CEIP Maps: Context-embedded Information Product Maps

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ABSTRACT

This study presents a second-generation coding and visualization technique for IP Maps to improve usability and analyzability. We expand the details of IP mapping to convey contextual elements of the data production process. We ground our modifications in theories on information quality, context theory and argumentation theory. In-depth case studies allowed us to develop and test the applicability of CEIP mapping techniques. Our interdisciplinary research approach is both theoretically grounded and empirically tested.

Context-embedded IP (CEIP) Mapping facilitates data quality root-cause analysis and problem-solving in the case studies by visually representing the contexts in which data production occurs. CRIP Map notation facilitates: (a) knowledge sharing at the enterprise scope; (b) deciphering layers of information and business processes; and (c) root-cause analysis of IQ problems, particularly the handoffs and bottlenecks in between the boundaries of processes and organizations. Case studies exemplify the applicability of CEIP Mapping. We conclude our study with implications for both theory and practice.

Keywords

context, data production process, information flow, data quality (DQ), information quality (IQ), information product (IP), information product map (IP Map), context-embedded information product map (CEIP Map), 3 C's (data collector, data custodian, data consumer)

1. INTRODUCTION

Organizations often experience difficulties when they try to share information across business functions, system boundaries, or organizational boundaries (Lee et al., 2006). Often, organizations roll out new systems such as enterprise-wide systems with a hope that the new system will eliminate the data quality problems and be ready for sharing information. New systems solve some problems yet much data quality problems persist.

Much research has been conducted to identify common data quality problems found and solutions applied. The research areas include definition, measurements, and assessment of data quality, which set the foundations for data quality principles. On the practice side, many companies have applied the principles from the research and other methodologies in the market that prescribe what should be done to improve information quality. For individual organizations and practitioners, they ended up following the common approach or most well-known methodologies in their organizations without fully exploiting the local knowledge residing across various places of the entire organization, individual knowledge about data quality problems, and solutions held by individuals.

One way of sharing the information starts from sharing the knowledge about and behind the information. The Information Product Map (IP Map) contributed to this end (Pierce, 2005; Lee et al, 2006). It records the information flow explicitly and the entire process can be easily shared among the members of an organization or among partnering organizations. As more recent research reveals more complex data quality problems embedded in data and business processes, a clear and easy way to share IP Map that has a capacity to record the complex setting of data is needed.

Information sharing resembles communications occurring in a context. We use context theory and argumentation theory as key guiding theoretical foundation, upon which we build Context-embedded IP (CEIP) Mapping template. We also use field study method and included three in-depth cases to form the empirical basis for the CEIP Mapping template.

The paper is organized including the following sections. First, we review the key theories; second, we discuss the method used; third, we discuss the existing IP Map; fourth, we describe the method of CEIP mapping; fifth, we discuss implications for research and practice; and finally we conclude the paper.

2. THEORETICAL GROUNDING

When we first considered the challenge of improving IP Map notation, it became apparent that we needed a theoretical framework in which we could analyze problems and apply solutions. Two key theories provided useful ways of approaching DQ problems associated with IP mapping: Context Theory (Lee, 2003-2004) and Argumentation Theory (Toulmin, 1964).

Context Theory

Context Theory, from which derives the name "Context-embedded IP Map," (CEIP) foregrounds the significance of context in shaping and solving DQ problems. Five context categories are identified (Lee, 2004): Goal, Role, Paradigm, Time and Place.

Goal

The goal context includes "objectives that individuals and organizations aim to achieve through creating, using, and processing data." In other words, the goal context refers to the intended use(s) of an information product, or *why* the information is being produced.

Role

The role context refers to "specific roles that individuals play in the information discourse and the entire information production system," which are threefold. The standard nomenclature for the three roles is Collector, Custodian, and Consumer, or "The 3 C's."

Paradigm

The paradigm context refers to the "principles that individuals hold and apply when designing, collecting, storing, and using data … [which] are collectively agreed upon, taught, and practiced in a particular field over time, and have a lasting influence on how individuals solve problems." Paradigm is what might be conceived of as the general context of data production: *how* the data is being used, manipulated and accessed.

Time

The time context is "the time frame during which, or for which, data is used and processed." The significance of the time context becomes apparent when we recall that information products, like all products, have a life-span. The IP life-span, along with the intended use(s) of the IP (the goal), informs the production process for that product.

Place

Place context refers to "the locale for which data are generated, used, or processed." Place does not necessarily refer to a specific location—several processes might be completed on a single computer—but rather the occurrence of a process in relation to other processes. Another way to think of place is as the intersection of Time and Role.

We expand on previous research on the influence of context, which focuses primarily on how context shapes demand for different types of data, to include the influence of context on data production and DQ problem diagnosis. Context Theory drew our attention to the categorical context details of data production and DQ problem diagnosis, but it was Argumentation Theory that provided the logical and philosophical perspective with which to carry out analysis and problem diagnosis.

Argumentation Theory

Stephen Toulmin's Argumentation Theory (Toulmin, 1964) identifies the form and process of arguments of everyday human communications: newspaper articles, political speeches, debates with friends, etc. The model Toulmin developed begins with *Data* as the grounds for an argument, which is then supported by a *Warrant* and *Backing* (the reasoning of an argument), and further supported by a *Qualifier* and *Reservation*. The result of an argument is a *Claim*. Toulmin describes how a solid *Claim* can come only from reliable *Data* and well-reasoned supports, all of which are the components of an argument. Toulmin's consideration of the soundness of each component's logic provides a useful lens through which to scrutinize IP Mapping, especially with regard to the 3 C's: the Data is introduced by data Collectors, and the Information Product is used by data Consumers. All 3 C's contribute to the data production process, which is comparable to the structuring of an argument. Just as the soundness of a Claim relies on solid reasoning and Data, so the usefulness of an IP relies on the logic of the entire data production process. We recall that DQ research of the last two decades has increasingly emphasized the need for organizations to view data as a product, with a life-cycle, that must be managed (Wang et al., 1998). We extend this conclusion by drawing attention to the logic of each component of the data production process.

We draw from both Context Theory and Argumentation Theory that organizations need to analyze DQ problems in greater detail, broken down categorically. Examining each of the 5 Contexts is like examining the soundness of each production component's logic: by foregrounding the importance of these categories, we aim to guide more effective DQ problem diagnosis and problem-solving efforts. IP Maps are one of the most useful tools in DQ problem diagnosis because they visually represent the entire data production process. Given our theoretical grounding, we decided to analyze how effectively current IP Mapping techniques capture both the 5 Contexts and the components of data production. What we found is that current IP Mapping techniques fail to account for both context and components' logic: two significant influences on data production and DQ diagnosis.

3. RESEARH METHOD AND STRATEGY

We used the traditional theory-informed in-depth case analysis to study our CEIP Mapping. We initially started with seven pilot case organizations where information is the key resource in operating its business. They include Document Company (Figure 1A and Figure 1B), AIDS clinic, Global Financial Company (Figure 2), Education Organization, International Hospital (Figure 3), Healthcare Insurance, Real Estate Company. We paid attention to the variety of organizations in terms of the kind and scope of its operation and industry to cover a broad scope of data quality phenomena. We selected three organizations for the research strategy of easy access and timeliness of data collection and site visits. The three organizations include (1) a large financial company that operates global financial services, (2) an AIDS clinic in a large hospital, and (3) a small real estate company. All three organizations use information as their key resource for their business operation. The final company operates at the international level, the clinic operates at the domestic level, and the real estate company operates at the regional and local level. All three companies are the leaders in its industry and high performers.

For all three cases, we do not reveal their names. All three companies actively participate in the research with the authors. The duration of observation and participation of each case is 6 month at minimum. We recorded and observed relevant business process. Particularly we bring back the CEIP Map to get their feedback on application of the mapping approach. Although all authors are involved in analyzing and discussing all cases, we designated the ownership of cases to authors, thus all contributing to analysis yet have custody to certain cases for a pragmatic purpose. This worked out well to be able to discuss different cases with fresh viewpoints and relative distance for informed but non-biased discussion and analysis.

4. ANALYSIS OF EXISTING IP MAP

Based on our theoretical grounding, we conclude that an IP Map ought to represent all influences that affect DQ, including the 5 Contexts and individual components of data production. However, current IP Mapping techniques lack the means to represent the influence of context on DQ and data production. For example, when one reads an existing IP Map, there is no clear indicator of the Role context. One cannot gather from a single look at the IP Map for Document Company, Figure 1A, which of the 3 C's affects data production at any given point. In part, this is due to the fact that the data production process for Document Services Company has multiple entry points throughout the production process for additional information. This foregrounds another deficiency of current IP Map notation: there is no measure for the time-frame of data production. The linear arrangement of the IP Map in Figure 1 fails to account for the IP life-cycle, whose failure can hamper efforts at DQ problem diagnosis. Similarly, there is no indication of place. The goal context is misrepresented in that no systematic differentiation is made between internal and external data consumers. The cumulative failures to convey the contexts of data production inhibit analysis of the soundness of each production component's logic, or the paradigm context.

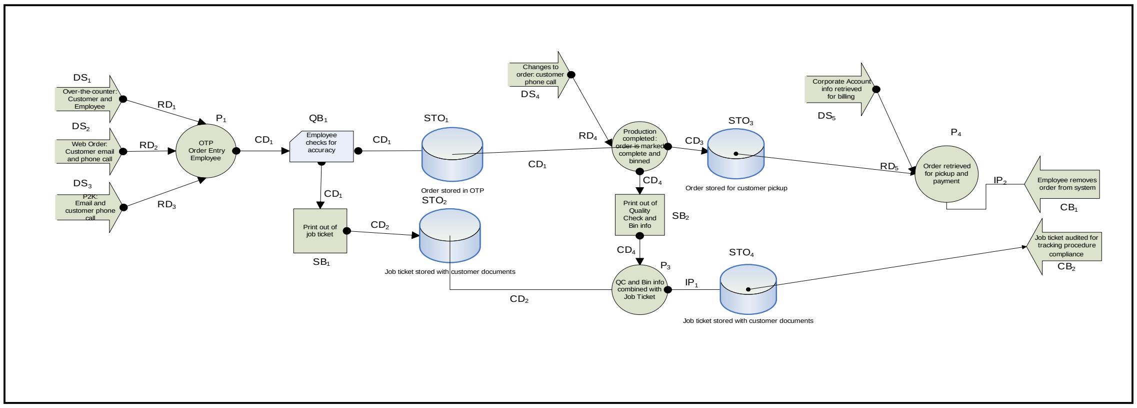


Figure 1A: Conventional IPMap (Document Company)

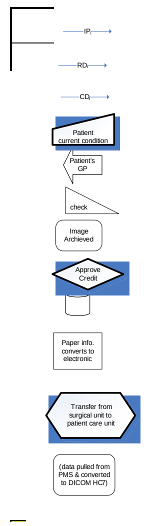
The overall lack of clarity in visually representing the individual components of data production, and the context which affects them, results in neglect of the paradigm context: one cannot determine the rules by which data is collected, stored, manipulated, and accessed if one cannot differentiate between, say, the 3 C's. Without clear representation of context and all data production components, one also faces difficulty analyzing the soundness of those components' logic. A more effective and more useable IP Map must account for these aspects of data production. We found that this was possible by expanding and improving the existing IP Mapping techniques.

5. CONTEXT-EMBEDDED IP MAPS

The existing IP Map notation does not indicate context, or provide recognizable differentiation between production components. Our first concern was to address the missing representation of Role (the 3 C's), Time, and Place. By adding these three elements, individuals can perceive their own impact on the organization's data production process, which in turn affects their performance in implementing solutions to DQ problems. Solutions can be custom-tailored to failures of specific roles; e.g., understanding that the existence of multiple data sources (Collector role) is the root of a DQ problem allows an organization to better address that problem. We came up with Context-reflective IP Maps that contain these and other missing elements. A Context-embedded IP Map adjusts the elements of a traditional IP Map to fit on a two-dimensional graph, with Time in one axis, and Production Stage in the other (see Figure 2 below).

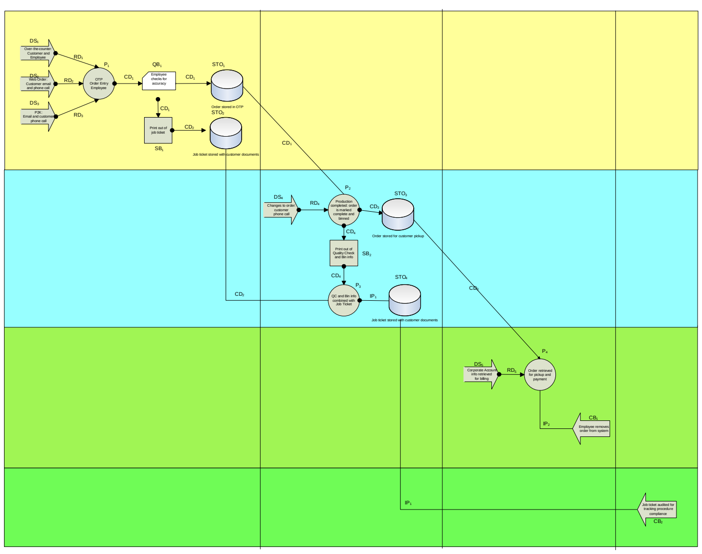
The x-axis, moving from left to right, represents the time intervals during which each production component takes place. The measurements of time can be fractions of a second, days, or even weeks. They can be precise measurements or generalizations if information does not always flow at the same pace through an organization. However, by grouping all related components into the same temporal fields, the CRIP Map ensures that the viewer receives a clear picture of when individual production components are performed.

Production Stage is shown along the y-axis, beginning with data collection, descending to data manipulation and storage by data custodians, and finally arriving at data utilization by data consumers. Although we made no changes to the individual icons used in IP Mapping, we added a color-coding system, which, if universally applied, ensures that any viewer receives the same unambiguous picture of which production components are performed by which role. Production Stage includes both role and place contexts. When read in conjunction with the Time axis, the Production Stage axis shows clearly which production components are performed where, when, and by whom.



Information Product
Raw Data
Component Data
Source Block
Customer Block
Data Quality Block
Processing Block
Decision Block
Data Storage Block
Information Systems Boundary
Business Boundary Block
Info. Systems- Business Boudary Block
Data Collectors Background Layer
Data Custodians Background Layer
Data Consumer Background Layer

Table 1 Extending IP Map: CEIP Map symbols



Time

Figure 1B Example of CEIP Map (Document Company)

Y-axis: Data collector in yellow; data custodian in blue; data consumer in green (internal and external consumers)

X-axis: time

The CEIP Map's two-dimensions clarify the remaining two contexts: goal and paradigm. By visually separating the data consumer(s) from the remainder of the data production process, the CEIP Map allows its viewer to always keep in mind the intended use(s) of the information products. By grouping production components according to time, place and role, the CEIP Map also allows DQ professionals to more clearly analyze the paradigms that shape how individuals in different roles interact with data and affect data production. The grouping of related production components also facilitates analysis of the logic employed by the individuals in any given role. While we recognize that paradigm and logic are not readily mapped in the same way that goal, roles, place and time are, we believe we have created a more versatile and useable IP Map so that, under analysis, the paradigms and logic that determine data access and use—and the problems associated therein—are more easily recognized.

Table 2 outlines the components of data production that are shown by IP Mapping, and how CEIP Mapping techniques expand or improve on the visual representation and interpretability of those components. All components are arranged to show which context they are a part of. Furthermore, each context is shown side-by-side with its corresponding part of Argumentation Theory, in order that the reader may keep in mind the logical perspective afforded by that theory.

IP Map	Context-Embedded IP Map (CEIP)	Context Theory	Argumentation Theory
IP, IP Consumption	IP, IP Consumption	Goals	Claim, Qualifier
Data, IP	3 C's (who), Data, IP	Role	Data
(not shown)	Analysis of IP Map (embedded rules) Principles of IP problem-solving 3 C's (how)	Paradigms	Warrant, Backing
(not shown)	Time	Time	--
Database storage (limited), system and organization boundaries	Place: stage of production, 3 C's (where)	Place: the intersection of Time and Role	Data, Warrant, Backing
Quality Checks	Quality Checks	--	Reservation

Table 2. Areas in which CEIP Maps show context information missing from IP Maps, with correspondence between Context and Argumentation Theories.

6. CASE STUDIES: USING CEIP MAPPING

Case 1: Global Financial Company

"Trade Request Denied - Fee Mismatch," the error message said. The IT Analyst who worked for Financial Company alerted the production support team and initiated an investigation as to why the trade failed. The team supports a gateway system which receives incoming messages from a third party, processes them into other formats, performs order processing, and then sends response messages back to the third party. The ***paradigm*** of the information process dictates that failed trades are generally handled by the municipal bonds traders themselves, as far as business goes, but from the technical perspective, the production support staff had to ensure that there were no system issues at hand.

The failure occurred because Financial Company and their third party Market Company calculated conflicting fees for the same product. Based on the information that Market Company had, their calculation was correct; Financial Company was using multiple sources of information (unavailable or unutilized by Market Company) to infer extra information about the product when performing their calculation. While the specific business rules and reasons for the calculation discrepancy remain unknown to the IT Analyst (as they are beyond the scope of the roles of the production support staff), a phone call to the Financial Company trader confirmed that everything had been worked out on the business side of things.

If Market Company had access to the same information that Financial Company did, the trade would never have originally failed. Inherent in the design of the messages sent between the businesses is a lack of full context required to perform the correct fee calculation. Although the trading system design suffices for most bonds, this bond one was one that demonstrated its limitations. This systemic shortcoming can be explained using ideas from Stephen Toulmin's Argumentation Theory.

Taken in the context of Toulmin's Argumentation Theory, we can ascribe the roles of Claim, Data, Warrant, Backing, Rebuttal, and Qualifier to various aspects of this situation (see Figure X). Implicit with incoming information from Market Company is a ***claim*** that said information is complete, trustworthy, and accurate. ***Data*** supporting the information claim that comes from Market Company is that of internal financial product reference information. Both the ***warrant*** which bridges the claim and data, and the ***backing*** credentials of the Market Company are present as the Market Company's position in the financial industry as a player which generally has correct and timely information. This credential has been established over a historical business relationship with the Financial Company. The data quality problem of fee mismatch is an exemplary ***rebuttal*** to the claim that is the input data coming from the Market Company. However, this rebuttal, which appears as a flaw in the system, is only valid if it is supposed that the ***qualification*** of the initial claim is one of absolute correctness. Because this fee mismatch situation is a known issue with the system, from the Financial Company's perspective, the system's users have come to implicitly regard the qualification of input data from the Market Company as being "generally" correct, for most cases. In this case, where the mismatch occurs because of the particular bond type, the claim of accuracy of the data is qualified to be that of nothing.

The CEIP Map depicted in Figure 2 conveys the ***claim*** of the input data, and the associated ***rebuttal*** of the quality check that is performed on the input data. The diagram also spells out the ***paradigm*** for the situation.

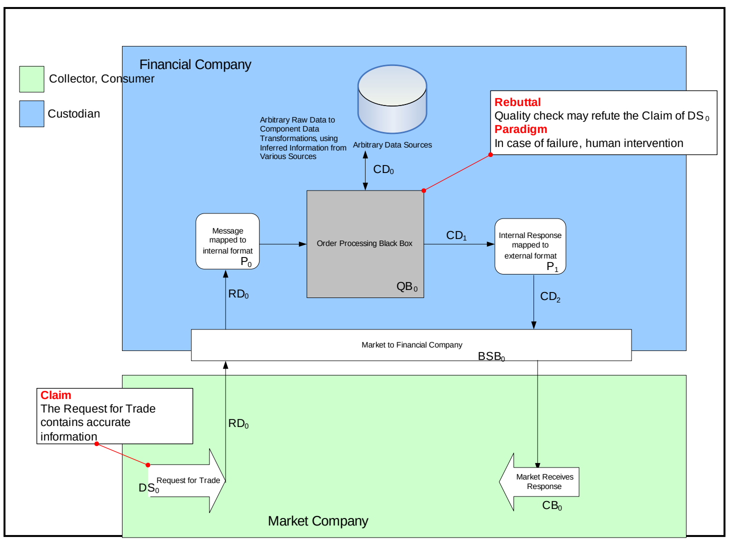


Figure 2 Global Finance Company

Case 2: AIDS Clinic: Hospital

AIDS Clinic is part of a larger hospital with several specialized divisions for patients with specific needs. AIDS Clinic must comply with state standards for patient care in accordance with regulations attached to state funding. Repeated compliance violations could result in a loss of funding. To demonstrate compliance, AIDS Clinic must periodically furnish reports on patient care with information garnered from a server-side database where patient medical information is kept. Unfortunately, this database is ill-maintained, and the reports frequently suffer from poor quality data, particularly data on medical history. For example, dates of prescription for medication are in many cases either misleading or flat-out wrong. Part of the problem's source lies in incomplete collection of these dates, e.g., a month is specified but no day. Data quality further deteriorates due to the procedure followed by custodians in such cases.

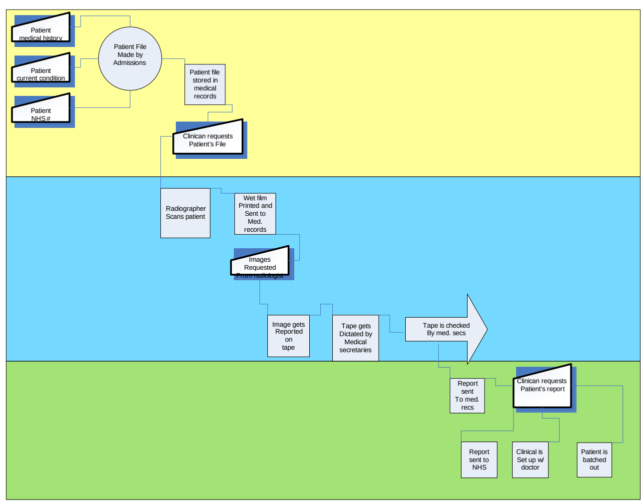
One unit of data that had to be inputted into the database was whether a patient was on HAART (Highly Active Anti-Retroviral Treatment). For a patient to be on this treatment, he or she had to be taking certain combinations of anti-retroviral medication. However, these qualifiers were vague and could get confusing when a patient was taking a certain medication that combined two types of anti-retroviral drugs into one. When asking a doctor for clarity, oftentimes the judgment call came from information only a doctor would have. Thus knowledge of the field and an explicitly defined ***paradigm*** was required to make sound and reliable judgments, yet was not available.

Data custodians at AIDS Clinic were instructed that for incomplete dates of prescription, they should simply input the first day of the month if no day was given, or the first day of the year if no month was given. They were not told why the date was even important. Confusing notation and poor handwriting also contributed to the poor quality of data in the database. Because data custodians at AIDS Clinic mistakenly thought that the date of prescription for a patient *was not* important on the enterprise scale—in other words, did not understand how they fit into the entire data production process—those custodians introduced false data. If, on the other hand, data custodians knew that the date *was* important, then they would manage data sedulously, verifying that such dates were both correct and entered correctly. Knowing why a task is important is crucial for assuring that the task is done properly.

It is too often the case that one (or all) of the 3 C's (collector, custodian, and consumer) overlooks the ***paradigm*** governing his or her ***role*** in data production. Even one individual who is kept ignorant of his or her place in the entire process of data production can adulterate the final information product. Such a systemic problem can be difficult to identify if DQ professionals are not cognizant of the paradigm context of each role. Existing IP Map notation makes it difficult for DQ professionals to diagnose and solve AIDS Clinic's data problem. When looking at a traditional IP Map, it is not clear how individual components fit into the entire data production process.

DQ professionals face the same problem as the data custodians above in that the contexts of data production are unclear or not known at all. Limited understanding of context means that decisions, in data production or in problem-solving, are made from incomplete or inaccurate information. A CEIP Map facilitates DQ problem diagnosis and problem-solving by allowing the viewer to home in on the individual components of data production. This is accomplished by the CEIP Map's design, which organizes the data production according to several contexts: Role, Place, and Time. The result is an easily digested visual representation of the impact of every individual who contributes to data production. The CEIP Map's organization allows DQ professionals to examine each component's contribution in context, and, in the case of AIDS Clinic, identify the custodial paradigm that was the root of the problem.

We included Figure 3 to further depict the ***role*** contexts of Hospital case. The three colored areas represent the three data roles and corresponding processes.



time

Figure 3 CEIP example (Hospital)

Case 3: Small Real Estate Company

Small Real Estate Company is one of the most successful small real estate businesses in a thriving Pennsylvania suburb, and is known nationally within their parent company, Big Real Estate Company, for their aggressive selling strategy, usage of technology, and friendliness with their clients. They use two databases to manage their customer information, both accessed and updated in-house. Database maintenance is often neglected as databases are updated hastily, resulting in typing errors, double entries, and missing data. These errors significantly decrease DQ, and affect the company's success in the long run. Mapping out the components of data production on a Context-embedded IP Map shows when, where, and by whom (Time, Place, and Role contexts) the information is being affected.

Small Real Estate Company embraces technology, which gives it a short-term competitive advantage. To remain competitive in the long run, they need to establish standards for information quality, and the first step is to understand the information flow. By plotting the databases on a CEIP Map, viewers can identify where information comes from and where it goes after leaving the database. Furthermore, it differentiates ***role*** (the 3 C's) and ***time***. For Small Real Estate Company, such differentiation is crucial to solving their DQ problem: employees in their business regularly oscillate between the roles of collector, custodian, and consumer. These different roles must not be confused because each contribution is unique to the entire data production process. Understanding the *place* context in terms of the intersection of ***time*** and ***role*** will help an individual understand how his or her various actions, done at the same location but at different places in the data production process, affect data quality and have real consequences for the company's business.

If employees understand the ***place*** context of their contributions to data production, errant behavior can be corrected. Organizations can institute standards that define how employees interact with data, addressing poor quality data at the source. Place is a particularly relevant for smaller companies like Small Real Estate Company because technology maintenance, and especially information quality, is often not a top priority. Individuals find themselves performing many jobs in many different roles and failing to differentiate between the tasks of those multiple roles. CEIP Maps explicitly depict the place, by referencing time and role, where data is manipulated, and allow DQ professionals to easily identify which component of data production needs to be address to solve the DQ problem.

7. IMPLICATIONS: RESEARCH AND PRACTICE

This research offers implications for both research and practice. For research, the next step might include deeper understanding of new concepts introduced in this paper as we apply to a larger set of case organizations for a longitudinal study. The longitudinal study on the same set or extended set of case organizations will offer more complex data and site examples to study. The relationships among the concepts and how they are applied to CEIP Mapping will offer deeper understanding of how data quality diagnosis and preventive actions can take place in organizations.

For practice, as exemplified in the seven cases above, CEIP Mapping was proven to be easy to use and easy to spot problem areas in terms of where, *place,* in the information production system. Identifying additional important contexts such as roles, time, and paradigm, which are embedded in business processes helps to identify and solve data quality problems.

In short, explicitly including contexts backed up by argumentation theoretical grounding made the extended CEIP Map closer to the reality of data quality in the organizations we experimented. A contextualized IP-Map, with information on exactly where your data came from, and exactly what it will be used for, expand the scope of the judgment to a sufficient size to make reliable choices on data custody. In other words, the 'knowing-why' of information (Lee and Strong, 2004): knowing why the information is the way it is, and why it needs to be transformed a certain way, is just as, if not more important than the self-explanatory 'knowing-what' and 'knowing-how' of the data.

8. CONCLUSION

Understanding the context—time, function, place, role, goal, and paradigm—of where information comes from and where it goes helps to define the interactions between work processes and technological processes. This knowledge is invaluable to a company, because management can more appropriately diagnose problems and improve overall information quality. However, technology has become so integrated into daily business operations that management will soon have to adjust its company's culture so that more than just management and the information services department, or its equivalent, understands the flow of information.

In an increasingly competitive business environment, companies can use information quality as a point of differentiation. Effective information quality management can increase customer satisfaction and the value of their product or service, grow revenues and profits, and serve as a strategic competitive advantage. Distributing IP Maps throughout the company is a new practice that is rarely, if ever, done. This change in corporate culture is a new concept, but one that could have unprecedented benefits. Just as companies invest on training employees on how to use a new software product, they should also invest on training employees on how to manage information as a product (Wang et al., 1998).

This study has produced a template that aims to make the flow of information more transparent for users. If companies are willing to adopt this map, the benefits could be significant—costs could decrease, productivity could increase, and information quality could improve. There are still many other research possibilities within the Context-embedded IP Map. Now that that the information flow is plotted on a two-dimensional graph, there are new opportunities to mathematically calculate slopes of flows and explore relationships between the contexts. The product life-cycle of information can be traced through series of Context-embedded IP Maps. The most immediate work, however, involves using this context-embedded template to draw future IP Maps and using the new maps in companies to proactively encourage employees to improve information quality.

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