Engineering Component-Based Knowledge Applications for e-Learning Organizations: The Software Architects' Challenge in Organizational Transformation

Kam Hou VAT
Faculty of Science & Technology
University of Macau, Macau
fstkhv@umac.mo
Fax: (853) 837-954

Abstract
This paper investigates the idea of enterprise transformation appropriate to the context of an electronic version of learning organization (LO). Specifically, we discuss how the design of an enterprise component architecture (ECA) could facilitate architected applications development for enterprise knowledge processing, through its constituent business and technology architectures. The paper explores the component-based development (CBD) of our learning organization, which is situated in a university context. This LO comprises numerous information systems (IS) for different functionality, collectively known as the LOIS. The particular LOIS subsystem supporting specific knowledge work is constituted by organizational activities involving respective knowledge resources. To enable an organization to leverage on the intellectual assets (knowledge) behind those activities, we consider the idea of electronic transformation (e-transformation) within the LO, in the area of collaboration for organizational learning. The paper concludes by discussing challenges in architecting the blueprints of our LOIS solutions.

Keywords: Learning Organization Information System, Enterprise Component Architecture, Electronic Transformation, Collaboration, Knowledge Management.

1. INTRODUCTION

Nowadays, enterprises including educational institutes are challenged to do things faster, better and more cost-effectively in order to remain competitive in an increasingly global economy. Consequently, there is a strong need to share knowledge in a way that makes it easier for individuals, teams, and enterprises to work together to effectively contribute to an organization's success. This idea of knowledge sharing has been well discussed in the notion of a learning organization (LO) [16, 30, 31, 39]. A learning organization refers to an organization, which focuses on developing and using its information and knowledge capabilities in order to create higher-value information and knowledge, to modify behaviors to reflect new knowledge and insights, and to improve bottom-line results. Based on this characterization of LO, there are many information system (IS) instances that can be incorporated into a learning organization. When applied to a university setting, the guiding question to start our exploration of LO, and its subsequent LOIS (Learning Organization Information System) [48] subsystems, typically involves the identification of strategic enterprise applications, and the design of how they could serve as the foundation for knowledge synthesis (development and transfer). This paper attempts to expound from the perspective of software architects, the component-based development (CBD) [2] required to realize these knowledge activities in the form of specific LOIS subsystems, incorporating the requirements of an organization's electronic transformation (e-transformation) in the direction of a digital learning organization. In particular, we will describe the idea of enterprise component architecture (ECA) [21] and discuss how it could enable our CBD efforts to realize enterprise-wide collaborative LOIS applications for organizational learning [3, 28, 37].

2. THE SITUATION OF CONCERN

Organizations today are realizing that their competitive edge is mostly the intellectual capital (brainpower) [43] of their employees, and they are particularly interested in harnessing their human capital in order to stay ahead of the pack. The soaring attention on knowledge management (KM) [33] has propelled many enterprises to embark on their journeys of organizational transformation in order to tap the intellectual assets belonging inherently to their people. Many an organization is actively reflecting on their organizational design to transform their bricks-and-mortar (physical) entity into its clicks-and-mortar (digital) counterpart. We call such a transition effort the electronic transformation of the organization, or simply the e-transformation effort [22, 25]. Obviously, the e-transformation effort requires an objective methodology, which must be instrumental to creating a productive and efficient electronic organizational (e-organization) model. Preferably, this model could enable us to follow an iterative development sequence so that we could plan and prepare for a launch based on a new business model within an estimated cycle time. Specifically, the e-organization model should enable the organization to launch and learn, and then incorporate those lessons and launch again. Consequently, we consider an enterprise undergoing organizational transformation, as the learning organization [16, 39], implying its constant efforts to better itself for coming challenges, including those involved in its e-transformation into a digital learning organization. An example of learning organization is to consider a university as a knowledge organization [32]. A university comprises valuable assets coming from her teams of knowledge workers, who have a strong formal education, have learned how to learn, and have a habit of continuing to learn throughout their lifetime. Nevertheless, these human capitals are the organization's assets only through their application and reuse [7, 43]. These then are good reasons to capturing the intellectual knowledge of people, however implicit it may be, and making it explicit within and without the organization whose competitive advantage comes from having and effectively using knowledge. Moreover, with the present advent of the World Wide Web and the Internet, universities indeed are well poised to deliver customized educational services worldwide for life-long learners. However, this vision requires e-transformation efforts on the part of the conventional university, to take advantage of the new technologies and opportunities. The result could eventually be a virtual university (VU) [20, 6, 46], which is an electronic form of the original university renewed based on the working model of a learning organization, to enable a re-engineered vision of the university's education process.

3. THE PROBLEM

Organizational transformation in the direction of a learning organization (LO), including the e-transformation effort towards its digital counterpart, necessarily involves some organization modeling [34] comprising the e-organization models which are required for the subsequent architectural development of the underlying information systems. From the software architects' perspective, each information system (IS) has its own architecture, denoting the integrated structural design of the system, its elements and their relationships depending on given system requirements [5]. We might consider the architecture as an abstract plan including the corresponding design process of the system's structure appropriate to the goals of the system based on a methodological framework. Besides, the architecture has to represent all relevant aspects of a system, which are defined by models representing different system views. These models are often derived from the goals the system has to fulfill and the constraints defined by the system's environment. In our investigation, the acronym "LOIS" (*Learning Organization Information System*) [48] as applied to an organization is used as a collective term representing the conglomeration of various information systems, each of which is a functionally defined subsystem of the enterprise LOIS, i.e., it is defined through the services it renders. On characterizing the requirements for the different LOIS services in support of our LO model for knowledge synthesis, we did arrive at some concerns to be seriously examined.

The first is the contextualization of our e-organization models according to the learning organization concept. Most current discussions of learning organizations focus on high philosophy and grand themes. For example, Peter Senge, who popularized learning organizations in his book *The Fifth Discipline* [39], described them as follows. These are places "where people continually expand their capacity to create the results they truly desire, where new and expansive patterns of thinking are nurtured, where collective aspiration is set free, and where people are continually learning how to learn together." To achieve these ends, Senge also suggested the use of five "component technologies": system thinking, personal mastery, mental models, shared vision, and team learning. Without question, these recommendations are absolutely desirable, but we still need a framework for action. As software architects, we need to know what policies and programs must be in place to get our organization from here to there. To initiate our LO-based organizational modeling efforts, we follow Harvard Business School professor, David Garvin's [16] suggestion to create an actionable framework for organizational transformation. First is the question of meaning. We need a plausible, well-grounded definition of learning organization; it must be actionable and easy to apply. Second is the question of management. We need clearer guidelines for practice, filled with operational advice rather than high aspirations. And third is the question of measurement. We need better tools for assessing an organization's rate and level of learning to ensure that gains have in fact been made.

The second is the issue of knowledge characterizations that help structure and facilitate knowledge implementation and interconnectivity. The struggle to define knowledge is somewhat fuzzy as exemplified by the range of complexity and intellectual richness, from Plato's "justified true belief" [35] to a more mundane "the capacity to act" [44]. How it is characterized, used, and even created within an organization is very complicated. However, we believe that knowledge is subject to some level of modeling, and thus may be architected, integrated, and designed into an organization [9, 31]. We do so with some uncertainty, but with informed discretion just as human beings may manipulate and change the environment, in effect, changing the direction of our evolution and adaptation. Our working definition of knowledge is interpreted in terms of its potential for action and its ability to change context and goals – the rules of relevance and adaptation.

The third is the application of our LO model at the university context, attempting to create an instance of a LO-based virtual university (VU) model, bearing in mind its principal mission as a knowledge organization enabling knowledge synthesis (knowledge development and transfer) within and across its organizational boundary. As software architects, we are particularly interested in the LOIS's underlying process for system architectures and requirements management [48]. As organizational architects, we are concerned with the business models behind which the VU's organizational design is being established.

4. THE METHODS

The methods employed to execute our research include a combination of techniques. First, through literature reviews, we have come up with a practical scenario [11, 12, 16, 17, 39] to initiate our investigation into the specifics of organizational development based on a working model of learning organization. Second, from the perspective of action research, we are to document the complexity of the technological challenges faced by software architects in realizing the e-transformation vision. Third, through organizational modeling, we are to introduce the important input from organizational architects in transforming the organization. Fourth, through business modeling, we are to describe how software architects (playing business modelers) construct the business architecture, serving as the foundation for requirements' process. Fifth, through software modeling, we are to elaborate how the software architects achieve the transition from business architecture to software architecture, by managing the software requirements acquired. Briefly, the process of architecting organizational transformation involves constructing a number of essential viewpoints for modeling our system architectures on the part of the software architect. These include, following the suggestions of the Reference Model for Open Distributed Processing (RM-ODP) [26]: the enterprise viewpoint, the information viewpoint, the computational viewpoint, the engineering viewpoint, and the technology viewpoint. Each viewpoint is a perspective on an underlying information system, providing descriptions that address the questions and needs of particular stakeholders in the system. The set of viewpoints is also not closed so that additional viewpoints can be added as the needs arise. Now that the philosophy underlying the component-based development (CBD) approach is cost-effective manufacturing in a repeatable way using components [13, 15, 23] that are easy to swap, mix and match, plug and play at the enterprise level. Components are thereby considered as standardized building blocks that can be used to assemble, rather than develop information systems.

Indeed, CBD is emerging as a software development approach [24], where all aspects and phases of the development lifecycle, including requirements analysis, architecture, design, construction, testing, deployment, the supporting technical infrastructure, and also the project management, are based on components. This definition explicitly declares CBD to consist of building software using component-based thinking to the extent that the whole software development is component-centered. In fact, thinking of an IS in component terms, even if the components do not already exist, is believed to be a useful way to mastering the complexities of our LOIS subsystems development, especially in the areas of collaborative knowledge applications supporting the transformation into a digital learning organization.

5. THE ENTERPRISE COMPONENT ARCHITECTURE

The enterprise component architecture (ECA) serves as our LO's high-level description of the complex endeavor of how to construct software systems that meet the requirements of the enterprise, and of how to construct an environment and infrastructure that simplifies the task of building systems that conform to the CBD approach. Understandably, development of software systems involves many different tasks, ranging from the collection and specification of business requirements, to the actual software development process, to deploying and maintaining the systems in an operational environment. Each of these activities involves a different set of concerns, people and solutions, and all these represent aspects of a true enterprise-class architectural solution. Principally, the architectural precepts [2, 8] communicated in an ECA include the following: separation of concerns, accommodation of change, independence from technology, and a phased approach to implementation. Separating concerns means that the architecture problem space is divided into a set of related sub-architectures, each of which addresses one or a few related concerns. The main benefit of this separation lies in the simpler artifacts created and communicated in a format and style that is meaningful to the intended audience. We call such a separation of architectural concerns a viewpoint because it addresses the architecture from a particular point of view. The ability to accommodate change is another fundamental characteristic of a good architecture. Typical architectural analysis often identifies what is likely to change in the system, so that any developed solution insulates the rest of the system from changes in those areas. This is done by using an abstraction layer which presents an unchanging model to the rest of the system, and then by mapping that model to a specific technology. Moreover, we cannot make business stop and wait while the architecture is being completed. Instead, we must continually release new applications. This fact of life requires that we have a phased implementation process, where pieces of the infrastructure are implemented as part of specific projects and subsequent projects continue to both build on and enhance the architecture over time. The ECA underlying our LOIS is designed to include two important viewpoints, including the business architecture, and the technology architecture. The former mainly includes the business models, the process models and the applications models of our LO, whereas the latter comprises the technical aspects, the implementation aspects, and the operations aspects, which allow an iterative implementation and deployment of the business architecture.

5.1 Business Architecture

The business architecture comprises components of the ECA that are related to modeling the business functionality of the organization. Its design should be guided by the overall re-engineered vision of the digital learning organization, and must be grounded in the realities of the organization's current execution. Our business architecture is generally divided into three distinct components: business models, process models, and applications models. The business models provide a high-level perspective of the LO's business initiatives, of which an example is to determine the organization's target market and primary audience for its goods and services. Another example is to work out a careful analysis of the organization's resources for reusability and valuation. The process models are aimed to describe the internal and external processes representing the organization's daily behavior. They often reflect the organization's information strategy and the individual business models chosen for implementation. The application models are aimed to represent the electronic applications to be developed to streamline business processes from the end-user perspective. Specifically, they outline the overall application functionalities from the end-user perspective, in the form of a user-interface mock-up, which allows users to step through the process via the application's navigation aids. Often, such functionalities are supported by some data and object models, which describe the underlying data structure and usage for a target application.

5.2 Technology Architecture

The technology architecture is aimed to translate the organization's business vision into effective electronic applications that support the re-engineered intra- and inter-organizational business processes. It is typically composed of distinct stages of development of such sub-architectures as the technical, the implementation and the operations aspects. The technical sub-architecture describes the overall design of the LO's applications, particularly, the functional layers and the tiers into which an application can be divided. It also describes the infrastructure to support software development, which the company intends to rely on as it constructs component-based applications. The implementation sub-architecture derives from the requirements imposed by the specific standards and products used in a specific application. The operations sub-architecture derives from the specific operational requirements of the applications. These sub-architectures are generic in the sense that they apply to all of the component applications the LO will develop. Of particular interest in our discussion is the technical sub-architecture, which describes the structure of our software systems realizing the individual LOIS subsystems. Essentially this sub-architecture consists of a conceptual model and a development infrastructure. The former provides a conceptual foundation of the software system and describes the details of two basic concepts: functional layers and distribution tiers. The latter provides the tools to support software development, including frameworks, utilities, and patterns. Functional layers describe the responsibilities of related components and place them in their respective architectural positions. Distribution tiers describe how different components are mapped to a distributed computing system. Frameworks are customizable generic solutions to specific application problems and may include tools for generating code. Utilities provide an infrastructure that allows applications to use common functions throughout the system. Patterns are solution templates for commonly encountered problems.

6. KNOWLEDGE APPLICATIONS – COLLABORATION IN ORGANIZATIONS

The knowledge applications provisioned in our digital LO, are conceived as specific LOIS sub-systems, aimed to support organizational learning (OL). According to Garvin [16], OL can be defined as a continuous process of creating, acquiring, and transferring knowledge accompanied by a modification of behavior to reflect new knowledge and insight, and to produce a higher level asset for the organization. We believe this definition of OL is quite consistent with our understanding of a LO which represents the important concept of better knowledge for better behavior for better performance (value). Today the view that knowledge is a valuable organizational resource has fueled interest in researching into the various activities of knowledge management (KM) [10, 38, 42]. These include identification, collection, adaptation, preservation, application and sharing of the organization's knowledge. KM has emerged to help enterprises manage their knowledge resources in order to facilitate access and reuse of knowledge including their intellectual capital, which belong inherently to people and are the organization's assets only through their application and reuse [7]. KM attempts to address the issues of capitalizing on individual know-how in a collective knowledge so that others do not have to relearn "what the enterprise already knows" leading to the improvement of organizational work processes and productivity [36]. However, KM must provide the instruments to employees of the organization who are confronted with the need to optimize the control and management of their knowledge resources. The idea is to prevent bottlenecks caused by an inadequate knowledge household from the perspective that knowledge is the crucial production factor. To accomplish this mission, KM often entails the following activities. 1) Formulating a strategic policy for the development and application of knowledge. 2) Executing this knowledge policy with the support of all parties within the organization. And 3) improving the organization where knowledge is not optimally used or is not adapted to changing circumstances. Subsequently, we have a number of objectives set in operational terms of the following KM processes. First, we have to ensure an effective and efficient development of new knowledge and improvement of existing knowledge, paying attention to the strategy of the organization and individual objectives of the employees. Second, we need to ensure a specific distribution of new knowledge to other departments and to new employees through knowledge transfer or relocation of knowledge bearers. Third, we must ensure an effective securing of knowledge, which is also easily accessible to the whole organization. Fourth, we must ensure the effective and efficient combination of the best knowledge available within an organization or network of organizations. Overall, we need a process model for implementing knowledge management. And this model is often referred to as the KM cycle [41, 42], in which KM is perceived as a cyclic process composed of four iterative activities: review, conceptualize, reflect, and act. 'Review' means checking what has been achieved in the past, and what the current state of affairs is. 'Conceptualize' is trying to get a view on the state of the knowledge in the organization, and analyzing the strong and weak points of the knowledge household (an organization relying on its knowledge flow to survive). 'Reflect' is directed toward improvements: selecting the optimal plans for correcting bottlenecks and analyzing them for risks that accompany their implementation. 'Act' is the actual effectuation of the plans chosen. Obviously, the analysis, plans and actions are usually formulated in terms of the four above-mentioned 'KM processes' which aim at an integration of strategy formation and executive tasks where learning about the application and development of knowledge assumes a central role within the organization. Through literature review, we discovered two types of organizational knowledge: formal and informal [7]. Formal knowledge refers to the stuff of books, manuals, documents, and training courses. It is the primary product of knowledge work, captured easily by the organization. And informal knowledge is the knowledge created and used in the process of creating the formal results. It includes ideas, facts, assumptions, meanings, questions, decisions, guesses, stories, and points of view. It is as important in knowledge work as formal knowledge is, but is more ephemeral and transitory. Thus, it is hard to capture and to keep informal knowledge. The knowledge pool in an enterprise is often stored in the form of both the formal and the informal knowledge whose interaction results in the continuous creation of organizational knowledge [35]. Our knowledge applications [18], conceived as an individual sub-system of the collective LOIS, is equipped with its own IS architecture incarnated as a three-tiered knowledge infrastructure [45] composed of the front-end KM services supported by back-end organizational memory (OM) [7, 19, 46] through a mid-layer KM architecture. More, different sets of KM services could be configured as different sub-systems of this peculiar LOIS subsystem, whose individual IS architectures could be derived according to their respective requirements.

7. THE OM SCENARIO FOR KM SUPPORT IN ORGANIZATIONAL LEARNING

We envision that the installation of a LOIS subsystem called OMIS (Organizational Memory Information System) to enhance the organization's competitiveness by improving the way it manages its knowledge. It is the core of a learning organization, supporting sharing and reuse of individual and organizational knowledge and lessons learned. From an IS perspective, this OMIS could be considered as an iterative means to realize the KM services offered incrementally according to the ongoing functional requirements of the organization's execution models. Technically, the OMIS could be implemented as a 'Web information system' (WIS), representing IS efforts geared towards exploiting the benefits of the Web platform. The OMIS is the system knowledge workers use to perform KM processes. The underlying WIS(s) [14] may comprise numerous Intranet-based and Extranet-based distributed applications which are usually tightly integrated with the back-end OM in the form of, say, distributed databases or knowledge servers. We also imagine the OMIS is supported by intelligent KM services actively providing any user working on a knowledge-intensive task with the information required for fulfilling the task. Such information is largely based on the organization's formal knowledge, captured through explication of informal knowledge within the organization. It is mainly the 'what, how, why, when and who' of the knowledge resources. It is believed that individual knowledge workers construct and re-construct organizational knowledge through sharing with their colleagues the following. What information is needed; why it is needed; where it could be found; how it could be processed to achieve a specific result; and when which information is needed. Of particular interest are human knowledge sources whose knowledge must be made explicit so that others can access through the OM.

In practice, there are different stakeholders involved in our LO's knowledge applications. Knowledge providers represent the specialists or experts in whom the knowledge of a certain area resides. Knowledge users are the people who need to use that knowledge to carry out their work successfully. And knowledge decision-makers are the managers who have the position to make decisions that affect the work of either the knowledge providers or the knowledge users. Under the OM context [10], we also have knowledge engineers who acquire and model knowledge, and knowledge watchers who gather, filter, analyze, and distribute knowledge elements from the external world. There are also OM-developers, who concretely build, organize, annotate, maintain and evolve the OM. It is important not to forget a team of validating experts, who validate the knowledge elements before their insertion in the

'OM'. Overall, our idea of an OM is not centered on a passive information system, but an intelligent assistant to the user [1, 4, 40], who can freely access and reuse memory elements. This OM context could indeed be refined for different scopes, such as at the levels of the whole organization, departments, programs, or even communities of practice gathered by a common interest of organizational learning.

One of the university's learning experiences we advocate is to enable knowledge development and transfer among teachers and students in an interactive and collaborative atmosphere. Students actively participate in generating, accessing, and organizing the required information. They construct knowledge by formulating their ideas into words and then develop these ideas as they react to other students' or teachers' responses to their formulations. Knowledge construction can then be considered as the process of progressive problem solving, which encourages students to be innovative, create intellectual property, and develop and acquire expertise. Meanwhile, in order to enable students to better select and manage their studies, we are experimenting with the component-based development of individual degree programs. Basically, each degree program is to be re-structured as webs of logically coherent courses, which are in turn organized as series of logically complete modules that are again expressed as serial sets of sessions to enable renewal and reuse of teaching materials. Hence, each program and all its components can be dynamically configured such that programs can change their courses; courses can change their modules; and modules can change their sessions. To achieve these knowledge tasks, our academic staffs need considerable skill and knowledge to deal with the acquisition, creation, packaging, and application of emergent knowledge [12, 27]. We expect an OMIS could facilitate these knowledge tasks through knowledge sharing across academic domains. It is about leveraging the expertise of people and making the most effective use of the intellectual capital of an organization [47]. Understandably, it is important to have good coordination, evaluation and evolution of all these knowledge activities.

8. REMARKS FOR CONTINUING CHALLENGES

The field of information systems [29, 30] operates on the paradigm of identifying relevant data, acquiring it, and incorporating it into storage devices that are designed to make it readily available to users in the form of usable information resources. Importantly, each IS represents a system for collecting, processing, storing, retrieving, and distributing information within the enterprise and between the enterprise and its environment. Each IS has its own architecture [5], denoting the integrated structural design of the system, its elements and their relationships depending on given system requirements. The LOIS architecture has to guarantee that the mission of the enterprise is taken into account in the process of design, and that the system will support the enterprise in achieving its objectives. The models of the LOIS should provide sufficient evidence for the designers to believe that this will indeed be the case. From these models the system properties should be derivable and conversely, the models have to be designed so that the system requirements can be fulfilled. Collectively, LOIS can be considered as a scheme to improve the organization's chances for success and survival by continuously adapting to the external environment. This is done by providing a variety of timely services such as the following [48]. LOIS should support structured and unstructured dialogue and negotiation among organization's knowledge workers. They need to support reflection and creative synthesis of information and knowledge and thus integrate working and learning. They should also help document information and knowledge as it builds up (e.g. by electronic journals). And they have to make recorded information and knowledge retrievable, and individuals with information and knowledge accessible. Consequently, we stand a better chance of increasing social participation and shared understanding within the enterprise, and thus foster better learning. Practically, we agree [23, 24] that the evolution of CBD will start off with the ability to build individual components efficiently. Then it will evolve through efficient construction of component-based solutions in new domains, efficient adaptation of existing solutions to new problems, and efficient evolution of installed solutions by people with limited technical knowledge. Finally, it will achieve the efficient integration and evolution of sets of solutions. The real challenge is to derive a coherent set of principles that will bring the whole of system development, including technology, infrastructure, distributed system architecture, methodology, and project management, into a single component-centric whole.

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