# Health Care Revolution Via The Application Of Knowledge Management And Semantic Technologies

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ABSTRACT:

The application of Knowledge management and semantic technologies to health care requires at least some level of cooperation between insurance companies, emergency care, hospitals, pharmacies, general practitioners, specialists, researchers, and patients. Once partnerships are formed, the open health care information architecture of Health 3.0 would be able to take shape, creating greater collaboration, visibility, and accountability in the health care system.

The study aims to review health care revolution via the application of knowledge management and semantic technologies. First, the study analyzes semantic web, Health 2.0 and Health 3.0, semantic web and healthcare information challenges, OWL and linked knowledge, from linked data to linked knowledge, consistent knowledge representation. Secondly, the research analyzes two case studies of the applications of KM in Healthcare. Finally, the study recommends the healthcare industries need to start from customers rather than technology when constructing health 3.0.

Keywords: *Knowledge management, Semantic Technology, Health 3.0, Healthcare*

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## 1. Introduction

Traditionally, information exchange has been mainly performed through traditional modes of communication - verbally. Early stage Health 1.0 information has predominantly been available in the form of an "e-pamphlet" with a one-size-fits-all approach (Beggelman, 2008). Health 1.0 has also included the information exchange, but has not emphasized with the user interaction and the cooperation, personalized and the use of Web 2.0 information tool. Since the birth of Internet, health care providers recognized the advantages of using the Internet medium to preach health information, thereby the concept of Health 2.0 emerged (Eysenbach, 2008). The subsequent generations of Health 2.0 tools are interactive and deliver personalized, more valuable information that is geared specifically to the user's input. With the advent of advanced tools, consumers are no longer limited to being passive recipients of pamphlet-style information; in these milieus they interact with each other or with sophisticated software that analyzes cases on an individualized basis.

Increased personalization is advantageous to consumers for several reasons: first, it directs them toward relevant information more quickly and decreases the time spent wading through a lot of noise; additionally, the more advanced tools go beyond delivering information - they analyze the user's information and render the type of feedback that might be expected from a medical professional. Advanced tools are being used by Internet entities as bait both to drive traffic and to capture detailed user profiling data. Several categories of interactive Health 2.0 tools are available, including advanced search engines that deliver more accurate results; social media sites in which individuals hone their medical knowledge through interactions with each other (Beggelman, 2008).

Finally, expert systems - sophisticated software programs that analyze a consumer's profile and, based on the analysis, pinpoint the most relevant educational information necessary to support the consumer's healthcare decisions. This information will be distributed by a set of "virtual reasoning" tools that simulate expert decision-making. As these tools become available, they will provide a focal point for information-sharing between consumers and physicians. Virtual reasoning tools that combine the capacity to "think like humans" and to connect consumers and experts through knowledge-supported social media represent the next direction in Internet health or Health 3.0. These expert system tools basically simulate human reasoning. They apply algorithms (with branch-chain rules) and complex calculations to more or less simulate expert human data processing. Expert systems are in the early stages of development, but they have the potential to elevate software capabilities close to the level of a human expert and generate a virtual expert opinion. Examples of current expert systems include software that assists with insurance plan selection, treatment optimization, differential diagnosis, medication analysis, etc. (Beggelman, 2008).

People have been actively searching for more effective ways to utilize the Internet and the new movement to achieve semantic web to enhance health services, has led to the notion of Health 3.0. Social networking is a popular and powerful tool for engaging patients in their health care. These virtual communities provide a real-time resource for obtaining health-related knowledge and counseling (Eysenbach, 2008) Internet and American Life Project report that greater than 90% of young adults and nearly three quarters of all Americans access the internet on a regular basis. Greater than 60% of online adults regularly access social networking resources. In addition, 80% of internet users search for health-related information (Pew, 2011a). Definitive evidence of health benefit from interaction with health-related virtual communities is currently lacking as further research needs to be performed (Eysenbach, et al., 2004). H3PO is an open virtual community that is actively working on the future potential for Health 3.0.

Knowledge management and semantic technologies are currently being explored, improved, and applied to health care in a movement known as Health 3.0. But what exactly are semantic technologies and how can they improve a healthcare system? The study aims to review what constitute a Health 3.0 system, and explore greater collaboration, visibility, and accountability in the healthcare system.

## 2. Literature Review

### 2.1. Semantic Web

The Semantic Web is a collaborative movement led by the World Wide Web Consortium (W3C) (W3C, 2012) that promotes common formats for data on the World Wide Web. The term was coined by Tim Berners-Lee, et al. (2001) the inventor of the World Wide Web and director of the W3C, which oversees the development of proposed Semantic Web standards. He defines the Semantic Web as "a web of data that can be processed directly and indirectly by machines." While its critics have questioned its feasibility, proponents argue that applications in industry, biology and human sciences research have already proven the validity of the original concept.

The word “semantic” is broadly defined as “meaning,” and in the context of the Internet, the term is used to describe how computers can understand the meaning of words and text, which could be on a page or in a database. Traditionally, computers have not been able to understand the meaning of the words and numbers that they process; but with semantic technologies, they can start to do so. This is not to suggest that computers are intelligent, but when they have enough information from which to work, they can make connections between different pieces of information that wouldn’t otherwise be brought together. In a health care environment, this is very valuable because it’s simply not possible for any one medical practitioner to have enough knowledge to recognize every symptom or pattern of illness and connect it to every available cure. Because computers can process information much faster than people, semantic technologies for data linking can greatly reduce the time to make the correct diagnosis and perhaps curtail the patient’s uncertainty and pain from months to a few days or hours.

### 2.2. Health 2.0 And Health 3.0

Health 2.0 as well as the closely related concept of Medicine 2.0 (Eysenbach, 2008), are terms representing the possibilities between health care, eHealth and Web 2.0, and has come into use after a recent spate of articles in newspapers, and by Physicians and Medical Librarians (The Economist, 2007; Giustini, 2006). A concise definition of Health 2.0 is the use of a specific set of Web tools (blogs, Podcasts, tagging, search, wikis, etc) by actors in health care including doctors, patients, and scientists, using principles of open source and generation of content by users, and the power of networks in order to personalize health care, collaborate, and promote health education (Hughes et al., 2008). A possible explanation for the reason that Health has generated its own "2.0" term are its applications across health care in general, and in particular it potential in public health promotion. One author describes the potential as "limitless" (Crespo, 2007).

Health 3.0 is a health-related extension of the concept of Web 3.0 whereby the users interface with the data and information available on the web is personalized to optimize their experience (Pew, 2011b). This is based on the concept of the Semantic Web, wherein websites’ data is accessible for sorting in order to tailor the presentation of information based on user preferences (Berners-Lee, 2001). Health 3.0 will utilize such data access to enable individuals to better retrieve and contribute to personalized health-related information within networked electronic health records, and social networking resources (Shaw, 2010 a/b; Nash, 2008). A similar idea of semantically organizing digitized health records to create an Open Healthcare Information Architecture, was defined as health 3.0 (PRWEB, 2010). The idea was also suggested in the commentary in response to the U.S. government's new $1.2 billion investment as a part of the American Recovery and Reinvestment Act. The commentary explains how the idea of Health 3.0 can fit in to better develop and implement electronic health records. The ideas were the use of social media and incorporation of virtual tools for enhanced interactions between health care providers and consumers/patients (Shachak & Jadad, 2010).

Goals of Health 3.0 include improved access to health related information on the web via semantic and fact that resources will facilitate an improved understanding of health issues with the goal of increasing patient self-management, preventative care and enhanced health professional expertise (Shaw, 2010 a/b; Nash, 2008). Health 3.0 will foster the creation and maintenance of supportive virtual communities within which individuals can help one another understand, cope with, and manage common health-related issues (Nash, 2008).

Personalized social networking resources can also serve as a medium for health professionals to improve individuals' access to healthcare expertise, and to facilitate health professional-to-many-patients communication with the goal of improved acceptance, understanding and adherence to best therapeutic options (Nash, 2008; Shachak, Jadad, 2010). Digital healing emerged as one of the main goals of health 3.0. Digital healing exploits the idea of interaction through social media, in an attempt to obtain reassurance, support, and validation. Therefore it augments the health 2.0 of seeking health information from online. This psychological aspect from the social media hence creates the notion of digital healing, and it makes up Health 3.0 (Coughlin, 2010).

Health 3.0 is recommended to be able to gather imparted data through web-based technologies. Consumers and experts are to be connected by virtual reasoning tools - an expert system. The expert systems that can utilize the collected information through the web-based technologies represent health 3.0 (Beggelman, 2008).

### 2.3. Semantic Web And Healthcare Information Challenges

The semantic web is a model for linking information and representing knowledge, and semantic technologies for linking data will be a vital tool in solving the healthcare information challenge. To understand why our current approaches to healthcare IT do not scale and don't work for the problems of understanding and optimizing healthcare services while controlling healthcare spending, let's go back to the beginning, of how we store and characterize data in the first place (Brown, 2009).

The semantic web was designed exactly for such a challenge as integrating the complex and fast changing universe of health information. Rather than building more silos of data, everyone can keep their data where it is, but let's give data an address and start to use the common language of the semantic web to express the relationships between the data and start to link it together. The biggest bottleneck in the health care information equation is getting meaningful data into the system in the first place. Good doctors sit with their patients and listen to their stories. They do not want to be spending that time filling in structured forms of data. Every patient story starts as unstructured data about what is going on in the patient's life. Many different illnesses can present similar symptoms, and medicine is full of nuance in deciphering such complex issues with many variables (Brown, 2009).

### 2.4. OWL And Linked Knowledge

Drawing from the well understood area of Description Logics, the Web Ontology Language (OWL) provides a substantially more expressive vocabulary to axiomatically describe entities for enhanced reasoning. Building these kinds of ontologies not only requires domain expertise to properly define describe the entities, but also requires a keen understanding of formal knowledge representation so that knowledge is properly captured and becomes intuitive to query using an information system. Several projects have now demonstrated the use of OWL-based information systems. The HCLS know-ledge base contains a collection of instantiated ontologies used to identify interesting molecular agents in the treatment of Alzheimer's (Ruttenberg et al., 2007). With consideration of how genetics plays a role in effective drug treatment, the

Pharmacogenomics Knowledge Base (PGKB) offers depression-related pharmacogenomic information that facilitates additional knowledge curation (Curation=Care, Management and Use.) beyond the PharmGKB database (Dumontier & Villanueva-Rosales, 2009). Thus, ontologies can play an important role both in semantic data integration as well as guide curation activities with well established use cases towards populating a specialized knowledge base.

### 2.5. From Linked Data To Linked Knowledge

Dumontier and Hoehndorf (2010) indicated RDF linked data efforts currently employ a simple model for representing knowledge: entities are either related to other entities or related to valued attributes through a single relation. Model 1 (Figure 1) exemplifies a typical linked data model for representing the volume of a protein using a decimal data type. Such a model does not express the unit of measure, and no statements can be made as to how or under what conditions the value was obtained. In contrast, Model 2 overcomes these limitations by explicitly representing the entity, quality, measurement value, and the unit as distinct entities. However, moving from 2 triples in Model 1 to the 8 triples required in Model 2 translates to a 4x increase in the storage requirements and requires more sophisticated query to retrieve all the relevant information. The benefit increasing our capacity to make meaningful statements about any one of these entities, which cannot (easily) be done in Model 1, is nevertheless substantial.

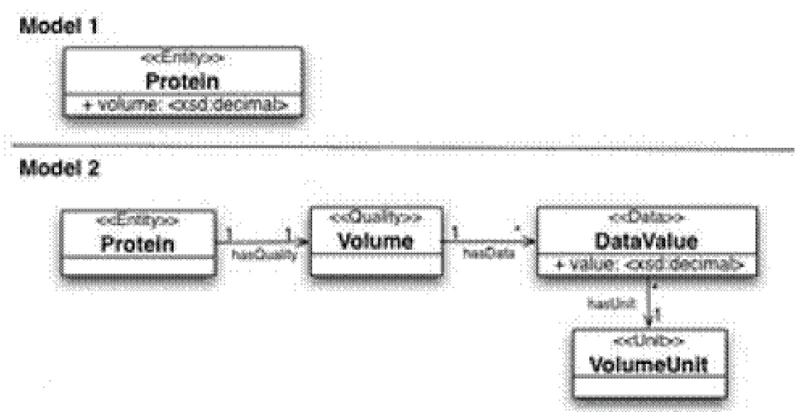


**Figure 1: Two Models For Representing A Physical Attribute (Dumontier and Hoehndorf, 2010)**

### 2.6. Consistent Knowledge Representation

In Figure 1, if Model 2 is deemed desirable, then the challenge lies not only in getting scalable systems to accommodate this influx of triples (possibly by devising customizable indexes), but also in getting users to learn about and deploy standard patterns which they can apply to their own data. The patterns should be coherent, intuitive and well specified such that non-experts can read, understand and apply the guidelines found therein. Importantly, these patterns should specify the relations that hold between instances, and for this reason having a coherent, well founded set of types and basic relations supported by formal ontology is of critical value. While BFO+RO (Basic Formal Ontology, BFO and Relation Ontology, RO), combination provides guidance for instant-able types, it lacks the capacity to handle all elements of scientific discourse (Dumontier & Hoehndorf, 2010), specifically with types that may be hypothesized (putative agents of disease), predicted (genes and proteins from genomic sequences), or simply do not occur (perpetual motion). This necessitates significantly more effort in developing a foundational ontology (types + relations) to represent a more diverse array of knowledge, including that which is already found in linked data.

Recent work by the W3C subgroup (HCLS, 2005) on translational medicine has produced a knowledge base composed of the Translational Medicine Ontology, which provides 75 core classes mapped to 223 classes from 40 ontologies, and acts as a global schema over a set of fake patient data and linking open data (LOD) resources (Dumontier et al., 2010). They featured queries that span bedside to bench by not only matching patients to clinical trials, but also in finding trials for which their drugs had different mechanisms of action so as to potentially avoid common side effects. Here, the integration of electronic health records with public data provides new avenues for clinical research and improved health care. With increased interest in building smarter health care systems using electronic health records, Semantic Web technologies can play a pivotal role in incentivizing interoperability between health care providers by linking valuable to public data.

## 3. The Case Study

### 3.1. Case 1: Semantic Web For Healthcare - Personal Knowledge Management

SemanticWeb.com (2010) has studied consumer health sites that are leveraging semantic web technology and how semantic web technology is being used by researchers in pharma and biotech firms. Now, they indicated how all the participants in the "health graph" can start to work around a common set of data standards in what may be the first glimpse of 21st century healthcare. In their first post on Healthcare wrote: "Attempting to know enough about how to combat a nasty long term disease is hard enough. It is much harder when you are facing the emotional and physical trauma of the disease itself. The subject itself is complex. But even greater complexity comes from the overlapping and contradictory knowledge frameworks of the different participants:

- ❖ Patient and the close relatives/friends who are advocates and caregivers.
- ❖ The trusted General Practitioner who really knows the patient but is not a specialist in the disease.
- ❖ Many specialists. What is exciting about medical advances today is the cross-disciplinary cooperation. The breakthrough may come from outside the mainstream. But each specialist has their own framework for looking at the problem.
- ❖ The Pharma companies who have drugs that are already FDA (Food and Drug Administration) approved and others in the pipeline where they want patients for clinical trials.
- ❖ Academic and scientific researchers.

Definitely, the patient has to be the center of this "health graph". Their framework is the one that matters in the end." The answer of course is the fabled Electronic Health Record (EHR) (SemanticWeb.com, 2010). The product being promoted in this case study is called Kyield from a seasoned entrepreneur called Mark Montgomery. It is one of those hard-to-categorize products. This categorization problem is common with emerging technology. The answer is of course to just focus on solving problems and ignore categories. Savvy investors also ignore categories and just look for hard problems being solved in different ways. Customers also obviously just want their problem solved. In the case of Kyield, one analyst positioned it as "personal knowledge management". This does not resonate at all. Firstly, "knowledge management" (KM) is a category that never really happened. It is sort of related to Intranets, collaboration and semantic web, but as a label it is not useful. It is too broad and conceptual. KM may not be dead, but it is in a coma, or sleeping, or walking wounded. Pick your metaphor. As for "personal" KM, who needs? Actually the people who need it are the analysts who write about it. Analysts need something like KM to do their job, but we all evolve our own tools to do this and these tools have to be dirt cheap and the market of analysts is too small to monetize via advertising. Actually, there is a use case for Personal KM. If you have a life-threatening disease, you need to manage an awful lot of complex knowledge (SemanticWeb.com, 2010).

### 3.2. Case 2: Partners Healthcare Systems On 'Clinical Knowledge Management'

Partners Healthcare System's Clinical Knowledge Management Group, a division of Clinical Informatics Research and Development, was formed in order to implement content management infrastructure and support the management of the vast amount of knowledge encoded in clinical systems across the enterprise. These ontologies and rules are served up through applications and services to support guided observation capture, guided ordering, and guided interpretation of clinical data. Workflow portals leveraging this knowledge include the electronic health record for care-givers and consumers, quality performance management, and clinical research. During phase 1, an inventory of encoded knowledge assets was performed and a meta-knowledge document library of the knowledge specifications for encoded knowledge was published to an internally developed portal. During phase 2, Documentum eRoom and Content Management Server solutions were implemented to support virtual, collaborative updating of decision support content as well as robust life-cycle management at the 'meta-knowledge" level (Miller, 2004).

In phase 3, the group begins a series of projects to implement new knowledge-encoding editors for ontologies (Health Language Inc.; Cerebra) and rules (ILOG) which they will integrate with Documentum to support life-cycle management of in-production encoded content, inheritance/propagation of content across dependent knowledge bases, and better visualization of content-interrelationships for knowledge editors and subject matter experts alike. ILOG is a recognized industry leader in Business Rule Management Systems (BRMS), decision management, visualization components, optimization and supply chain solutions enrich IBM software portfolio with next generation of the market-leading products and solutions. For example, when the definition of a contraindication to a drug such as a beta-blocker must change, this definition must be propagated to all dependent rules, order sets, documentation templates, and quality management reporting systems. Health Language Inc. supplies medical terminologies and their inter-mappings. Cerebra supply OWL-based ontology editors, a description-logic engine, and run-time recognition services. ILOG supplies rule editors and rule execution services. Documentum supplies collaboration, content-lifecycle management and business process management services for the sharing, cataloguing, and publishing of content. Partners Healthcare System recognizes that the advent of personalized medicine will exponentially increase the rate of change of clinical knowledge that drives research and clinical care. This emerging knowledge management infrastructure is mission critical to reduce the cost and increase the speed of knowledge discovery and knowledge acquisition by our clinical decision support systems. The innovation adoption curve for healthcare greatly depends on a robust knowledge management infrastructure for translational medicine (Miller, 2004).

If we define knowledge as a higher form of information, based on uniquely defined linked concepts and then we can easily see the Semantic Web as a way of implementing 'connected knowledge'. As a healthcare IT vendor Agfa recognizes the high importance of the Semantic Web in achieving their goal: making systems that cross the borders of departments, hospitals, home, universities en governments and give all stakeholders intelligent tools, using knowledge and guidelines, to obtain a higher quality and more cost effective health care. Currently they focus on a decision support system, going beyond classical clinical pathways in that it dynamically creates a path, based on the current and constantly changing clinical information of the patient, the environment and the guidelines. Execution of procedures creates new data that will be taken into account to calculate the next steps in the path. They believe that one system cannot contain all medical knowledge. Therefore they make use of the fact that ontologies can be merged and connected to leverage existing and fragmented but highly specific pieces of knowledge (Colaert, 2005).

BioDASH is a Semantic Web prototype of a Drug Development Dashboard that associates disease, compounds, drug progression stages, molecular biology, and pathway knowledge for a team of users. Since such relevant information usually resides across many intranet database servers and different R&D groups, the challenge is more about leveraging the information one already has in a semantically coherent fashion than about making new data models. Here Haystack, a generic RDF-based user interface tool, is used to create "lenses" for aggregating and viewing drug and molecular pathways information used in drug discovery. Data from several sources are integrated, on the client, and explored in a variety of views (Miller, 2006).

Life science is, at root, a collaborative discipline. Each scientist draws upon the canon of knowledge, established through experimentation and verified through peer review and publication. But modern technological approaches to managing data and papers in the life sciences in many cases can make the discovery process harder. Data is stored in different formats, exposed in different interfaces, and knowledge is locked up in document formats that don't bring the full power of computation to bear on behalf of the individual scientist. Knowledge Discovery Platform of Language & Computing accelerates drug development through knowledge extraction and semantic integration. Analyzing and interpreting vast repositories of scientific literature and other sources of biomedical knowledge is a daunting task to researchers in the life sciences. Language and Computing has created a powerful knowledge discovery system that offers significant value to these challenging endeavors. This highly automated system gleans information from thousands of scientific documents, domain-specific taxonomies, public and proprietary databases and other external ontologies combining these into an integrated knowledge base (Miller, 2006).

## 4. Conclusions And Recommendations

The semantic web was designed exactly for such a challenge as integrating the complex and fast changing universe of health information. The biggest bottleneck in the health care information equation is getting meaningful data into the system in the first place. The study analyzes semantic web, Health 2.0 and Health 3.0, semantic web and healthcare information challenges, OWL and linked knowledge, from linked data to linked knowledge, consistent knowledge representation. In addition, the research analyzes two case studies of the applications of KM in healthcare.

Technologies like semantic web can be used to provide enhanced and reliable health care service since it associates meaning to the data, so, it is effective in generation of knowledge base to manage various aspect of the health care system. Restriction of counterfeited medicine is an important aspect of health care system and it can be effectively achieved using this technology. The Semantic Web promises to make Web-accessible data more amenable to machine processing. This paper presents several proposals for the Semantic Web's strategic role in supporting more effective knowledge management at several levels.

Finally, the study recommends the healthcare industries need to start from patients (customers) rather than technology when constructing healthcare system. And the high importance of the Semantic web in achieving industrial goal: making systems that cross the borders of departments, hospitals, home, universities en governments and give all stakeholders intelligent tools, using knowledge and guidelines, to obtain a higher quality and more cost effective health care.

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