Developing a Data Quality Research Taxonomy – an Organizational Perspective

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Data and Information Quality (DIQ) is a fast growing research area aiming to improve the effectiveness of decision making in organizations. Due to the multi-disciplinary nature of DIQ research, it is challenging to outline the domain from various views. As a consequence, researchers often focus on only one single aspect of DIQ issues. As far as we know, there is no comprehensive taxonomy of DIQ research area available, in particular including organizational aspects. This paper analyses contributions from relevant journals and conferences addressing DIQ issues. Our analysis shows that managerial and strategic issues are dominant in DIQ research, followed by the role of information technology in the organizations. Our analyses also demonstrate that managing information processes lacks research attentions at present. Furthermore, the analysis indicates that there is a research gap for designing the processes in order to control information problems in organizations.

• Information systems→Data and Information Quality • Information Systems→Organizational Study→Taxonomy Developement

Additional Key Words and Phrases: Data Quality, Taxonomy Development.

1. INTRODUCTION

Since the effectiveness of business information management within an organisation is determined by the quality of information (Chaffey & White, 2010), Data and Information Quality (DIQ) is considered to be an important issue in an organisation. In order to address the DIQ issues, different researchers have taken different views to investigate DIQ. For example, some papers distinguish between data, information, knowledge and wisdom quality (Baskarada & Koronios, 2013; Waheed & Kaur, 2014), some other papers view DIQ from an information technologists' perspective (Botha, Botha, & Herselman, 2014). Because of a variety of views on DIQ, DIQ is sometimes termed as Data Quality or Information Quality. In this paper, we use the term DIQ that is interchangeable with Data Quality and Information Quality.

DIQ has been addressed in different research disciplines such as statistics, management and computer science. Statisticians are the first to investigate some of the problems related to DIQ by proposing a mathematical theory for considering duplicates in statistical data sets (Batini & Scannapieca, 2006). Following the statisticians, management researchers at the beginning of the 1980's focused on how to control data manufacturing systems in order to detect and eliminate DIQ problems. Later, at the beginning of the 1990's computer scientists begin to study how to define, measure, and improve the quality of electronic data stored in databases, data warehouses, and legacy systems (Batini & Scannapieca, 2006).

More recently, researchers donate the DIQ studies in a specific domain such as (Blake, 2010; Helfert & Ge, 2006; Lima, Maçada, & Vargas, 2006; Madnick, Wang, Lee, & Zhu, 2009; S. Sadiq, N. K. Yeganeh, & M. Indulska, 2011; Zhang, Wu, Zhang, Liu, & Huang, 2013). Accordingly, the understanding of DIQ issues is usually bounded to a specific domain such as Healthcare or E-Commerce. Thus, there is lacking a detailed DIQ taxonomy with organizational perspectives. The utility of taxonomy has been well recognized in the information systems (IS) research (Nickerson, Varshney, & Muntermann, 2013). Taxonomies provide structure and organization to the knowledge

of a field. They enable researchers to study the relationships among concepts and hypothesize possible relationships (Nickerson et al., 2013). For practice, it helps organisations to solve their problems by finding the root of problems and relationships between the concepts (Williams, Chatterjee, & Rossi, 2010). In DIQ research, it is important to derive a taxonomy to detect emerging research direction, especially with today's rapid technological changes such as Big Data (Cai & Zhu, 2015; Saha & Srivastava, 2014), crowdsourcing (Lukyanenko & Parsons, 2015), social information system (Tilly, Posegga, Fischbach, & Schoder, 2015) and semantics web (Fürber, 2016), it becomes critical to identify emerging research directions with taxonomy. Therefore, our developed DIQ taxonomy tends to analyse the status quo of DIQ research and outline the promising research topic in DIQ.

Since DIQ management can be considered as a sub-discipline of information management (Chaffey & White, 2010; Gorla, Somers, & Wong, 2010), we have reviewed DIQ research in the scope of information management. There are four different views of information management, which include process, organisational, library and personal views (Detlor, 2010) . We map the DIQ issues to the four determined aspects to clarify the relationship between the DIQ issues and their roots. The contributions of the papers three folds: (1) we have analysed recently published papers in order to identify important DIQ research areas, with a particular focus on the recent years of 2014-2016. (2) We have proposed a comprehensive DIQ taxonomy in organizations. (3) The proposed taxonomy demonstrates emerging research directions for researchers and practitioners.

The remainder of the paper is organised as follows. Section 2 defines our research scope in DIQ relating to information management. Section 3 describes our research methodology. Section 4 presents our analysis of selected research contributions and discuss the results. The last section concludes the work and provides key findings and indication for future studies.

2. RESEARCH SCOPE

DIQ management in information systems was introduced by (Brodie, 1980). He states that Data Quality cannot be achieved without emphasis on both structure and behaviour. The seminal work that focuses on DIQ dimensions which help organizations to measure DIQ was introduced by (Wang & Strong, 1996). They extract different dimensions that are important to data consumers and categorize the dimensions in four classes. A large number of DIQ papers are following the derived dimensions and categories from (Wang & Strong, 1996).

There are very different issues that should be considered in DIQ (S. W. Sadiq, N. K. Yeganeh, & M. Indulska, 2011). As a conclusion, researchers with different scientific backgrounds try to represent different taxonomies based on their knowledge. For example, some researches focus on finding a comprehensive list of DIQ dimensions (Huang, Lee, & Wang, 1998) and some try to elaborate the correct meaning of DIQ and different aspects of its Management (Lillrank, 2003). Besides that there are a many papers in other disciplines such as medicine, health, and physics that use the results of DIQ research.

Given the multi-disciplinary nature of DIQ Research, we observe different views in this area such as Database, Data Mining, Management, and Domain-Specific. In order to develop a useful DIQ taxonomy, we review papers from different point of views with both Quantitative and Qualitative Research Methods.

Some papers focus on database and data warehouse aspects. They focus on data source and database design according to data sources, schema and instances (Gschwandtner, Gärtner, Aigner, & Miksch, 2012; Oliveira, Rodrigues, Henriques, & Galhardas, 2005; Rahm & Do, 2000). They also propose another representation of DIQ problems that shows 6 different types of problems that all are from technical aspects of attribute, tuples, Relationships (Oliveira et al., 2005). (Simmhan, Plale, & Gannon, 2005) derive a taxonomy for data provenance. They propose 5 different classes, which are use of provenance, subject of provenance, provenance representation, storing provenance, provenance dissemination.

In a broader view of DIQ, researchers classify the problems into three classes based on the content, form and time dimensions (Kim, Kishore, & Sanders, 2005). Content dimension deals with the intrinsic information content issues that are geared toward providing users with accurate, relevant, and complete information. Form dimension deals with information presentation issues that are geared towards enhancing users' cognition. Time dimension deals with information delivery issues that are geared towards providing users' better control over temporal aspects of their actions thereby providing them with a sense of temporal orientation. Likewise, (Du & Zhou, 2012) conduct studies and propose a two-dimensional ontology-base classification schema for DIQ. The first dimension is anchored in ontological foundation including completeness, unambiguity, correctness and the second dimension is based on the abstraction level of ontology that consists of schema and instance.

On the other side, there are some researches that clarifies the DIQ domain and main issues of the DIQ management. For example (Madnick et al., 2009) classifies the topics of DIQ in four groups which are DIQ impact, Database related technical solutions for DIQ, DIQ in context of computer science and IT and DIQ in curation. (Zhang, Zhang, et al., 2013) focus on categorization and find the evolution of the filed in different periods. They propose 6 classes and examine the fastest growing filed in DIQ is computing technology. However their research is also more technical focused than the comprehensive taxonomy that can help organizations manage the quality of their data and information with respect to holistic view of the organization.

There are also some studies that use quantitative and data mining approaches. In a quantitative approach, latent semantic analysis is used to find the core topics and theme in DIQ and find 6 different related topics (Blake, 2010). In (S. Sadiq et al., 2011), a vast number of papers is analysed and they derive the taxonomy based on the keywords of the papers. They find 18 DIQ related issues. Further, there are also some efforts towards finding the conceptual classification for DIQ from the theoretical and practical views. (Lima et al., 2006) suggests a conceptual model for DIQ in different layers and views.

Although there are many papers that aim to clarify the issues and describe the border of the DIQ, there are limited that analyse the relationship between DIQ and information management. As such, there is a gap between DIQ and organizational perspective of it.

3. RESEARCH METHOD

In order to provide an overview of the DIQ research area, DIQ related papers from relevant DIQ as well as Information System journals are selected. In order to assess the relevancy, we conducted open interviews with 5 experienced DIQ researchers. According to their suggestions we choose the most prestigious journals and conferences. The list includes “ACM Journal of Data and Information Quality (JDIQ)”,”

International Journal of Information Quality (IJIQ)", "Journal of Information Technology", "Journal of Management Information Systems", "Information Systems Research", "Journal of Strategic Information Systems". In addition, we included papers from the proceedings of "International Conference on Information Quality (ICIQ)" due to the importance of the conference. The following Table summarizes the number of papers we have identified that are related to DIQ from each of the sources.

Table I Total Number of Papers in Each Source

Source title	Papers
International Conference on Information Quality(ICIQ)	219
International Journal of Information Quality(IJIQ)	53
Journal of Data and Information Quality(JDIQ)	41
Journal of Information Technology	1
Journal of Management Information Systems	12
Information Systems Research	7
Journal of Strategic Information Systems	2
MIS Quarterly: Management Information Systems(MISQ)	4
European Journal of Information Systems	2

Considering the direct relevance of the published papers, all the papers from ICIQ, IJIQ, and JDIQ are considered to be relevant to DIQ. In order to find DIQ related papers, we analysed the topics using an application called MineMyText[1]. Using this application the papers with the word "Quality" in topics are found, then the selected papers are examined by the DIQ experts and papers that subjectively are identified as DIQ papers are chosen.

In order to develop an organizational taxonomy of DIQ, we applied an inductive methodology suggested by (Nickerson et al., 2013). This is a prominent and acceptable approach for taxonomy formation. The key steps are depicted in Figure 2. It is important to note that this process is iterative.

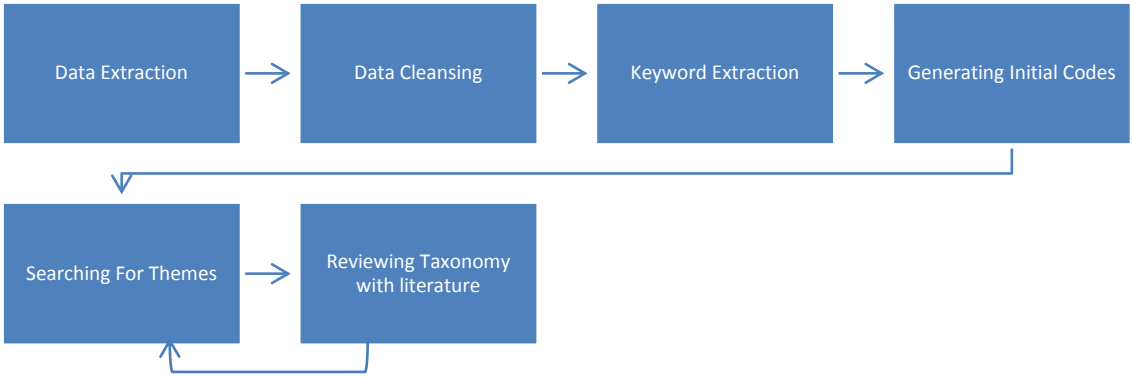

Figure 1 Taxonomy Formation Research Methodology

The first step, data extraction extracts keywords from the selected papers. Three types of keywords are extracted. The first type is the keywords listed by the author(s). The second we used the indexed keywords from Scopus. The third one is keywords suggested by the research team. These are used in cases that papers lack of keywords or when the keywords could not reflect the concern of the paper. *Data cleansing* phase

[1] https://app.minemytext.com

consists of different methods like spell checking, case matching, and transformations in order to unify the format of the keywords for analysis.

In the next step, we developed a three-layer hand coding system for combining the keywords and forming the themes. For *generating initial codes*, similar keywords are combined to each other and named with a code by the researchers. For example words cleaning, cleansing, missing codify as cleansing. Then in each layer, the coding system is used to integrate the related keywords and form a new theme. At the last stage, they are combined in four different categories according to information management research area. In other words, the extracted themes are mapped to the information management area according to the researcher's point of view.

In order to complete the taxonomy of DIQ, other proposed taxonomies or mapping for DIQ are used to improve our initial taxonomy. This is done in order to improve the coverage of the proposed taxonomy and checking the themes with previous taxonomies. An iterative method is used to improve the taxonomy every time after each cycle when changes are made. The themes are verified in other papers in order to form a suitable and validated taxonomy.

For the final stage of the taxonomy development, information management papers are studied to find a mapping between DIQ and Information Management in organizations. For that reason, information management studies are reviewed in order to find the related organisational works (Brancheau & Wetherbe, 1987; Hashem et al., 2015; Orozco, Tarhini, & Tarhini, 2015; Rowley, 1998; Yang, 1996). From the review, it is found that the Detlor model (Detlor, 2010) captures a broader and comprehensive view on information management. Therefore it is decided to use the proposed model for information management to classify the top level taxonomy. According to Detlor, there are four aspects that try to control the lifecycle of information processes from creation to use for the improvement of organization (Detlor, 2010). Moreover effectiveness of business information management within organizations determined by the quality of the information (Chaffey & White, 2010).

The four aspects of information management are: (1) information as a resource that view and treat information as a strategic resource that need to be managed. Organizations are looking for the value of information and the costs associated with acquiring, storing, processing and using that information. They consider information as a strategic asset of organization and try to make competitive advantage for their organization based on it(Karim & Hussein, 2008). (2) The second aspect is managing information processes that manage full lifecycle of information ranging from creation to use. (3) The third one is the information technology role of information management in organizations, where IT is a technical medium. (4) The last aspect of information management is concerned with organizational information processing that is described as an organization's ability to process information in this paper. It is the core of managerial and organizational competencies with improving information processing capabilities for increasing an organization's information processing capacity and reducing an organizations need for information (Detlor, 2010).

After finalizing the taxonomy formation, the published papers of the last two years are analysed for two reasons, firstly, validating the results with the published papers. Secondly, uncovering the research focus of recent years and find the most focused research areas from 2014 to 2016. In order to find the most important issues in one research area, it is important to find the focus of researchers in different themes. For example the extracted themes show that the main focus of researchers is on Data Integration and also Data Provenance that is the result of advanced in technologies

like Big Data and Semantic webs. It can also be find the possible research gaps in the domain or also analyse the impact and future direction of researches by it.

4. RESULTS

In the first step all three types of extracted keywords from the selected papers are qualitatively analysed in order to find the themes and the taxonomy of DIQ. The proposed taxonomy has 4 layers. The two top layer in the taxonomy of DIQ areas is shown in Table 2. The left column is extracted from information management domain and the right column is extracted from the papers with the keyword analysis.

Table II Top layers taxonomy of DIQ

Information as Resource (Organization)	Managerial Issue
	Business Requirement
	Data Life Cycle
Managing Information Process (Process)	Enterprise Architecture
	DIQ Process
	DIQ Standardization
Information Technology (Tools)	Data Analytics
	Visualization
	Business Applications
	Internet Application
Information processing (Infrastructure)	DB & DW Design
	Data Integration
	Query and Processing
	Data Cleansing and Curation

As the second step, we have added the new keywords and cleaned them. As such, a list of all keywords and their frequencies are extracted in order to extract conceptual themes. In the following figure, top ten most used keywords in the selected papers is demonstrated.

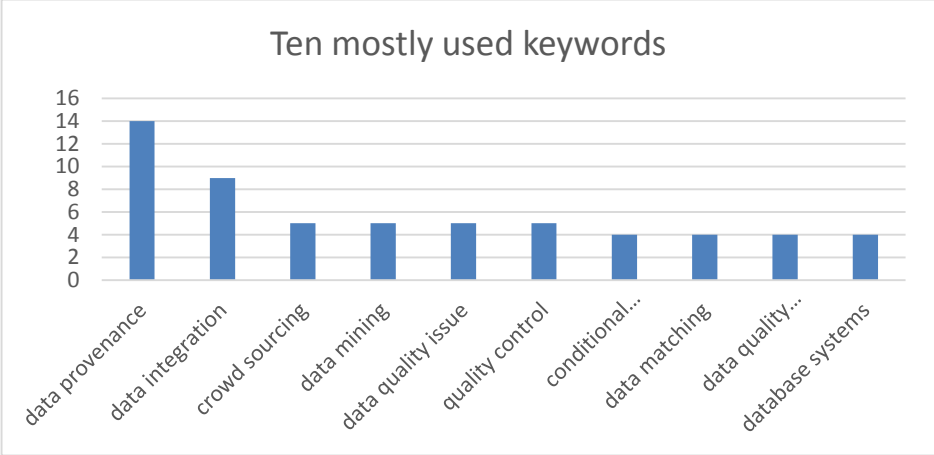

Figure 2Top 10 Mostly used Keywords

After finding the keywords and their frequencies from the recursive processes, conceptual themes in different layers are obtained. At each iteration, the keywords that are in the same field are combined and produce a code, after that in order to confirm the theme and modify them, the result are checked with the literature and fine-tuned the theme. It is also found the importance of each area by checking the frequency of each theme.

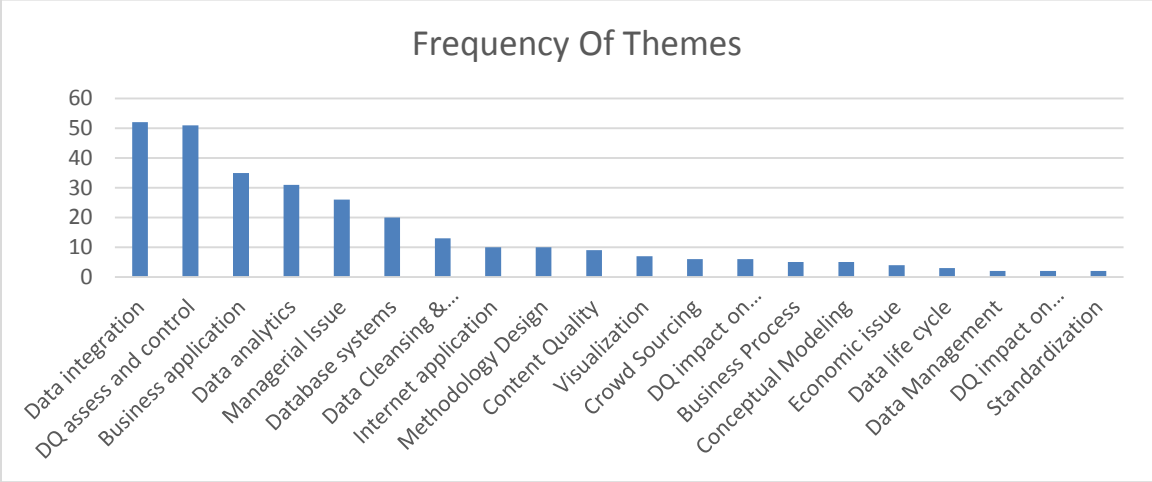

Figure 3 Extracted Themes of DIQ

According to the above findings and also analysing the papers in the area of DIQ and information management, the structure for DIQ from an organizational view is represented. In the following Figure 5 this structure that is reflected by a complete taxonomy of DIQ in organizations is shown. It can be seen that the proposed taxonomy can be mapped to the four main aspects in information management.

The first aspect is *information as resource*, which is named as organizational issues in this research. In this class business requirement analysis such as DIQ assessments and its impact on security, trust and operations is studied. Strategy and policy making issues such as economic and business aspect of DIQ is discussed in this class. The second aspect is related to *information technology* role in organizations. This class is related to technology and tools that are developed for DIQ management. These tools are categorized in four sub branches including data analytic methods such as data mining methods for missing data detection, noise detection and visualization methods for spatial data or GPS applications, and enterprise- and web-based solution developing methods for management of DIQ. The third aspect is about *managing information processes* that covers the architecture, process and standardization issues for DIQ. The main issue is to investigate the process and modification of architectures in order to assure the quality of information. The last aspect is *information processing* issues that cover all issues to help organizations optimize the needed infrastructure. It focuses on database and data warehouse related issues such as design, integration, cleansing and query processing issues.

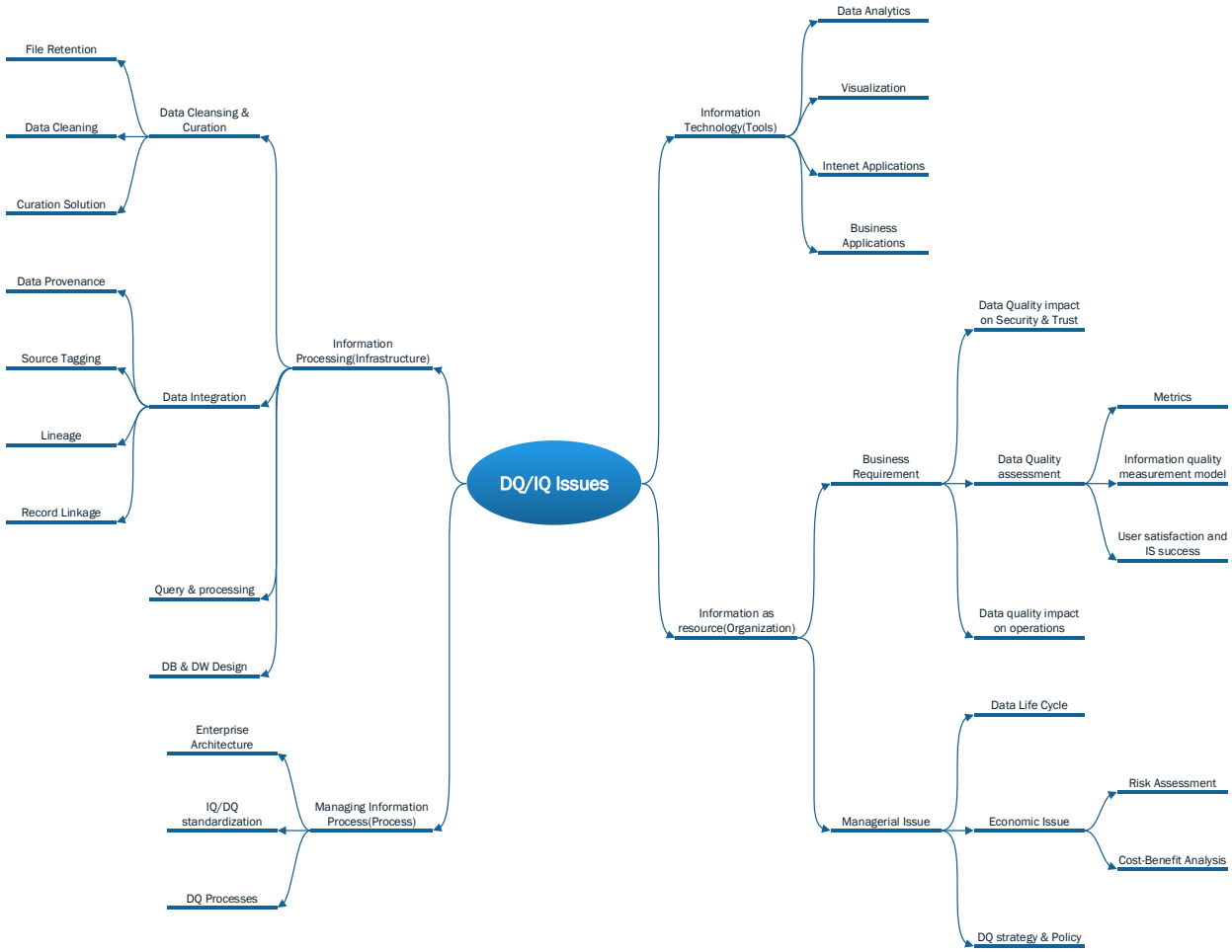

Figure 4 Taxonomy of DIQ

From the taxonomy and by checking it with other works, it can be concluded that there is no major changes in the well-known problems of DIQ. For example, the problem of integration has been stated in the earlier studies as well as in recent studies. Interestingly, certain emerging stream for research in DIQ research are found. For example, there are emerging streams like user generated content quality, Big Data Quality, and provenance that are coming along with other new research areas such as Big Data analytics and Semantic Web. (Ge & Helfert, 2007) has proposed three aspects for DIQ, which are assessment, management and context. From the three aspects, it can be seen that there are only changes in the context. That means limited issues are emerging and only previous problems in the new context is focused. For example, researchers begin to concern the DIQ metrics or assessment in social networks and this however does not affect the top layers in the taxonomy.

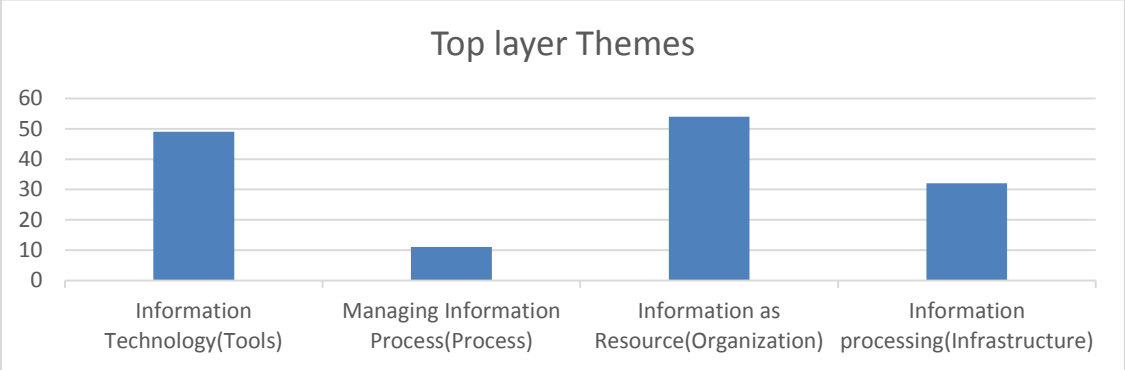

Figure 5 Frequency of Top layer themes

Among the top layer themes at Figure 6, Information as Resource is the most frequently appeared theme. It means that organizational and managerial issue is the most studied theme for the DIQ researchers. After that, developing tools for businesses is the second important. It indicates that after or realizing or analysing issues in organizations practitioners tend to develop new tools or use existing tools to solve these issues. Although managing information process is the last ranked theme, there can be a potential gap in the process area that would be worthwhile to close. It seems that there is a need to design the processes in order to implement and control the information problems in organizations.

It is inferred that the managers understand the strategic value of the data and also its quality. There is also dramatic changes in organizations data sources from internal data towards external data sources such as user generated and social media (Lukyanenko & Parsons, 2015; Tian et al., 2016) . Managers may have considered the changes and try to clarify the related problems. There is also notifiable focus from computer scientists who try to develop new tools for extraction and analysis of new sources of data. But it seems there are not enough efforts to develop new processes to manage DIQ for new multinational, distributed organizations that need the data from external sources.

5. CONCLUSION AND FUTURE WORKS

This paper has employed qualitative and an iterative approach in order to develop a comprehensive taxonomy for DIQ. We have reviewed and consolidated a significant amount of relevant papers and derived our taxonomy. Furthermore our research revealed that the main focus of DIQ research in the last two years is mostly on the managerial issues. Most papers discuss about strategic and governance issues related to information. Also, there is a focus on tool development for DIQ management. This could be the result of recent Big Data research and new concepts like social networks and Data Science. All these concepts are dealing with a considerable amount of data and require relevant tools. All identified DIQ research streams fit into the top layers of our taxonomy. Based on the DIQ classification from (Ge & Helfert, 2007) we found that the emerging changes in the DIQ research are mostly related to the context such as Big Data, Social Networks, Cloud Computing or Crowd Sourcing, indicating that the traditional data quality model begins to be applied in new contexts. Especially, we have noticed that DIQ metrics have been recently used in social networks.

In addition, the presented taxonomy can be used for examining areas that need to be more focused by researchers and practioners. It can also be used by new researchers who need to find promising research areas. As a future work, we plan to study the

evolution of DIQ in the decade that helps to find the causes and future changes of DIQ issues. It is also promising to apply some machine learning models like topic modelling or clustering in order to find the sub disciplines of DIQ more accurately. Moreover, since knowledge quality is intensively related to DIQ, deriving a knowledge quality taxonomy can be considered as an extention of this work.

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