Taxonomy Development in Health-IT

Completed Research Paper

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ABSTRACT

Health-IT is attracting increasing attention in the research community. To understand the relevant constructs and the relationships among them, many authors present taxonomies or typologies for classifying different things in health-IT. Even with much attention to health-IT, there is still limited theoretical knowledge in this field. This may be attributed to our observation that the process of developing taxonomies has not been adequately addressed in the health-IT literature. In this paper we address this challenge by (a) a comprehensive literature survey that shows a high diversity in the field and that the related discussion of the structural nature has largely been ad hoc, (b) presenting methods for developing health-IT taxonomies, and, (c) contributing to the theoretical foundations of the field by a taxonomy for health-IT applications.

Keywords

Health-IT, taxonomy, method.

INTRODUCTION

Health-IT is an emerging area that encompasses the use of IS/IT to address healthcare problems. Some examples are Electronic Health Records (EHRs), Personal Health Records (PHRs), online tools and applications for health, decision support for healthcare, and m-health (Varshney, 2009). Health-IT is also a diverse area as it deals with patient demographics, healthcare professionals, healthcare processes, regulators, and payers, among others. Understanding the different phenomena in this area is challenging because of this diversity. Many researchers have addressed this issue by developing classification schemes in the form of taxonomies or typologies that classify things of interest in health-IT. Classification is often used to help order knowledge and provide a structure to the area (Glass & Vessey, 1995). The uncovered order and structure allows researchers to investigate the relationships among other concepts within an area (McKnight & Chervany, 2002).

With increasing research in health-IT, there is a need to classify different things of interest in health-IT. Several examples include taxonomies for

- Assessment of health-IT (Grémy and Degoulet, 1993)
- Strategic management of health technology (Heidenberger and Roth, 1998)
- Healthcare Information Systems (Hasselbring, 1999)
- E-health business models (Parente, 2000)
- Contributions of information services to hospitals (Abels, Cogdill and Zach, 2002)
- Telemedicine Systems (Tulu, 2005)
- Representational affordances for EHRs (Xie and Zhang, 2006)
- Models for economic evaluation of health technologies (Brennan, Chick and Davies, 2006)
- Personal Health Records (Beranek and Horan, 2006; Vincent, Kaelber, Pan, Shah, Johnston, and Middleton, 2008)
- Health Information Technologies (Dixon, Zafar and McGowan, 2007)

- Health-related habits (Alonso, Walsh and Salvador-Carulla, 2010)
- Critical factors for EHR adoption (Castillo, Martínez-García and Pulido, 2010)
- Comparison of e-health websites (Esteves, 2010)
- Consumer health portals (Nguyen, Burstein, Fisher and Wilson, 2011)
- Clinical decision support tools (Wright, Sittig, Ash, Feblowitz, Meltzer, McMullen, Guappone, Carpenter, Richardson, Simonaitis, Evans, Nichol and Middleton, 2011)
- M-health interventions (Sanner, Roland and Braa, 2012)
- Health alerts in EHRs (Murphy, Reis, Sittig and Singh, 2012)

Developing a taxonomy, however, is a complex process, which, although studied extensively in other fields including biology (Eldredge & Cracraft, 1980; Sokal & Sneath, 1963) and the social sciences (Bailey, 1994), has been little studied in the health-IT field. We thus ask the following research questions: (a) Do existing taxonomy development methods suffice? and (b) Can an existing taxonomy development method be used to develop a taxonomy for health-IT or is a new one needed?

To address these questions, we first examine how taxonomies in health-IT have been developed in the past. As we show in a subsequent section, taxonomy development in health-IT has been largely ad hoc. We then review several methods for developing taxonomies and argue that one particular method would serve well for taxonomy development in health-IT. Finally, we demonstrate the efficacy of this method by using it to develop a taxonomy for healthcare applications. Our approach follows the design science paradigm of evaluating a method by using it to build an artifact. In our case, the artifact built is a taxonomy for health-IT applications.

This paper is organized as follows. First we present a literature survey of healthcare taxonomy papers and our analysis of the papers surveyed. Then we present several methods for taxonomy development and select a recently proposed method. Next we demonstrate the use of the taxonomy development method by developing a taxonomy of health-IT applications. Based on the taxonomy, we make several interesting observations. We conclude the paper with discussion and suggestions for future research.

SURVEY OF TAXONOMY DEVELOPMENT LITERATURE IN HEALTH-IT

We conducted a literature survey of papers on development of taxonomies in healthcare and health-IT. We identified the papers by searching the following databases or outlets with the search string "health" and "taxonomy" OR "health" and "typology":

1. ISI Web of Knowledge (www.webofknowledge.com)
2. Top 30 of the AIS meta journal ranking (ais.affiniscape.com/displaycommon.cfm?an=1&subarticlenbr=432)
3. AIS Electronic Library AISeL (aisel.aisnet.org).

We identified 109 relevant papers that propose taxonomies for some aspect of healthcare or health-IT. We classified each paper by its principal domain: healthcare or health-IT and noted the type of taxonomy and the approach or method used for developing its taxonomy. We classified the approach into one of the following categories:

- Inductive
- Deductive
- Intuitive

The inductive approach analyzes empirical cases to determine dimensions and characteristics in the taxonomy. The analysis may be done using statistical techniques such as cluster analysis or less rigorous informal analysis.

The deductive approach derives a taxonomy from theory or conceptualization. It identifies dimensions and characteristics by a logical process derived from a sound conceptual or theoretical foundation.

The intuitive approach is essentially ad hoc. The researcher uses his or her understanding of the objects to be classified to propose a taxonomy based on the researcher's perceptions of what makes sense. There is no explicit method in this approach.

Several other approaches were found that did not fall into these categories including the use of existing taxonomies.

Table 1 shows the distribution of approaches used in the papers that we surveyed.

Principal domain (number of papers)	Taxonomy Development Approach				
	Inductive (statistical analysis)	Inductive (informal analysis)	Deductive (may be followed by empirical verification)	Intuitive	Other
Health-IT (19)	0	3	9	5	2
Healthcare (90)	25	21	7	20	17
Total (109)	25	24	16	25	19

Table 1. Taxonomy Development in Different Domains

We make the following observations about these papers, which we structure according to Nickerson et al. (2013) in order to uncover similarities and differences across different domains. While our focus is on health-IT, Nickerson et al. (2013) analyze papers in information systems in general.

• A total of 109 papers were found and surveyed in this research. Thus, there is considerable interest in using classification schemes in information systems and healthcare. The sample is dominated by application domain (i.e. healthcare) papers and less has been published in the health-IT domain.

• Of the surveyed papers, 50 papers use the term taxonomy and 47 papers use the term typology. The rest did not use either of the terms explicitly. Some authors are imprecise in their use of the term taxonomy. They may classify the literature into two or three simple categories or present a list of functions to be performed as a taxonomy.

• With two to four dimensions, most of the presented taxonomies are of limited complexity. However, there exist a few examples with more than ten dimensions. There is no agreement on an appropriate number of dimensions.

• It appears across different domains that many papers neither follow a clear method nor review the existing taxonomy literature. We classified nearly one fourth (25) of the papers as not identifying the method used. We interpreted these papers as using a purely intuitive approach.

• Many papers do not base their taxonomy on a solid foundation, whether conceptual, theoretical, or empirical. Authors may review the literature but their taxonomy is often ad hoc. We classified these as using an intuitive approach.

• Out of papers with an inductive approach (49), about half (25) use statistical analysis to identify appropriate clusters. The other half (24) use informal techniques to examine their empirical cases. Papers that use a deductive approach (16) were hard to identify. Some of the papers that we identified as using an intuitive approach may, in fact, use a deductive approach. Since healthcare involves significant practitioner component, taxonomies are likely to use existing objects for classification (inductive) as opposed to deriving ideal types for classification (deductive).

• Papers related to health-IT (even in healthcare journals) tend to be more deductive (theory-based) in their approach (9 out of 19) or intuitive (5 out of 19). We did not find any paper in health-IT that used inductive approach for classification. Papers in healthcare are more likely to use an inductive approach (46 out of 90).

We note that these observations are similar to those of Nickerson et al. (2013) in their survey of taxonomy development in information systems, with some domain-specific differences. A general conclusion is that many researchers in healthcare find taxonomies useful. Overall, there is no consensus on a systematic method as a vast majority of authors used ad hoc methods, or methods that cannot be easily used by other researchers. We conclude that a taxonomy development method that most researchers can use for health-IT would be very beneficial.

METHODS FOR TAXONOMY DEVELOPMENT

Methods for taxonomy development have been proposed in several disciplines. In biology, taxonomies may be developed using an approach called phenetics or numerical taxonomy in which the researcher identifies different characteristics of organisms and then uses statistical techniques to cluster the organisms into similar groups based on these characteristics

(Sokal & Sneath, 1963). Alternatively, biological researchers may use an approach called cladistics in which the researcher classifies organisms based on their evolutionary relationships (Eldredge & Cracraft, 1980).

In the social sciences, several methods for taxonomy development have been in use. Bailey (1994) provides a thorough review of these methods. These include a conceptual approach in which the researcher develops a taxonomy starting with a conceptual or theoretical foundation and then derives the taxonomy structure through deduction, and an empirical approach, which starts with data and derives the classification from this data using cluster analysis or other statistical methods. Bailey also proposes a third approach, which he calls an indicator or operational approach, in which the researcher has two choices: start with the conceptual approach and then examine empirical cases to see how they fit with the conceptualization or start with empirical data clusters and then deductively conceptualize the nature of each cluster (Bailey 1984).

In the information systems field, Nickerson et al. (2013) propose a method for taxonomy development that extends Bailey's indicator or operational approach. Their method begins with the selection of an overall characteristic, which they call a meta-characteristic, that serves as the basis for the choice of characteristics in the taxonomy. Then their method iterates through an empirical-to-conceptual approach and a conceptual-to-empirical approach until certain pre-selected ending conditions are reached. Figure 1 shows their method in a flowchart (Nickerson et al., 2013, page 10). They present guidelines for selecting the approach at each iteration and propose objective and subjective ending conditions to determine when to end the process.

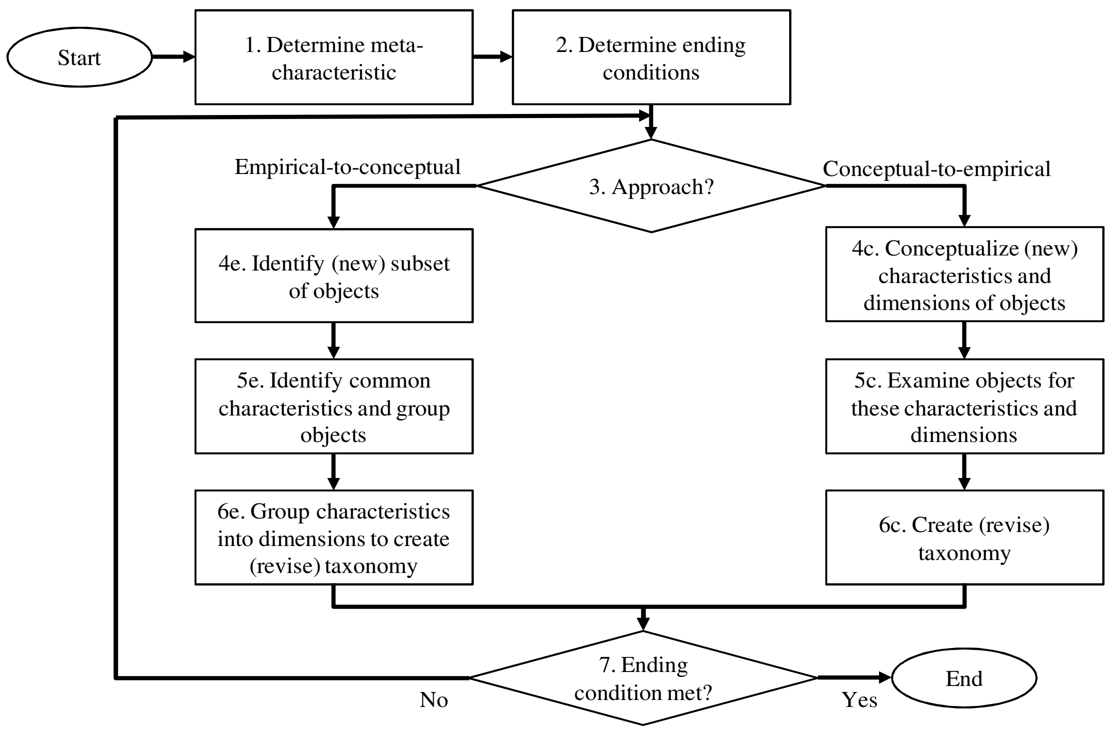

Figure 1. The taxonomy development method (Adapted from Nickerson et al., 2013)

Any of the approaches described here could be used for developing taxonomies in health-IT. Numerical taxonomy from biology, with its reliance on statistical clustering, would suffice in situations involving significant data. The cladistic approach from biology may be harder to apply as it requires identifying evolutionary relationships, which may be difficult to find outside of the biological domain. The empirical approach in the social sciences is based on numerical taxonomy and could be used in health-IT. The conceptual approach from social sciences could also be used as could Bailey's indicator or operational approach. We find, however, that the Nickerson et al. (2013) method includes elements of other approaches in a unified pattern that does not limit the researcher to one approach but rather allows the researcher to choose the best path or paths leading to the final classification. The richness and completeness of this method, as well as the fact that it has been demonstrated in information systems, leads us to select it for developing health-IT taxonomies.

DEVELOPING A TAXONOMY FOR HEALTH-IT

We now apply the Nickerson et al. (2013) method for our taxonomy development and identify the steps with the numbers in Figure 1. We define a healthcare application as a use of information technology for a particular health or medical purpose such as health conditions, medications, and locations of patients or healthcare professionals. Healthcare applications are provided by IT services that have the infrastructure necessary to deliver the application.

We want to be able to use our taxonomy to identify how healthcare services are delivered by the applications. Specifically, the purpose of our taxonomy is to distinguish among healthcare applications based on the context in which the healthcare services are delivered. Such a taxonomy helps us identify whether new applications are unique from healthcare perspectives and where applications do not exist in the taxonomy, suggesting opportunities for new applications. The meta-characteristic for our taxonomy development process is the context of healthcare delivered by the application. In general, context includes who (identity), when (time), what (activity), and where (location) (Varshney 2009). More details on meta-characteristics and how to define a suitable meta-characteristic can be found in (Nickerson et al., 2013).

Step 1: Meta-characteristic: the context of the healthcare delivered by the application

Step 2: Ending conditions: The method will end when the taxonomy is determined to be concise, sufficiently inclusive, comprehensive, extendible, and explanatory (Nickerson et al., 2013). In addition, no new dimensions should be added in the last iteration.

Iteration 1:

Step 3: Approach: Empirical to conceptual

Step 4e: We identify the following healthcare applications from the literature (Tulu 2005, Varshney 2009)

• Telemedicine: These applications use telecommunications technologies to provide healthcare services to patients in other locations. In general, these applications require immediate response from healthcare professionals. Their aim is reduce or eliminate location constraints on patient care.

• Health monitoring: These applications involve measuring and transmitting multiple vital signs and biomedical parameters of the patient to healthcare professionals who then make healthcare decisions.

These applications need to know the patient's location to determine if some types of care, such as transportation to a healthcare facility, are needed.

• Intelligent emergency response: These applications use enhanced emergency systems to manage emergency calls, emergency vehicles, and incident management. The response to an emergency situation is immediate and in a specific location.

• Healthcare inventory management: These applications involve tracking of medical supplies and equipment inventory and, based on different thresholds, ordering and receiving additional items. Not directly related to the patient care, these applications can affect the quality of care.

Step 5e: We identify the following context characteristics in these applications and group the applications:

- The application is used by the patient (who)
- The application is used by healthcare professional or administrator (who)
- The response to the application is immediate/urgent (when)
- The response to the application is non-immediate/not urgent (when)

For example, telemedicine applications as described previously are used by the patient and involve immediate response.

Step 6e: We group these characteristics into the following dimensions to form our first taxonomy:

- User dimension: patient and healthcare professional/administrator characteristics (who of context)
- Response dimension: immediate and non-immediate characteristics (when of context)

At this point we have our first taxonomy, which we describe formally as

T_1 = {User (Patient, Healthcare Professional/Administrator),

Response (Immediate, Not-Immediate)}.

Table 2 shows the classification of the applications examined in this iteration using this taxonomy.

Applications	User		Response	
	P	HP	I	NI
Telemedicine	X		X	
Health monitoring	X			X
Intelligent emergency response		X	X	
Healthcare inventory management		X		X

Table 2: Taxonomy of Healthcare Applications after Iteration 1

Step 7: Ending conditions: The taxonomy is concise, extendible, and explanatory. However, its limited number of dimensions and characteristics may not be sufficiently inclusive. It is not known if it is comprehensive because more healthcare applications exist that need to be considered. Two dimensions were created in this iteration. At least one more iteration is needed.

Iteration 2:

Step 3: Approach: Conceptual to empirical

Step 4c: We conceive that some applications involve patient's direct interaction and others involve indirect interaction (may be assisted by device or healthcare professionals). We identify this dimension as role dimension:

• Role dimension: primary (direct interaction with patient) and assisted (indirect interaction) characteristics (what of context)

Step 5c: We identify instances of these types of application. For example, telemedicine applications as described previously are primary application whereas health monitoring applications are assisted applications.

Step 6c: Adding this dimension to the previous three dimensions creates our next taxonomy:

T_2 = {User (Patient, Healthcare Professional/Administrator),

Response (Immediate, Not-Immediate),

Role (Primary, Assisted)}.

Table 3 shows the applications examined so far classified using this taxonomy.

Applications	User		Response		Role	
	P	HP	I	NI	PRI	AST
Telemedicine	X		X		X	
Health monitoring	X			X		X
Intelligent emergency response		X	X			X
Healthcare inventory management		X		X		X

Table 3: Taxonomy of Healthcare Applications after Iteration 2

Step 7: Ending conditions: The taxonomy is concise, extendible, and explanatory. The addition of another dimension makes the taxonomy more inclusive. It is not known if it is comprehensive because more healthcare applications exist that need to be considered. One dimension was added in this iteration. At least one more iteration is needed.

Iteration 3:

Step 3: Approach: Conceptual to empirical

Step 4c: We conceive of one more dimension: Some healthcare applications work better knowing the location of its users, whereas other applications do not depend on where the user is located:

• Location dimension: location-based (application uses the user's location) and non-location-based (application does not use the user's location) (where of context)

Step 5c: We find a number of applications with these characteristics. For example, telemedicine applications free up the location constraint of the patient. Health monitoring applications use patient's location in responding to an abnormal condition.

Step 6c. Adding this dimension to the previous three dimensions gives us our next taxonomy:

T_3 = {User (Patient, Healthcare Professional/Administrator),

Response (Immediate, Not-Immediate),

Role (Primary, Assisted),

Location (Location-based, Non-location-based)}.

Table 4 shows the use of this taxonomy to classify the applications we have examined so far.

Applications	User		Response		Role		Location	
	P	HP	I	NI	PRI	AST	LB	NLB
Telemedicine	X		X		X			X
Health monitoring	X			X		X	X	
Intelligent emergency response		X	X			X	X	
Healthcare inventory management		X		X		X	X	

Table 4: Taxonomy of Healthcare Applications after Iteration 3

Step 7: Ending conditions: The taxonomy is concise, extendible, and explanatory. The addition of one more dimension makes the taxonomy sufficiently inclusive. It is not known if it is comprehensive because more healthcare applications exist that need to be considered. One dimension was added in this iteration. At least one more iteration is needed.

Iteration 4:

Step 3: Approach: Empirical to conceptual

Step 4e: We identify additional applications to consider (Varshney, 2009):

• Monitoring of smart home: These applications use of sensors, RFID, and networks embedded in a home-stay patient's environment to monitor the overall activity of daily living (ADL).

• Stray prevention and monitoring: These applications use location-aware technologies (sensors, RFID, GPS) to track patient location and to prevent patients, especially those with diminished mental capacity, from wandering away. The role of these applications is in assisting with patient safety.

• Electronic Health Record (EHR) and healthcare data storage: These applications involve digital storage, access, and updating of information related to patient care. These applications are used by healthcare professionals in providing suitable care to patient and the patient's location does not affect these applications.

• Behavior health monitoring: These applications allow patient's family and caregivers to monitor various conditions related to behavioral health, such as mood, activities, sleep, diet, and weight loss. These applications play assisted roles in delivery of healthcare. The patient's location is important in these applications for safety as well as necessary care reasons.

Steps 5e and 6e: We cannot identify any new dimensions from these applications. We group the new applications, along with the previous applications, using the existing characteristics and dimensions as shown in Table 5.

Applications	User		Response		Role		Location	
	P	HP	I	NI	PRI	AST	LB	NLB
Telemedicine	X		X		X			X
Health monitoring	X			X		X	X	
Intelligent emergency response		X	X			X	X	
Healthcare inventory management		X		X		X	X	
Monitoring of smart home		X		X		X	X	
Stray prevention and monitoring		X	X			X	X	
EHR and healthcare data storage		X		X		X		X
Behavior health monitoring		X		X		X	X	

Table 5: Taxonomy of Healthcare Applications after Iteration 4

Step 7: Ending conditions: The taxonomy is concise, extendible, sufficiently inclusive, and explanatory. With four additional applications, the taxonomy appears to be comprehensive. No dimensions were added in this iteration. The method ends at this point based on the guidelines from Nickerson et al., 2013.

Our final taxonomy of healthcare applications is as follows:

- User dimension: patient and healthcare professional/administrator characteristics (who of context)
- Response dimension: immediate and non-immediate characteristics (when of context)
- Role dimension: primary and assisted characteristics (what of context)
- Location dimension: location-based and non-location-based characteristics (where of context)

A more formal description of the current taxonomy can be given as

T_3 = {User (Patient, Healthcare Professional/Administrator),

Response (Immediate, Not-Immediate),

Role (Primary, Assisted),

Location (Location-based, Non-location-based)}.

The taxonomy can be useful in designing new applications. By examining the taxonomy in Table 5, we can make several observations, including the following:

1. The majority of applications are used by healthcare professionals. New applications could be developed for patients considering safety and comfort dimensions. These could focus on wellness, information retrieval, and activity reminder.

2. The numbers of applications needing immediate and non-immediate response are about equal. This may show that various scenarios of their use have been included. Some applications can be designed to provide immediate or non-immediate response based on the context.

3. Most applications do not involve direct interaction with the patients. There may be opportunities for applications that facilitate more direct patient interactions. Applications on healthy living and wellness may fill this void.

4. Most of the applications use patient's location as the care is provided by knowing the location. The future applications will continue to utilize locational information in the context of healthcare delivered.

5. Several voids exist in the taxonomy. There are no applications with combined characteristics of patient (centric), immediate response, primary (direct interaction with patient), and location-based. Thus, a medication or activity reminder application can be designed as this would be patient-centric, requires immediate response, involves direct interaction with patient and needs the current location of the patient. The future applications will deliver more personalized healthcare to patients. The use of context in our taxonomy could facilitate the design and classification of such applications.

We demonstrated that the method (Nickerson et al., 2013) works well in health-IT. We are able to classify several known health-IT applications using the known/derived dimensions. The derived taxonomy is concise, extendible, sufficiently inclusive, and explanatory. With the consideration of 8 different applications, the taxonomy appears to be comprehensive.

DISCUSSION

To better grasp the fast growing knowledge, the health-IT community has shown an interest in developing taxonomies. This is supported by our literature survey, which also uncovered many interesting patterns, including the ad hoc nature of taxonomy development. We presented and discussed several methods of taxonomy development in biology, social science, and information systems. We decided to use a recently proposed method (Nickerson et al., 2013) that offers guidelines for taxonomy development in many different areas.

Using this method, we developed a taxonomy of health-IT applications. In the process we were able to use all the steps in the method. We also applied guidelines on the selection of the meta-characteristic and subjective and objective ending conditions. Using the meta-characteristic of "context of the care", we identified four dimensions and two characteristics in each dimension. We were able to add applications, by analyzing them in the context of the care, to the taxonomy easily. We demonstrated that the resulting taxonomy provided a useful classification of eight types of applications. As new types of applications are identified, these can be easily classified using the taxonomy. We conclude that the method we used was effective in developing a taxonomy in health-IT.

SUMMARY/CONCLUSION/SUGGESTIONS FOR FUTURE RESEARCH

We surveyed a range of healthcare literature and concluded that, whereas many health-IT researchers have found taxonomies useful, often the process of developing a taxonomy is ad hoc, and thus a method for taxonomy development would be beneficial. There is also a need to develop more taxonomies to structure the emerging knowledge and research in health-IT.

This paper demonstrates the efficacy of a particular taxonomy development method by developing a taxonomy in health-IT. The approach that the paper took followed the design science paradigm by evaluating the method by using it to build a taxonomy (artifact), and finally evaluating the taxonomy by using it to classify objects in the health-IT.

The most important contribution of this paper is the application of a method for developing taxonomies. The method addresses the process of taxonomy development and provides guidance during the design science build/evaluate cycle of developing taxonomies and evaluating them against a set of necessary conditions for usefulness. Using the method, many existing health-IT taxonomies can be expanded. This is one of our near-term research goals.

Finally, applying the method to other domains and investigating the resulting taxonomies is an ongoing area for research. There is a need to study the high complexity and diversity of healthcare and health-IT in taxonomy development research. The identification and structural nature of relevant constructs could be a step towards developing theories in health-IT.

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