relationships (between artifacts' content and behaviors) addresses all three dimensions of general requirements and the step of associating artifacts with functionalities is aimed at identifying system capabilities in support of the daily practice as we will see in the next section.

Design to the Test of Ward Life

The first two steps of the analysis method could be associated to the development of almost any (traditional) software application, since they simply regard the (bottom-up) analysis of the application domain. Conversely, the third step can not fit (or support) the development of just any application. As said in Section It's All a Matter of "Observance", it regards the specification of small and self-contained modules of application logic; we propose this approach as a way to rethink how the requirement of autonomy could be actually delivered to users, and hence it deserves some further discussion. In [49] we proposed a high-level language so that users with a short training could directly express conditional relations in terms of computable specification, i.e., if-then statements that a (still prototypical) interpreter could execute without further intervention of professional programmers. At MOHU and MAPU, we did not propose this language. However, in order to involve practitioners with no special inclination towards formal specifications in the design of what "their record does" (see Section Background and Motivations), we invited them to express any conditional rule between situations and the system's behaviors candidly, in their own language. Real cases from the settings can help illustrate the importance of this modular approach to involve users in the direct specification of the EPR's application logic.

In Italy some very expensive chemotherapy drugs (e.g., Rituximab) are reimbursed by the National Health Service only through a specific process that allows for stricter verification. To trigger this process and give the hospital the right to reimbursement, the doctor who prescribes one of these drugs by means of the Drug Order Form (DOF) is supposed to also compile a special form (Reimbursement Form, RF), which is collected by the Hospital Pharmacy and then transmitted to the Regional Health Agency. An EPR could support this practice in two ways: either by forcing the doctor to `consolidate` and `transmit` the RF to the Pharmacy, otherwise she can not `consolidate` or even `write` the DOF at all (a solution strongly advocated by the Pharmacy); or by automatically `annotating` the single inscription of the prescription (e.g., by underlining it in red) in case one of these drugs was inserted in the DOF, in order to remind doctors to also fill in the RF (a solution of awareness promotion that was proposed by the head physician). The first solution could be expressed as follows: *if* 'the doctor has `written` *Rituximab* in a portion of the *DOF* named *drug-prescribed*' *then* "create a RF, `write` it by `copying` the prescription details from the field *drug-prescribed* and disable `consolidate` of the DOF until also the RF is `consolidated`". The second and blander behavior would be like the former one, but with a slightly different then-part: '[...] `annotate` the *drug-prescribed* field in red'. This business rule (which is local to *that* hospital in *that* region) could have been embedded in any traditional (but highly customized) EPR. Yet from one day to the next, the Regional Agency changed the rules and demanded that an RF would be compiled for every *other* drug prescribed in the same chemotherapy cycle of, for example, Rituximab, irrespective of its typology. While hospitals would have paid a fortune to have this functionality "quick and clean", to enact such new business rules on a standard EPR could be a pain. Instead, in terms of conditional rules, enacting this new behavior would just imply changing the if-part of the above mentioned rule as follows: "if the doctor has `written` *Rituximab* [...] and there is another *drug-prescribed* field compiled for the same cycle, then...".[3] In hospital work, cases in which business rules change unpredictably that have the potential ground-breaking impact on the hospital balance (or doctors' routine) are not that rare as in other business settings; this is mainly because many of these cases depend on external variables (e.g., national laws, ethical committees, risk management commissions) that the management cannot control.

A similar situation also occurred at the MAPU regarding the 'informed consent' procedure. The form used to document the procedure of gamete pick-up was designed when cryopreservation was a pioneer method and practitioners used to transfer male gametes into the partner's womb during the same day. Over time, cryopreservation became more popular and the government issued a specific law to regulate the times and ways of the procedure. Accordingly, all the pickup forms at the MAPU had to be changed to also contain a series of checkboxes in the header by which nurses could indicate if patients and partners had given their consent to cryopreserve their gametes for later use before undertaking the procedure. The almost sudden and unexpected need to adopt a new form again refers to the requirement of autonomy; yet having an EPR store a new variable (consent yes/no) and manage the workflow according to that (e.g., to avoid editing if the consent checkbox had not been checked) calls for an EPR whose application logic is modular as checkbox elements in the GUI are. In such an EPR, the logic would be almost effortlessly updated to comply with the new legislation by adding a simple rule that checks whether "the *informed-consent* checkbox of the *gamete pickup* form has been ticked off" and accordingly "enables the `writing` of all other fields, otherwise it disables that". Conversely, a nurse coming from another hospital told us how she felt frustrated then when she realized that just to add the checkbox in the pickup mask of the hospital's brand new EPR, she would have had to organize a meeting with a commercial agent of the ICT firm that supplied the EPR.

Another example will illustrate how it is important to flexibly support local conventions. At the MOHU, DOFs are daily sheets. Yet some drugs are to be administered several times a day at regular intervals. Occasionally, the last administration of a drug can be scheduled after midnight. In that case, the nurse who is going off duty usually puts the time of administration for the drug at exactly midnight (the last time-slot available on the DOF) and annotates a sign beside it. Then, the nurse on the next shift has to remember to copy the last scheduled administration at the right hour into the DOF of the next day. The local and conventional nature of this habit is evident [37]. The rule coping with this simple need for data redundancy [36] is almost trivial: it just `copies` values from a field to another in presence of a specific annotation. Yet, this situation is so delicate in current EPRs to have generated a recurring deadlock, known as 'midnight problem' in the literature [46].

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[3]Discussing this conditional pattern would make it necessary to dwell on the details of rule-based programming (or on the specific artifact logic of partitioning) and would be out of the scope of this paper.

In regard to workflow: Usually this term, understood as a way to foster (or impose) pipelined clinical processes and rigid transaction patterns between facilities, makes doctors suspicious, especially if they think of how they actually use their patient records. In Section It's All a Matter of "Observance", we have seen how "workflow rules" can be conceived in terms of autonomous and local (to artifacts) constraints to user's interaction. Parcelling a workflow into a set of atomic and independent conditional mechanisms can be fruitful, since it allows to relax punctual bonds while preserving others in a selective way. For instance, some constraints could be temporarily relaxed if and only if some conditions occur, e.g., if a patient is in danger of death. Other constraints could be notified to doctors, to be sure they are aware of them although they could willingly and consciously break them and proceed. In still other cases, specific limits could be raised to force doctors to comply with the rules and prevent any workaround if some other condition holds true (e.g., a particular health condition that calls for extraordinary safety measures).

This flexibility in articulating a workflow through autonomous modules could also help smooth some "design severities". For instance, the head doctor at MAPU, tired of reviewing incomplete charts in the consolidated records of his unit, insisted on putting a "block" (as he called it) into the EPR that would prevent physicians from prescribing any drug (i.e., `write` the DOF) unless they had gone through two formalities: that first they had formulated at least two probable diagnoses on the Clinical Examination Chart, in order to comply to a regional recommendation and enable better correlational studies; and that they had asked the patient for any known allergy affecting her, thus checking at least the box 'none known' on the Anamnesis Chart, under their own responsibility. The head doctor deemed this capability of the electronic record (i.e., hindering recording!) as one of the most important ones for the improvement of the clinical profession; he is not the only one who thinks this way. Whether the doctors from his unit will always put the second most probable diagnostic hypothesis in writing or not depends on several factors, but few can be traced back to how the patient record is designed. Yet, how many doctors would appreciate that such a single block to their core activity could be relaxed according to some condition (e.g., doctor's seniority) or be just removed when the regional recommendation will be withdrawn?

Summing Things Up

In this paper we have reported the main findings of an analysis & design experience, where we took seriously the provocation, murmured by different observers of ICT projects in healthcare that abstract and entity-based modeling, as it is applied in the top-down approach to the design of HIT, could contribute to its inevitable failure. In two field studies organized within two major digitization projects at the same hospital, we adopted a bottom-up approach to domain analysis and pursued a step-wise method to focus on collaborative artifacts. These were paper-based artifacts at the MOHU and already electronic at the MAPU, but in both cases they were artifacts that had been used proficiently by doctors, pharmacists, nurses and biologists for several years and that in this time span had embodied a whole stratification of changes and adjustments that made them stick to the field of work with an exemplary accuracy.

The method we reported in Section It's All a Matter of "Observance" can be seen as part of a wider design-oriented framework, which we called WOAD [50]; within this framework, we are refining an architecture that can *natively* leverage the indications collected during an artifact-centered analysis, "close the loop" of software development and therefore provide practitioners with a platform that supports them in both tuning their tools by themselves and in progressively programming the modular logic of their EPR. To the former aim, we designed a *template editor* that allows users draw their charts by positioning reusable 'field groups' (which we called didgets [38]) in blank documents like they would do in regular WYSIWYG word processors. To the latter aim, we designed a *mechanism editor*, with which users could associate business and conventional rules with the proper situations in which these rules could turn out to be useful. Unfortunately, we are not in control of the implementation choices that project managers will choose for the development of the two EPRs that will be deployed at the MOHU and MAPU: the overall development process will end only in mid-2010, if no delay occurs. Therefore, we cannot say if the application that has been designed by taking a full artifact-centered approach will raise less unintended consequences than regular ones or if the method we followed is a recipe that, when applied elsewhere, will certainly avoid disaster. In previous researches [38], we observed that the doctors were able to address the construction of chart templates in relatively short time and were willing to modularize the application logic of a prospective EPR in terms of reactive and self-contained mechanisms. Yet, we cannot generalize these previous findings to the MOHU and MAPU cases.

All things considered, then, we are aware of the qualitative nature of the experiences we gained from our field studies; yet these experiences represent a concrete contribution to the debate on whether the bottom-up and artifact-centered approach to requirement definition and system design can be a feasible alternative to top-down and entity-based strategies in the deployment of HIT in hospitals. As far as we put this approach to the test, we witnessed how practitioners felt more at ease in discussing fields and tables from real records rather than of abstract (yet somehow familiar) concepts like health episodes, exam requests and drug prescriptions; we also observed how practitioners who were marginally involved in the requirement analysis could join participative discussion sessions more easily when they were organized with little or no advance planning; and how key users could focus more quickly on the hot points left suspended from previous meetings when regular talks were organized on a loose schedule. From our experience, then, we can claim that enabling a deeper involvement of health practitioners in the autonomous development of their HIT, in virtue of an artifact-centered analysis and design that provides them with self-contained building boxes, can embrace all the three general requirements that we drew in the light of our research in the field (see Section Reconciling Requirements and Artifacts): in fact, it addresses the banal fact that to *build* an EPR that is complete and able to fulfill all the stakeholders that are involved in its use is irremediably utopistic, even if for its deployment developers adopt a truly iterative, incremental and participatory development process. In fact, the same models that underpin how actors and activities are supported by the application risk to become rapidly outdated [35] and hence hinder real close-loop feedback from the field of work. Thus, the need for users to be as autonomous as possible from suppliers (and even, from IT staff) and the need to prearrange localized and tailored sets of functionalities that promote collaboration awareness call for an approach where designers abandon the concept of *building* and instead adopt the concept of *growing* an information system and, in particular, a HIT. As proposed in [51], the metaphor of growing (or, we would say, cultivating) an EPR suggests that the evolutionary process of developing it and continuously tuning and adjusting it are more organic than predictable and more systemic than mechanistic, as we verified in our field studies.

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