Incorporating Knowledge Management Concepts into Engineering Education

by

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Abstract: *Knowledge Management (KM) is the process of creating value from an organization's intangible assets. This is many times referred to as intellectual capital, human capital, structural capital, or customer capital. The primary reasons for an organization to embrace knowledge management are to increase innovation within the firm, to retain workforce knowledge, and for return on vision. Increasingly, organizations in the 21st Century are entering the knowledge age and thereby becoming knowledge organizations. Knowledge organizations recognize the importance of their assets both internally and externally. Organizations increasingly have a need to insure that lessons learned, best practices, and expertise are transferred appropriately to employees, management, shareholders, and customers. This paper will explore each of these concepts and will provide a definition and description of knowledge management applications relating to the contemporary enterprise. It will also provide justification for the need to incorporate knowledge management concepts into the learning outcomes of university level engineering students. Engineering graduates often find themselves in management positions during their professional career path and they are many times faced with the expectation of increasing and/or improving an organization's position in the global marketplace. With a thorough understanding of knowledge management methodologies, techniques, and tools, future engineering graduates will be better prepared to capitalize on the organization's existing knowledge assets and to insure that critical assets to the organization's future success are transferred appropriately. This fact provides the organization an opportunity to become more competitive and have a stronger position in the world market with minimal investment. Also, engineering graduates will have additional critical tools with which to manage successfully existing and future enterprises.*

I. Introduction

Peter F. Drucker, world pioneer of management theory, first recognized the emergence of the knowledge worker, knowledge economy, and knowledge society in his earlier works - decades ago (Maciariello, 2005). Today, we see a society that in its history has been driven by resources such as land, labor, and capital as it is gradually becoming a "knowledge society" (Lai, Chu, 2002). According to (Santo, 2005), the organization of the 21st Century has become a knowledge organization, whereby the generation, sharing, and storing of knowledge has become an integral part of the organizational culture. Across industries, knowledge is being recognized as a strategic resource that becomes critical in gaining a competitive advantage, and as a result, much attention has increasingly been placed on knowledge management (KM) and the organization's ability to create knowledge (Piccoli, Ahmad, Ives, 2000). According to (Lai, Chu, 2002), "the ability to integrate and apply specialized knowledge by organization members is fundamental to a firm in creating and sustaining a competitive advantage" - this being the central goal of knowledge management which focuses on ways to manage how knowledge is disseminated and used in the organization (Koulopoulos, Frappaolo, 1999). As this is true, organizations are realizing the value of their employees, as it is their knowledge and experiences that can be used to better serve their target market (Piccoli, Ahmad, Ives, 2000), thereby creating a competitive advantage that cannot be easily duplicated (Koulopoulos, Frappaolo, 1999). The importance of knowledge management in today's economic society is not only evident at the corporate level, but also, among academia and educational institutions, such as colleges and universities who are increasingly offering specialized courses and subjects in knowledge management; In addition, its importance in national economic growth is being realized as it is being taken seriously by international development institutions (Grossman, 2006). An organizations formed by the United Nation, the Organization for Economic Cooperation and Development (OECD), recognizes that the key to replacing a globally aging workforce is to find innovative teaching methods in which to properly identify, codify, and disseminate good practices among students such that it will produce a competent workforce entering the workplace (Descoings, 2006). As the competitiveness nature in modern economy forces businesses to continuously improve such that they meet the demands of a changing business environment (Stuckenschmidt, 2005), they will require the support of a workforce that can initiate innovation and adapt to change. Furthermore, as this reality impacts all industries, according to The Engineer of 2020, as future engineer graduates enter the workforce, they will need to be prepared (through engineering education) to be capable workers in a global economy that is fueled by innovation and rapid technological advances (Anonymous, 2006). According to (Wulf, Fisher, 2002), the problem lies in the current state of the engineering discipline in that as the pace of this change is accelerating, engineering education – the foundation for future professionals, is not able to keep up with the growing demands. There needs to be an active connection between education and the current state of knowledge management in industry, in order to produce business graduates who can combine technical, business, and social skills (Raisinghan, 2000). Thus, these and future challenges will only be conquered through "transformational change rather than incremental improvements in how we recruit and educate engineering students" (Wulf, Fisher, 2002). As "engineers are hired, retained, and rewarded for their abilities to solve workplace problems" (Jonassen, Strobel, Lee, 2006),

knowledge management initiatives embedded in the engineering education can help to prepare future students for lifelong learning. In this paper, we will demonstrate that knowledge management initiatives that are being implemented among organizations industry-wide can also be effectively used to prepare future engineering graduates to have a successful and gradual transition into a changing workforce environment in which they're value to the organization will be based on the knowledge they possess.

Understanding the foundations of knowledge management, and its impact in business and industry is essential to realizing its applicability and effectiveness in educating future engineering graduates.

II. What is Knowledge Management?

As there is no universal definition of KM, literature review reveals a common view that KM focuses on making organizational knowledge available in such ways that it can facilitate decision making, as well as, ensure that information is available for future use (Liebowitz, 2004). As knowledge is in fact relevant information that is used to solve a particular problem (Koulopoulos, Frappaolo, 1999), KM makes information available such that it can be utilized by those who need it (Sabherwal, Sabherwal, 2005).The goal of the KM process is to create a systematic system that encourages the creation, acquisition, transfer, sharing, and renewing of employees' knowledge to enhance organizational performance (Lai, Chu, 2002). KM recognizes that knowledge exists in two forms: tacit (inherent in individuals' mind) and explicit (already articulated in some form) (Nonaka, Peltokorpi, 2006). (Sabherwal, Sabherwal, 2005). Tacit knowledge is not directly accessible to others as it results from individuals' expertise and experiences (Albert, 2006), making difficult to manage due to its implicit and personal nature; yet it can be retrieved best through face-to-face methods such as apprenticeships, mentoring, and Communities of Practice (CoP) (Koulopoulos, Frappaolo, 1999). Explicit knowledge on the other hand, is codifiable (Grover, Davenport, 2001), and can be easily documented and transferred using electronic tools such as intranets, web applications, to encourage and facilitate knowledge sharing among employees (Liebowitz, 2004). The organization's learning process thus involves the conversion of implicit and explicit knowledge through a sequence of: knowledge identification (tacit to tacit), knowledge acquisition and codification (tacit to explicit), and finally, knowledge retrieval and visualization (explicit to tacit); such that new knowledge can also be derived (Stuckenschmidt, Siberski, Nejdl, 2005). Although both types of knowledge are important, Western firms have traditionally focused on managing explicit knowledge (Grover, Davenport, 2001) due to the ease of conveying and capturing it, as compared to tacit knowledge (Koulopoulos, Frappaolo, 1999). However, organizations have recognized that the ability to manage the tacit knowledge within organizations, although most difficult, can lead to rewarding organizational results. The focus on tacit knowledge has led to the recognition of the "*knowledge worker*" who possesses valuable information that needs to be explicitly expressed, such that it can be used to solve organizational problems faced in the marketplace, as well as uncover best practices for future use; thus leading to the importance of a *"learning organization"*. KM experts have recognized the importance and value of a "learning organization"- an

organization in which knowledge plays a critical role in its dedication towards continuous improvement (Stuckenschmidt, Siberski, Nejdl, 2005). Literature reveals that by becoming a knowledge organization and embracing knowledge management, organizations can create a key source of competitive advantage, embrace innovation, and improve bottom-line results (Albert, 2006).

There are three basic appRaoches to KM: the information technology (IT) perspective, the human resources perspective and the integrated perspective (combination of the best of both appRaoches) (Santo, 2005). However, experts in the field of KM assert that the integrative appRaoch is the most practical for achieving KM goals. The U.S. National Research Council found that IT is only effective in the KM process when it is accompanied with "appropriate policy, strategy, talented and committed people, and sound organizational relationships" (Amidon, 2005). Furthermore, KM implemented properly, can result in the enhancement of organizational effectiveness, efficiency, and productivity (Liebowitz, 2004). As the IT perspective contributes to the KM process by way of providing the infrastructure which facilitates the communication and sharing of information (Lai, Chu, 2002), the organizational knowledge is however inherent within and created by the individual (Sabherwal, Sabherwal, 2005), thus introducing the human perspective and reintroducing the idea of the knowledge worker.

The involvement of the knowledge worker in the KM process is important as they are the owners and creators of the knowledge that facilitate the acquiring, organizing, sustaining, applying, and renewing of key information (Lai, Chu, 2002), thereby underlining the idea that social issues are significant in ensuring knowledge sharing (Kankanhalli, Tan, Wei, 2005). According to (Rao, 2005), technology's is used to demonstrate to employees the multiple possibilities of KM; however, the people are the essence of the KM initiative (which is people-centric). More so, through shared knowledge, individuals can acquire knowledge previously lacked, and they can then combine this knowledge with their prior knowledge to create new knowledge (Sabherwal, Sabherwal, 2005) - the source of innovation. As companies face emerging pressures from the marketplace to develop innovative capabilities, they are turning to their workforce to be able to deliver these capabilities.

III. Impact of KM on Business and Industry

Knowledge has been a topic of discussion as it relates to business and industry since the mid-1980s as it was a period in which organizations realized that their high investments in technology were not in fact contributing to bottom-line results (Amidon, 2005). This realization paved the way for the idea that intellectual capital could be a source of competitive advantage. Now we see a progression within organizations as they have gone from being labor and capital intensive; to viewing technology as a key source for meeting organizational goals and achieving results; to a more recent understanding that knowledge is a critical asset for competitive advantage (Rao, 2005), as it is a difficult asset for competing firms to acquire and duplicate (Lai, Chu, 2002), especially, when it is well managed. This brings rise to the importance that knowledge management has in today's organization. According to (Liebowitz, 2004), there is increasing pressure for

organizations operating in the United States to be able to intelligently utilize the knowledge within their organization as it results in increased effectiveness and efficiency, as well as it is necessary in order to stay abreast competition. The American Society of Training and Development states that "knowledge is a major source of competitive advantage" and this is supported as KM has become popular in business and industry among organizations who have implemented knowledge-focused strategies (i.e. Xerox, HP, Exxon, Accenture, British Airways, etc.), as well as among academia (Santo, 2005). Organizations are learning the value of their workforce, as they understand that their core strengths lie in the brainpower of their employees – their intellectual capital. According to Dr. Shereen Remez, the Knowledge Management Director at the American Association for Retired Persons (AARP), about 80% of the Fortune 500 companies have knowledge management teams (Liebowitz, 2004); United States (U.S.) federal government agencies and private sector organizations have recognized the need for formal knowledge management in their organizations. According to (Malone, 2003), KM poses to be a potential solution to current economic driven problems such as: an aging workforce, rapid technological advancement coupled with an overload of information available to managers and investors. As most engineers are continuously confronted with new problems and challenges (Henriksen, 2001), the ability to acquire new knowledge becomes essential. Furthermore, the use of KM in industry has emerged in face of a decrease in manufacturing professionals, geographically spread worksites, and an increasing percentage of retiring manufacture workers (Brandl, 2006). Much like in other industries, KM initiatives prove to be effective in solving some of the problems faced in the engineering industry.

IV. Engineers as Managers

In the engineering industry of the 21st Century, the role of engineering managers has significantly changed with the onset of the globalization of the manufacturing base, advancements in technology, and the shift towards a service based economy (Kotnour, Farr, 2005). In addition, with increasing time constraints that engineers face with projects, there is a high risk that knowledge that has been collected and stored from years of experience will be lost and thus will not be passed onto the next generation of engineers (Brandl, 2006). With "the changing nature of international trade and the subsequent restructuring of industry, the shift from defense to civilian applications, the use of new materials and biological processes, and the explosion of information technology" (Wulf, Fisher, 2002), engineers are faced with challenges that included "greater diversity; greater synchronization requirements; greater time pacing requirements; faster decision making, learning, and innovation" (Jonassen, Strobel, Lee, 2006).

As today's economy has shifted towards a knowledge economy, the job of an engineer (more than ever before) requires knowledge and the ability to synthesize that knowledge to solve real life problems (Henriksen, 2001), and to continuously create and transfer new knowledge that will be useful in the future. This is especially important as key information is lost as engineers who previously gained knowledge through their experiences are often absent, retired, or working with another company (Brandl, 2006). Often, engineers enter

the job market as project managers, technical salespeople, and lead systems engineers with the ability to handle information being a central task foe conceiving, designing, integrating, marketing, and testing complex and multi-functional technologies (Kotnour, Farr, 2005). As information overload becomes prevalent for engineers and project managers, they are faced with technological and organizational issues that must be hurdled so that information that is useful for solving specific problems is extracted from the various sources in which it exists (Henriksen, 2001).

Technologies are becoming increasingly complex, such that the engineering manager must also deal with challenges that include: (1) strategic planning for technology products, (2) new product project selection, (3) organizational learning about technology, and (4) technology core competencies (Kotnour, Farr, 2005). Managers in organizations are realizing that technological tools used in KM are useful in addressing business pressures (Rao, 2005). As the IT perspective of KM acknowledges that technology is an integrated part of the KM process, the IT industry continuously develops and introduces technological tools that facilitate the systematic process, by which knowledge is captured, created, transferred, and shared (Brandl, 2006).

Engineering education challenges:

According to (Grossman, 2006), "Accreditation and curricula standardization bodies have acknowledged the importance of knowledge management skill-sets in today's hypercompetitive knowledge based economy…" the Accreditation Board for Engineering and Technology (ABET) acknowledges that it is important for engineering programs to develop, train, and prepare future engineers to have the abilities to identify, formulate, and solve engineering problems in today's highly competitive knowledge based economy and to be able to function in multidisciplinary teams (Jonassen, Strobel, Lee, 2006). (Wulf, Fisher, 2002) Warns that the economic demands of today have been challenging to organizations such that in the next century, organizations will be required to operate at an even faster rate at which currently, we are not adequately prepared to meet those demands. If engineering education programs are to meet the challenges faced in a highly competitive economic environment, engineering students need to have an understanding of the nature of workplace problem solving in order to be prepared better prepare in the workplace (Jonassen, Strobel, Lee, 2006). According to (Kotnour, Farr, 2005), the 21st Century technical organization must be concerned with:

(1) maintaining an agile, high quality and profitable business base of products or services in a fluctuating economy,

(2) hiring, managing, and retaining a highly qualified and trained staff of engineers, scientists, and technicians in a rapidly changing technological environment; and,

(3) demonstrating a high level of capability maturity.

Increasingly, knowledge management is being recognized among today's organizations as a strategic initiative to combat economic and business challenges; thus future graduates must have an understanding of its importance and realize that they play a key role (as

knowledge workers) in the development of the KM process. However, engineering education plays a critical role in preparing engineering students to becoming knowledge workers and competent engineers. According to Wayne Clough, Chair of the Committee on The Engineer of 2020, "If the United States is to maintain its economic leadership and sustain its share of high-technology jobs, it must prepare the engineers of tomorrow for future technological and societal changes and to acquire new knowledge quickly and apply it to emerging problems" (Jonassen, Strobel, Lee, 2006).

As ABET has established a set of criteria of eleven learning outcomes that all engineering baccalaureate graduates should possess (Shuman, Besterfield-Sacre, McGourty, 2005), four of these outcomes represent skills that are essential for future engineers to possess in a knowledge intensive economy; and in a field that is increasingly being driven by knowledge management initiatives. These include the following:

Hard Skills

- an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice
- an ability to identify, formulate, and solve engineering problem

Professional Skills

- an ability to communicate effectively
- a recognition of the need for, and an ability to engage in lifelong learning

As knowledge has been expressed to be a valuable resource held by organizations, recruitment efforts by many organizations are targeted towards individuals who possess the skills and abilities to synthesize, share, and utilize knowledge. According to (Roman, 2006) engineers, who are able to quickly, efficiently and consistently convert data and information into competitive knowledge, are highly valued. Furthermore, organizations expect employees to have the ability to contribute to innovative solutions, effectively communicate knowledge to others, create new knowledge and evaluate information (Piccoli, Ahmad, Ives, 2000). Realizing these truths, the future engineer needs to be aware of the impact of KM in today's knowledge economy, as well as its applicability and use among businesses, specifically engineering organizations. According to (Raisinghani, 2000), "a connection is being established between educators and business leaders, as programs are being started throughout the country to establish connections between what students learn in classrooms and their preparation for subsequent careers". Through methods of classroom teaching and learning, engineering education can help to prepare the engineering students who will soon enter the workforce. According to (Jonassen, Strobel,

Lee, 2006), "engineering programs must support learning to solve complex, ill-structured workplace problems if they are to prepare their graduates for future learning and work." Recently, government, industry, and academia reports have consensually acknowledged the need for engineering education to include professional skills in the list of learning outcomes (Shuman, Besterfield-Sacre, McGourty, 2005). One of ABET's professional skills outcomes for engineering education is "a recognition of the need for, and an ability to engage in lifelong learning" (Shuman, Besterfield-Sacre, McGourty, 2005). Meanwhile, as one of the outcomes of implementing KM is to inspire continuous organizational learning (Koulopoulos, Frappaolo, 1999), through the teaching of KM concepts in engineering education, future engineers will not only gain an understanding of KM's impact in the engineering field, but also will realize that the work of an engineer in today's society requires ongoing, lifelong learning (Jonassen, Strobel, Lee, 2006).

Research provides examples of ways in which KM concepts can be introduced into education programs, as well as, ways in which the engineering community can be connected to the classroom experience in order to introduce real world events. These examples, when applied to KM and the engineering education can provide valuable methods for the inclusion and teaching of KM in the engineering education classrooms.

In the same way in which (Malone, 2003) suggests the implementation of KM into education programs, engineering professors should similarly introduce KM into the classroom by way of providing background lectures on KM, introducing the principle concepts related to the topic, in addition to assigning case studies using selected articles on knowledge management which will provide exposure to the use and benefits of KM in industry. (Roman, 2006) explains that "many schools are trying to establish links between technology education and the world of engineering…[by]…reaching out to local engineers who speak to their classes, conduct a special lecture or host a design challenge". Similar practices can also be initiated in the engineering education as KM related presentations, seminars, or activities are held by engineer professionals who work for organizations in which KM initiatives are used or by key knowledge officers from organizations.

"As one of the main focuses of KM is to make knowledge accessible to the people who need it" (Raisinghani, 2000), the task becomes even more difficult as globalization, and outsourcing activities have created great distances, often time zones, between engineers (Piccoli, Ahmad, Ives, 2000). The reality of this dispersion further reinforces the need for engineering education to ensure that ABET's requirement that students should have the ability to communicate effectively, and the ability to use the techniques, skills, and modern engineering tools necessary for engineering practice are met. Recognizing that knowledge transfer between departments is essential for improving core business processes, cross-functional skills are being taught in classrooms through the use of such things as case studies, team projects, and research papers with a cross-disciplinary focus (Raisinghani, 2000). Furthermore, as "engineering knowledge required to solve problems is usually distributed among a variety of people, including draftspersons, surveyors, other engineers, and administrators" (Jonassen, Strobel, Lee, 2006), engineering educators can implement the use of some of the electronic KM tools, such as Wiki technology which allows users to add or edit content pertaining to particular topic. This technology is used in corporate and

educational environments for collaborative knowledge creation (Raman, Ryan, Olfman, 2005). Using Wiki technologies as an interactive learning tool in the curriculum can help to model its use, applicability and benefits as it is used in organizations as part of the KM initiative – to encourage knowledge creation and knowledge sharing activities. According to (Raman, 2006), "Wiki technology can therefore also address some knowledge management goals for collaborative work and organizational learning"; This will help train engineering students to understand the collaborative effects of (organizational) learning, as knowledge is distributed among people, their tools and communication media, history, and the artifacts they create. Furthermore, (Raman, Ryan, Olfman, 2005) suggests nine conversational technologies that can be used to manage knowledge in corporations and that can be applied to the educational process; these include: "e-mail, static and database backed Web pages, discussion forums, internet chat, video-audio streaming, video-audio conference, Web log and Wikis".

Engineering companies develop teams to oversee and manage their product development, process improvement, and manufacturing activities. (Shuman, Besterfield-Sacre, McGourty, 2005). As such, it is important that engineering students are equipped with the ability and skills to function on multi-disciplinary teams, meeting one of ABET's learning outcome criteria (Jonassen, Strobel, Lee, 2006). "KM principles enable organizations to capture, organize, analyze, share, and reuse both explicit and tacit knowledge to make better and faster decisions across geographic, functional, and team boundaries" (Dow, Bobrinsky, Pallaschke, Spada, Warhaut, 2006). As engineers often work in group environments, they often rely on other peoples' knowledge to solve workplace problems; this allows the contribution of different skills and knowledge to solve engineering problems (Jonassen, Strobel, Lee, 2006). In the same way, cross-functional teams are used in KM in which individuals with different functional expertise are grouped together to work towards achieving a common goal (Dow, Bobrinsky, Pallaschke, Spada, Warhaut, 2006). Engineering educators are recognizing the need to develop multi-disciplinary skills, by designing more and more courses around teams (Shuman, Besterfield-Sacre, McGourty, 2005). In addition, introducing the concept of Communities of Practice (CoP) can help to illustrate to engineering students the importance and results of having the ability to collaborate with others in a group environment. CoP's were developed in the "organizational learning" movement under the understanding that knowledge flows best through networks of people who may not be in the same part of the organization, but have the same work interests (Grover, Davenport, 2001). These networks are built through informal or formal communities and create an opportunity for people who have a common drive to exchange their knowledge and uncover best practices. The result of designing course activities around teams is that it can "foster positive interdependence, individual accountability, promotes interaction, social skills, and co-construction of knowledge by engaging in authentic, collaborative tasks" (Jonassen, Strobel, Lee, 2006).

VI. Conclusion

Contemporary business managers and leaders are increasingly encountering more complex, and well defined competition models. This fact alone makes it imperative that today's management team be knowledgeable of and fully aware of the existing knowledge base in

their business enterprise. Knowledge management provides the processes and tools required to uncover, manage, and to organize existing and future knowledge assets that may be developed or gained within the enterprise.

The engineering graduate is increasingly placed in managerial positions that have the responsibility of improving the company's efficiency and bottom-line. This is compounded because of more and more complex technologies, processes, and products. Therefore, it is an absolute requirement that management have a firm and accurate understanding of the knowledge assets that the company possesses, and how to maximize the positive impact that the company's knowledge assets contribute to the company's success. Therefore, it is imperative that engineering education in our colleges and universities include, not only the sciences and mathematics, but also the managerial skills required of today's business and industry leaders. Knowledge management concepts must be a vital component of contemporary engineering education if U.S. organizations are to compete effectively in the world marketplace.

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