A Concept-to-Product Knowledge Management Framework: Towards a Cloud-based Enterprise 2.0 Environment at a Multinational Corporation in Penang

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***Abstract*—Knowledge management initiatives of a multinational corporation in Penang are currently deployed via its enterprise-wide portal and Intranet. To improve knowledge management initiatives from its current strength, efforts could now be focused on synergizing organizational workflow as well as computing resources and repositories. This paper proposes a concept-to-product knowledge management framework to be deployed in a cloud-based environment. It aims to provide effective support for collaborative knowledge management efforts at all stages of projects. The multi-layered framework is built upon the organizational memory which drives relevant processors and applications. The framework manifests itself in the form of a cloud-based concept-to-product dashboard from which employees can access applications and tools that facilitate their day-to-day tasks in a seamless manner.**

***Keywords*—knowledge management framework; organizational memory; Enterprise 2.0; workflow management; cloud computing; concept to product**

I. Introduction

Efforts to manage organizational knowledge have come a long way. From the days when the focus was on document management and policies for knowledge sharing, current knowledge management trends are shifting towards providing search and exploration facilities, and semantic capabilities. Web 2.0 is also a prominent feature with the concept of Enterprise 2.0, i.e. an effort that places importance on the social dimension of the Web. With effective knowledge management also comes effective visualization and mobility [1][2].

A multinational corporation (MNC) (the name of the corporation is withheld for confidentiality purposes) based in Penang (henceforth called MNC Penang) was set up in 1976 as one of the MNC's design centers worldwide. Operations in MNC Penang mainly concerns the design and manufacturing of the MNC's line of portable and mobile radio communication devices. In MNC Penang, knowledge management efforts have been initiated and made operable through its enterprise-wide portal and Intranet, particularly for lessons learned.

Although MNC Penang values knowledge management initiatives, the overall effort could still be improved from its current strength. These improvements primarily involve knowledge management initiatives in synergized organizational workflow that span across various functional groups, and their associated computing resources and repositories. Therefore, this paper proposes an integrated concept-to-product knowledge management framework with the following key features:

- Knowledge management at all project stages: Knowledge management support, in terms of applications or tools, is provided from conceptual design until the product is shipped.
- Effective support for collaborative efforts: Work practices are captured in Web 2.0 fashion that allows collaboration and interactivity between project members.
- Computing resources and repositories are centralized: All computing resources and repositories are centrally located in a cloud-based environment to minimize maintenance cost and maximize accessibility and efficiency.

The framework ultimately manifests itself in the form of a cloud-based concept-to-product dashboard from which employees can access applications and tools that facilitate their day-to-day tasks at any project stage in a seamless manner.

II. Related Work

There are many on-going efforts to realize knowledge clouds. One such effort to realize knowledge in a cloud [3] involves incorporating support for semantically rich data or knowledge, collaboration, and self-organization. In practical terms, these are achieved by providing seamless access to data (cloud storage), self-organization of data, distributed query processing, as well as ensuring data quality and security.

Work on the Enterprise Knowledge Cloud [4] views that the clouds would interconnect business partners and suppliers to customer and consumers. The clouds are potentially driven by social network, blogging, and wiki-type applications and these would be grouped into private (corporate), partner, and public clouds. The combination of these three clouds forms the Enterprise Knowledge Cloud.

Besides connectivity, cloud-based architectures have also been explored for specific purposes such as knowledge discovery [5]. For this purpose, three-layer architecture was developed. A service selection layer provides a variety of (knowledge discovery) services to be assembled into a workflow at the service workflow composition layer. Finally, the workflow is executed at the application execution layer on the cloud.

From a domain-specific perspective, a large-scale knowledge cloud called caBIG [6] was proposed for integrated cancer-related biomedical research, translational medicine, and personalized health management. It allows for various research initiatives from different institutions to connect to a grid-based network. This allows for the exchange of resources including those from federal establishments.

In general, cloud computing appears to be the way forward, building on the strengths of service computing, as well as grid and distributed computing. The challenge here would be the migration of legacy systems over to the cloud environment, as well as the reuse of existing data, applications, and services.

An overview of the layers is as follows:

- Object: The object layer consists of MNC Penang's organizational memory. This contains all formalized organizational data, information, and knowledge. The organizational memory is controlled or described by structural and domain taxonomies or ontologies. These control the structure of data, information, and knowledge that is stored in the organizational memory, as well as standardize the vocabulary that is used in the content. MNC Penang's organizational memory will be further described in Section III.
- Processors: Processors are basically processes and techniques that work upon the object layer content, i.e. the organizational memory, and taxonomies or ontologies. One or more processors are used to implement certain applications. The processors include those for data mining, machine learning, computational social and cultural dynamics, as well as for knowledge and language processing.
- Applications: The series of applications aim to assist

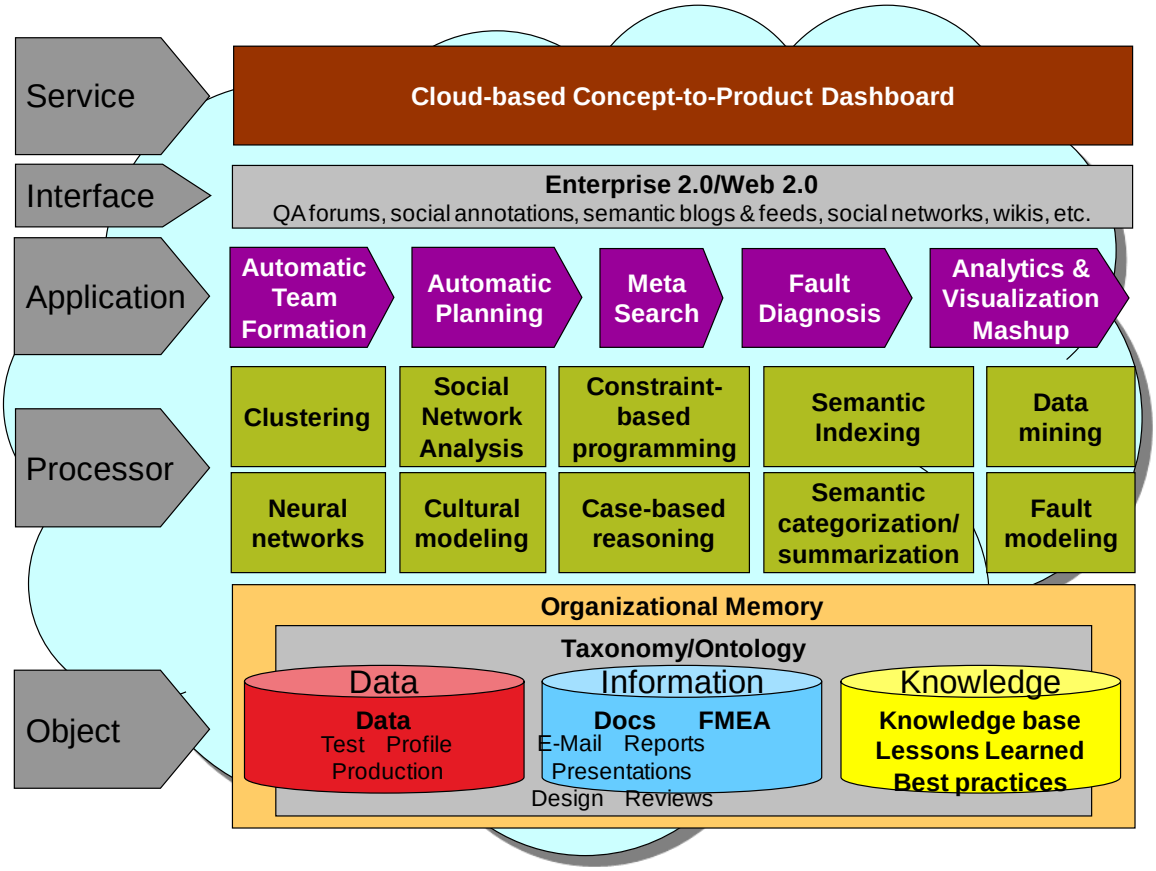

Fig. 1. Concept-to-product knowledge management framework

III. Concept-To-Product Knowledge Management Framework

The concept-to-product knowledge management (C2P-KM) framework is a multi-tiered framework. Fig. 1 illustrates the framework.

MNC Penang's employees throughout the course of a particular project, i.e. from a product's conceptual design to shipment. For example, at the commencement of the project, the proposed application would be automatic team formation, while at the shipment of the product and eventual conclusion of the project, the

analytics and visualization mashup would facilitate reporting and evaluation. Details of the applications would be provided in Section IV.

- Interface: The interface layer defines the interaction of the users with the available applications.
- Service: This defines the service that is available to the users, i.e. a cloud-based concept-to-product (C2P) dashboard. The dashboard is implemented in a cloud computing environment, allowing seamless access to applications and organizational memory.

IV. MNC Penang's Organizational Memory

The wide range of activities carried out at MNC Penang results in the generation of a variety of data, information, knowledge, and wisdom [7] that is distributed across many physical locations. Collectively, all these can be viewed as MNC Penang's organization memory (see Fig. 2).

MNC Penang's data includes test data from research and development activities. It would also consist of manufacturing-related data, i.e. materials, quality issues, costs, etc. Administrative data would also be included, i.e. employee profile and records, facilities management, etc.

At the information level, data would be analyzed and interpreted in an effort to ascertain the causes of certain test results. Subsequently, documents would be generated. Therefore, failure modes and effects analysis (FMEA) are generated at this level, and so are documents, e.g. reports, presentations, etc. All these provide information on the reason behind the data as well as to provide details on day-to-day activities.

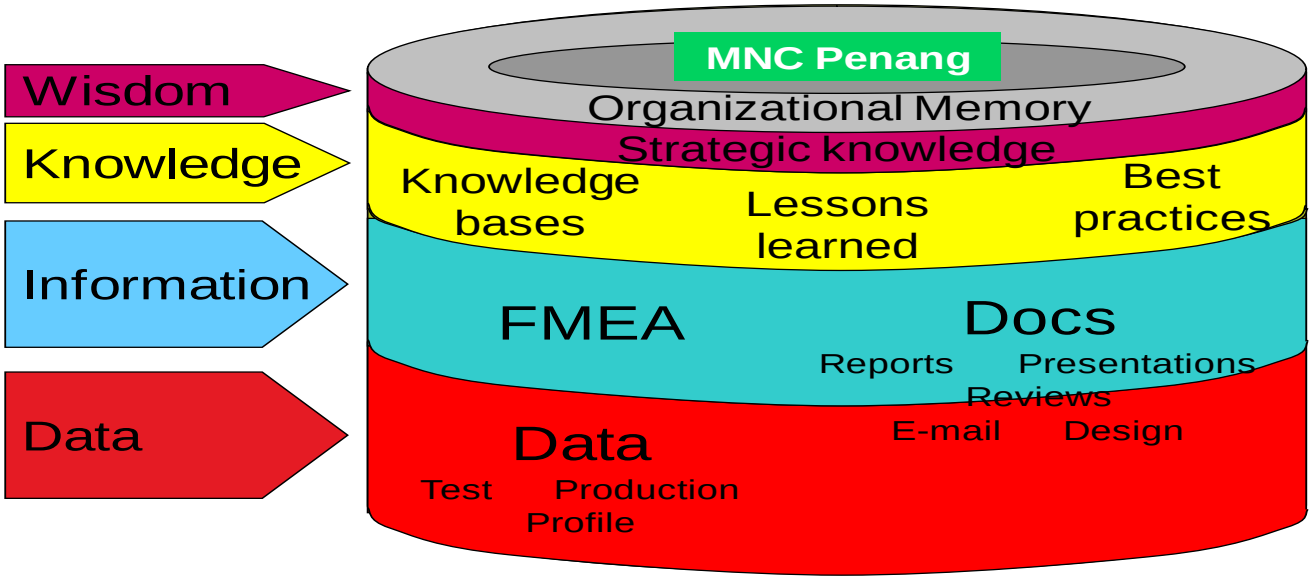

Fig. 2. MNC Penang's organizational memory

The knowledge level serves to form an abstraction or generalization of the information, allowing actions to be taken as a result. Information from the FMEA and documents could be used to build knowledge bases, compile lessons learned, or even establish best practices for the organization. While the information contained in FMEAs and documents serve as a basis for the knowledge level, the propagation and reuse of knowledge level items stand to benefit the organization the most. On the long-term, effective management of knowledge would help reduce the effects of brain-drain and employee turn-over.

Ultimately, at the level of wisdom, this would consist of strategic knowledge drawn from the experience of MNC Penang's senior employees. This would be the most unstructured level in the organizational memory, and includes tacit knowledge stored in the minds of the experts in the organization. Strategic knowledge would be drawn upon during strategic planning, decision making, and other activities to gain competitive advantage.

As an illustration, mechanical engineers measure a series of part dimensions (e.g. O-ring for water sealing in volume knobs) in the course of their work. These measurements are data. Over a period of time, trends in these measurements are analyzed. Compliance of the O-ring measurements to specifications is also noted (with those stored in manuals and reports). These processing of measurements and results of compliance are at the level of information. The trend in O-ring measurements and its compliance serve as triggers for knowledge-use. Deviation in O-ring measurements could have been due to parts that are out of specifications from a supplier.

In this case, the knowledge bases could be referred to in order to determine the best cause of action, e.g. to halt production, or to use alternatives. Finally, at the level of wisdom, senior management could decide on the severity of the non-compliance of the O-rings, and whether or not to continue procurement from a particular supplier on the long-term.

V. Knowledge Engineering At MNC Penang

The organizational memory is a rich source of data, information, and knowledge objects to be processed or "engineered", i.e. acquired, represented, and reasoned/processed. Fig. 3 illustrates how knowledge

engineering-related processes work on the organizational memory.

In terms of purpose, knowledge engineering processes, especially acquisition, and representation, allow organizational memory items to be brought in, thus building the object layer of the framework shown in Fig. 2. These processes make the organizational memory items operable, adding value to their existing state. Additionally, the processes of reasoning and processing allow the organizational memory to be made operable in the form of applications, thus building the application layer of the framework.

In the context of MNC Penang, some of the processes, or processors (processing structures) and technologies that are relevant for organization-wide usage include clustering, neural networks, social network analysis, cultural modeling, constraints-based programming, case-based reasoning, semantic indexing, semantic categorization/summarization, data mining, and fault modeling (see processor layer in Fig. 1). The utilization of these processors in various applications would be further described in the Section VI.

VI. From Concept To Product: Flow Of Applications And Supporting Processors

The organization is "alive" with activities, executing projects that have been defined. To facilitate the execution of the projects, a list of applications is proposed to assist MNC Penang's employees along the way (see application layer in Fig. 1). It should also be noted that in order to carry out the activities, relevant inputs are needed in order to produce the necessary outputs. In this regard, the organizational memory at the object layer serves to fuel the activities of the organization while at the same time acts as a repository for outputs of the activities.

A. Automatic Team Formation

Projects are executed by teams, and the success of a project depends on the performance of the team. Therefore, ideally, team members should be carefully chosen to ensure they are available, have the right skill set, work well together, and are motivated.

The current practice in many organizations, and MNC Penang is no exception, is to manually assign employees to a particular project. This is largely due to the differing project complexities and the engineers' skill-sets matching. However, if given a larger pool of employees and projects, automatic team formation would be an advantage.

Automatic team formation, inspired by coalition formation [8] and computational cultural dynamics [9] efforts, allow teams to be formed based on the profiles of employees stored in the organizational memory. Automatic team formation, having previously been carried out on learning environments [10] allows specifications of teams to be defined by managers. The employee profiles are then matched to fulfill the needs of the specifications while ensuring competency and cohesiveness. For this purpose, clustering and neural network processors would be relevant.

B. Automatic Planning

Planning is an essential step in the initial phases of a project as it facilitates looking ahead in an effort to ensure products are delivered on time. Within an organization, the core business activities are pretty much repetitive in nature in view that newer products and services are often modifications of existing ones.

Similarly in MNC Penang, where the nature of its business is in the design and manufacture of radio communication devices, projects do not differ very much in terms of the activities that need to be carried out. In this MNC, phase-gates for product development are set at specific intervals and relevant activities are carried out to meet the respective deadlines.

In view of this, planning can be automated where plans for previous projects could be used as a reference in planning for

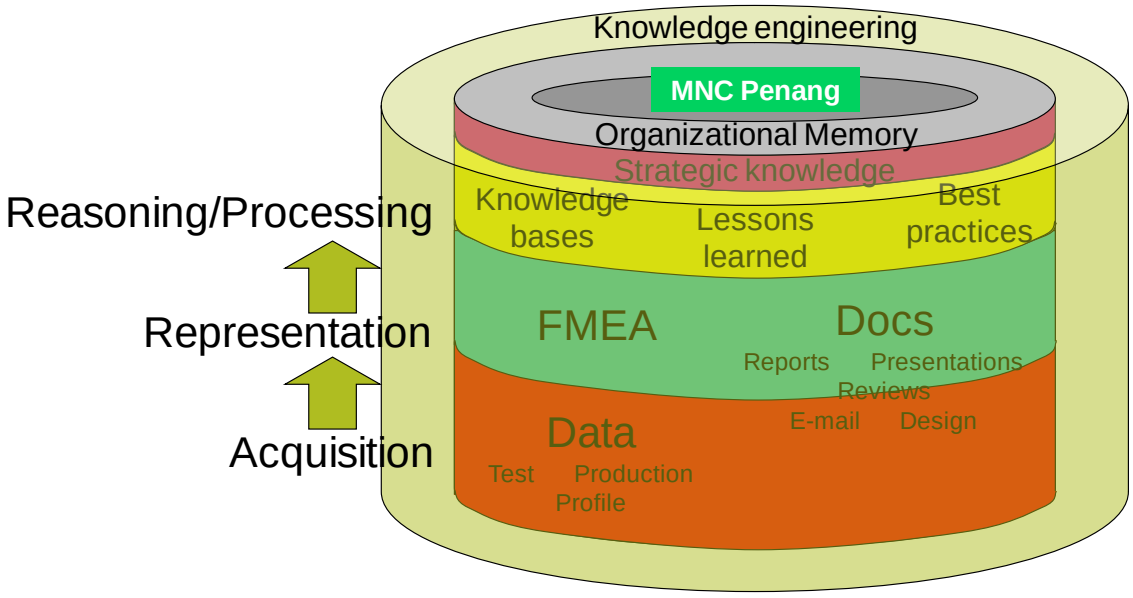

Fig. 3. MNC Penang's knowledge engineering processes

new projects [11]. Case- and constraint-based approaches may be suitable for such tasks. Additionally, re-planning may be necessary should serious problems arise, causing delays; or there may be instances when tasks may complete ahead of schedule. In such situations, dynamic planning strategies may be employed [12].

C. Meta Search

During the course of a project, many references are made to existing documentation and reports, manuals, correspondences, etc. In large organizations with multiple simultaneous projects, it is a challenge to search for the right resources in time as the collection or repository of documents, i.e. the organizational memory, is very large. An added challenge is that the required resources may be in different formats, and located in different locations. These locations could be on different servers, or they may even be in the personal possession of different employees.

Employees of MNC Penang, being part of a multinational corporation, have access to an even larger organizational memory. The current search facility employed in the MNC's web portal (based on OpenText's Livelink [13]) is powerful in the sense that it searches through a wide range of the MNC's online resources. The current search experience could be enhanced in the areas of search results, improving search speeds, presenting updated or most recent version of requested documents, as well as predicting and recommending relevant adjacent search results to the user.

MNC Penang's employees wanted a search facility with the following capabilities:

- with features similar to Google's
- able to search all databases
- a one-stop search portal
- results that are properly classified
- presents results intuitively

In order to improve the search facility, proper semantic indexing as well as semantic categorization and summarization could be carried out. It must be stressed that these are done "semantically" in order to understand the meaning and intention of the user, and the context in which the search is made.

Therefore, the way forward would be to incorporate semantic web technologies in the organizational memory itself [14][15][16]. This would lead to a search experience that:

- is personalized, e.g. Hunch (www.hunch.com)
- is incorporated in the documents that are being viewed, e.g. Zemanta (www.zemanta.com)
- incorporates natural language processing, e.g. Hakia (www.hakia.com)
- incorporates intuitive visualization to search results, e.g. Quintura (www.quintura.com)
- is entity-based, e.g. Freebase (www.freebase.com)

D. Fault Diagnosis

As much as the organization's reputation rests on the reliability of the products offered, customers also consider the quality of customer support when making purchase decisions. Therefore, after the delivery of products, organizations would be concerned about providing the best after-sales service to their customers.

In the context of MNC Penang, this is a critical business area in view that the MNC's radio communication devices are often deployed in situations where down-time has be minimal, e.g. incident scene and security management, high-volume logistics and fleet management, event management, etc. Therefore, there is a need for an expert-like system that could diagnose faults in a timely manner in both back-office or on-site scenarios. This could be achieved by using a hybrid of case base [17], knowledge base, and fault modeling approaches [18]. Also current are the use of fuzzy logic, neural networks, and neuro-fuzzy approaches [19]. Through these, it is hoped that "no stones are left unturned" in coming up with effective solutions.

E. Analytics and Visualisation Mashup

For strategic decision making purposes, data that has been collected during the course of the project needs to be analyzed and presented in a manner that would assist decision makers in their task. The challenge here is that there is a variety of data that is located at various locations that need to be scoured through.

MNC Penang's design and manufacturing activities undergo various milestones. Data and reports are generated at each stage by different departments. At the end of the project, these need to be consolidated in an effort to measure the outcome of the project.

A mashup that analyses data, and produces intuitive visual representation of the results would benefit decision makers. As opposed to traditional portals that provide various tools and functions separately, mashups aim to aggregate multiple tools and functions to present a seamless value-added output [20]. Ultimately, mashups could serve as a source of data mining for business intelligence [21].

VII. Collaboration and Agility Via Enterprise 2.0

Web 2.0 technologies are now explored in a good number of organizations. It can be considered one of the main driving forces behind the concept of Enterprise 2.0. Enterprise 2.0 covers the interface layer of the C2P-KM framework (see Fig. 1) and it addresses the user experience of the C2P dashboard. Enterprise 2.0 technologies are centered on the following concepts [22]:

- Search: Users must be able to find information they are looking for. Many employees are finding Intranet navigation/site maps to be less useful than keyword-based searches. Expert finders are also popular.
- Links: The usefulness of a document or item of information can be better measured by the number of links or references pointing to it. In return, links help

users arrive at a desired piece of information more quickly.

- Authoring: Writing should be made less daunting. Tools should be available to facilitate writing both individually and collaboratively, e.g. blogs and wikis.
- Tags: These help to make sense of the organizational memory and help users keep track of content. The tags form a folksonomy, i.e. a categorization system built by users, for users.
- Extensions: These make use of business intelligence and data mining within the organizational memory for the benefit of users. These include attempts to present results or information that are a step ahead of the user, e.g. search results that may be of interest to the user besides those actually requested.
- Signals: There needs to be a balance between push and pull of information, and hence, the right "signals" need to be given to users to prevent information overload. Current feed mechanisms, e.g. RSS and aggregators, are efforts in this direction.

While traditional desktop applications such as word processors, spreadsheets, and e-mail would continue to be popular tools, the level of flexibility and collaboration that can be achieved is limited. With social web technologies prevalent in Enterprise 2.0 frameworks, organizations could work towards being more open, transparent, agile, collaborative, and "social"-driven [23].

One can imagine the use of blogs instead of traditional word processing applications to document personal ideas and reports. Not only would the blog entry be available to a wider audience, it would also allow feedback and comments for further action if required. Communication via social networking applications instead of e-mail would simplify group discussions and facilitate the identification of experts. Another example would be the co-authoring of documents using wikis instead of sending documents back-and-forth via e-mail between the authors.

While all these seem attractive, the challenge in adopting Enterprise 2.0 would be to make the transition from "Enterprise 1.0" as seamless as possible. Traditional tools could be integrated as much as possible into the organization's Enterprise 2.0 framework.

VIII. Cloud-Based Concept-To-Product Dashboard

In view that the MNC's organizational memory is distributed across many physical locations, current client-server-based architectures could pose certain challenges in terms of maintenance and cost. In making computing services leaner and more affordable, cloud computing is perceived as the solution, i.e. by moving computing hardware and software to a centralized facility [24]. The location of the cloud or the computing resources is transparent to the user, and the users would use applications in the form of Software as a Service (SaaS) [25].

In the context of MNC Penang, certain online applications are hosted by the MNC headquarters (as a global organization) at a particular location. Issues to consider in such a setup include server load and bandwidth. With a cloud-based implementation of the MNC's computing hardware and online applications, sharing of computing power and applications would be made easier and achieved at a lower cost.

Another advantage of cloud computing is that the organizational memory would be centralized. When data and information are centralized, data processing and mining could be achieved more inclusively, thus allowing business intelligence to be better achieved in the cloud [26], and also facilitating knowledge management [27][28]. Therefore, MNC Penang's C2P dashboard could be made operable in the cloud as enterprise-wide services [29]. Not only would this facilitate infrastructural implementation, it would also encourage better software engineering practices through the reuse of existing services to form new application pipelines or process flows.

IX. An Example: Fault Diagnosis

Fig. 4 provides an overview of the processes of knowledge engineering for fault diagnosis and its relationship with the C2P dashboard and organizational memory.

Senior customer support engineers are required to share their knowledge via the C2P dashboard. This would be in a structured or semi-structured manner. Their knowledge would be used to produce various fault models. Besides knowledge from human experts, data from the organizational memory would be mined in order to discover fault and diagnostic patterns, and potentially new diagnostic knowledge. The fault models and mined knowledge would then be formalized, represented, and stored in the knowledge bases in the organizational memory.

When customer support engineers are out in the field supporting customers, or when they are at their home base trying to reproduce and resolve faults reported by customers, the fault diagnosis application would be utilize. The engineers would input observable and measurable signs of the complaints via the C2P dashboard and the application would then consult the knowledge bases for a likely solution to the problem.

While the fault diagnosis application would be the main application used by the engineers, they would still have the other applications (e.g. the meta-search, and analytics and visualization mashup) and supporting Web 2.0 tools in order to receive additional information and knowledge, as well as to collaborate, and receive feedback and support from their colleagues.

X. Discussion

The organizational memory would serve as the fuel for the C2P dashboard, minimizing the impact of the knowledge gaps of individual employees. While the organizational memory could be organized according to the data-information-knowledge-wisdom continuum, it is in actuality quite chaotic.

Therefore, the importance of the ontology cannot be discounted in such a cloud-based implementation. The ontology must successfully enforce standards in terms of document structure and vocabulary to facilitate effective knowledge sharing and reuse.

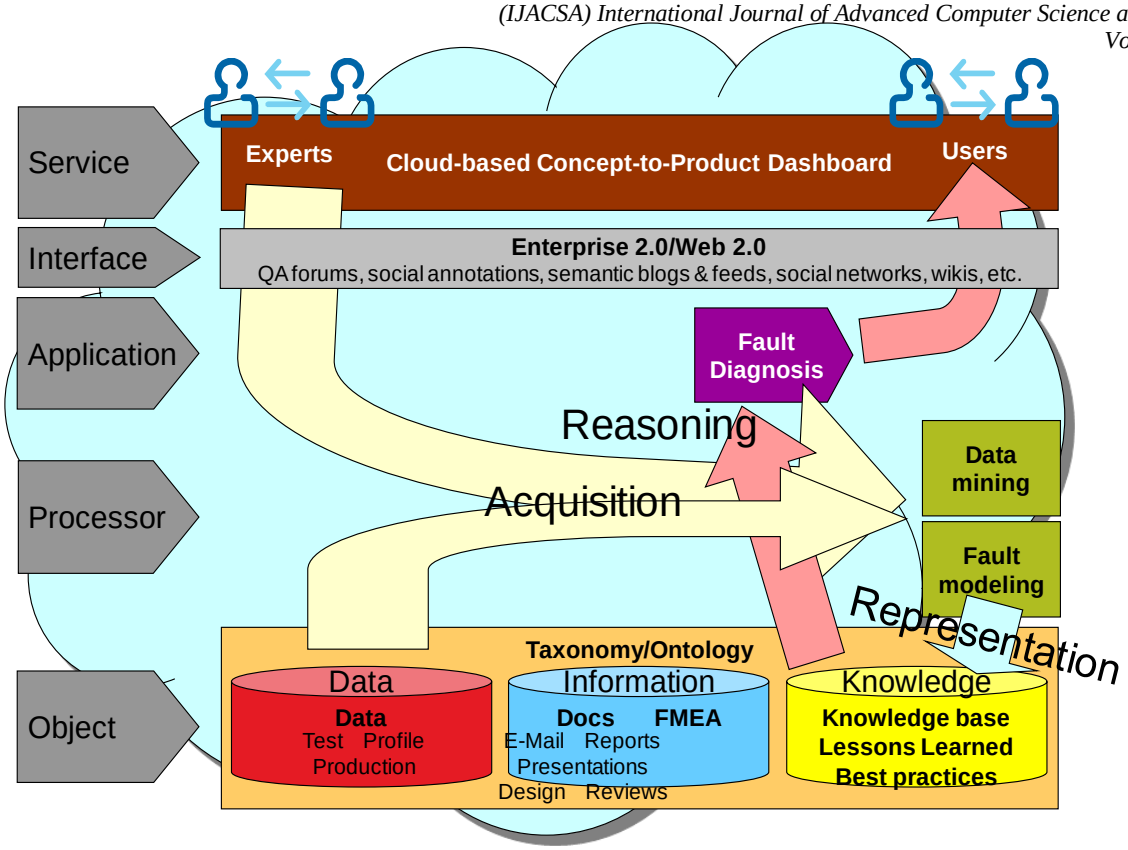

Fig. 4. Fault diagnosis knowledge engineering overview

The C2P dashboard's flow of applications described in Section VI serves as a starting point for more applications or project activities to be added. Applications such as project monitoring and logging could be inserted in the flow in the future. The existing applications such as automatic planning could be deployed in stages, focusing on planning for design and manufacturing, and perhaps extended later to include planning for human resource, etc. The analytics and visualization mashup could be implemented in a similar way, focusing first on mashups for engineers and later include those for senior management.

While Web 2.0 seems to be the main driving force behind the concept of Enterprise 2.0, the C2P-KM framework is already pointing towards Web 3.0 with the need for applications to be semantically aware. While it is important for the C2P-KM framework to capitalize on Web 2.0 technologies to encourage collaboration within the organization, Web 3.0 is expected to deliver results in a more semantically accurate manner. In this way, manual effort in fact-finding from multiple sources could be reduced by deploying semantically aware searches. These searches understand the intent and context of the query and therefore could proceed automatically. It is anticipated that Enterprise 3.0 is not far on the horizon.

The proposed C2P-KM framework for MNC Penang has far reaching implications in terms of content, and applications or services. The cloud-based deployment allows flexibility in creating content which in turn fuels the services. The maturity of cloud computing would further drive the Enterprise 2.0 idea.

Nevertheless, the success of a cloud-based deployment would depend on the need for computing power. Similarly, the reduction in computing cost would only be justified with the increase in demand for organization-wide computing power. Hence, MNC Penang needs to fully deploy computing intensive business intelligence applications to justify the C2P-KM framework.

XI. Conclusion

Many organizations strive to be lean and agile in today's very competitive business environment. In order to achieve this, many existing policies and procedures need to be simplified and streamlined, i.e. lean, and new policies need to be able to adjust to changes and evolving needs, i.e. agile. These needs can potentially be translated into powerful but straightforward applications that employees could use as part of their day-to-day work.

In this paper, the C2P-KM framework was proposed and described as an attempt to map out MNC Penang's existing operational and knowledge needs against future application and architectural demands. In this effort, it was realized that an integrated and seamless way to manage the organizational memory at MNC Penang and to design applications around it that could better assist its engineers and management in decision-making would be advantageous.

Going forward, the C2P-KM framework could be taken beyond the context of MNC Penang's needs but also that of the MNC in general. In view that cloud computing would be mainstream in the near future, it is hoped that any organization, irrespective of business domain, would eventually be able to capitalize and customize the proposed framework for its own use. This would result in a higher level of reusability, paving way for an open architectural standard for cloud-based knowledge management.

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