THE INTRODUCTION OF KNOWLEDGE MANAGEMENT INTO ENGINEERING EDUCATION SYSTEMS

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Abstract *— Recently, the government in Taiwan proposed a knowledge-based economic policy to reinforce the competence of Taiwan's industries in the 21st century. Industries in the age of the knowledge-based economy are information-intensive and must pay more attention to knowledge management than others. Many scholars have explicitly regarded knowledge as a critical success factor for enterprises. Effective knowledge management plays a key role for all industries in the future. Knowledge management is a conscious strategy of getting the right knowledge to the right people at the right time and helping people share and put information into action in ways that will improve organizational performance. The goal of knowledge management is to improve innovation. To meet the requirements of industries, more and more engineering schools begin to design curricula about innovation. This study will investigate the introduction of knowledge management into engineering education systems.*

Index Terms —engineering logic, innovation, knowledge, knowledge management

INTRODUCTION

Recently, the government in Taiwan proposed a knowledge-based economic policy to reinforce the competence of Taiwan's industries in the 21st century. Industries in the age of the knowledge-based economy are information-intensive and must pay more attention to knowledge management than others. Many companies are beginning to feel that the knowledge of their employees is their most valuable asset. The goal of knowledge management is to promote the ability of innovation. The processes of knowledge management involve knowledge capture, sharing, classification, and understanding. This article will study the introduction of knowledge management into engineering education systems from the point of industries by surveying several engineers in some manufacturing companies in Taiwan.

KNOWLEDGE

A firm's ability to perform an activity rests on its knowledge of that activity, that is, competence rests on technological and market knowledge. Technological knowledge is knowledge of components, linkages between components, methods, processes, and techniques that go into a product or service. Market knowledge is knowledge of distribution channels, product applications, and customer expectations, preferences, needs, and wants. Together, technological knowledge and market knowledge are the bedrock of capabilities. Boeing's ability to build airplanes, for example, rests on its knowledge in aircraft engines, control systems, navigation, and fuselage and how they can be linked together. It also depends on its knowledge of transportation, the airline industry, what airlines and passengers want, and how to translate all of these into an airplane. Merck is able to quickly synthesize new drugs only because of its stock of knowledge in combinatorial chemistry, physiology, pharmacology, and its ability to integrate them. Intel's knowledge in semiconductor device physics, circuit design, logic, instruction set architecture, and layout design as well as its accumulated intellectual property underpins its ability to offer microprocessors.

Three properties of knowledge determine how well a firm performs the activities that rest on the knowledge: newness, quantity, and tacitness.

Newness

One critical property of the knowledge that underpins an activity is how new it is to the function or organization performing the activity. If it is very different from existing knowledge, it is said to radical or competence destroying. If it builds on existing knowledge, it is said to be incremental or competence enhancing. The newer the knowledge, the more difficult it is for firm to perform the activities.

Quantity

The newness of the knowledge is just one factor. How much of the new knowledge is another. The move from a three-piece tin-plated steel can to a two-piece aluminum can, and the move from a Boeing 747 to a 777 both entail

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new knowledge. But the amount of knowledge needed for the plane is a lot larger than that needed for the can. This amount is a function of the complexity of the activities that go into the product, which may or may not result in a complex product. For example, the activities that go into the discovery and development of pharmaceutical products are complex and knowledge intensive. Yet the final product is simple. The activities that go into making a plane are also complex and knowledge intensive, and the final product is also complex.

Tacitness

Knowledge can be explicit (articulated, codified) or tacit. It is explicit if it is spelled out in writing, verbalized, or coded in drawing, computer programs, or other products. It is tacit if uncoded and nonverbalized. Tacit knowledge may not even be verbalizable or articulatable. Tacit knowledge can be converted to explicit and vice versa. An individual has his or her own image of his or her tacit knowledge. That image must be articulated in writing, drawing, products or actions. A customer may have some image of what she needs in a product, but may not be able to articulate it. Nonaka et al. [1], suggest that knowledge can be converted from tacit to explicit via metaphors, analogies, and models. Metaphors allow one to understand something by seeing it in terms of something else. Analogy helps us understand the unknown through the known and bridges the gap between an image and a logical model.

KNOWLEDGE MANAGEMENT

In this age of knowledge-based economy, many enterprises start to emphasize the management of knowledge. Knowledge management is a conscious strategy of getting the right knowledge to the right people at the right time and helping people share and put information into action in ways that will improve organizational performance. It is a complex process that must be supported by a strong foundation of enablers. The enablers for knowledge management are strategy and leadership, culture, measurement, and technology. Each of these must be designed and managed in alignment with other in support of the process. The knowledge management involves the following parts [2]:

(1) knowledge selection/mining
(2) knowledge obtaining
(3) knowledge learning
(4) knowledge creation
(5) knowledge diffusion
(6) knowledge construction/coding
(7) knowledge warehousing

The rapid growth of information and communication technologies promotes the development of knowledge management. The goal for knowledge management technology is to create a connected environment for knowledge exchange. Knowledge management technology must support the exchange and transformation of tacit and explicit knowledge. The processes of knowledge transformation and exchange involve knowledge sharing, knowledge capture, classification, and understanding [3].

According to the OVUM model [3] of the knowledge management architecture, a complete virtual learning community should provide the following four key functions:

(1) collaboration services which provide an environment for knowledge sharing
(2) discovery services which help users retrieve and analyze (understand) the information in the corporate memory
(3) the knowledge repository which provides the information-management functions for captured knowledge
(4) the knowledge map which provides a corporate schema for knowledge classification

According to a survey of some companies in Taiwan and a review of some related literature, we conclude some principles of knowledge management:

(1) Knowledge management is highly political
(2) Knowledge management requires hybrid solutions of people and technology.
(3) Knowledge management requires knowledge managers.
(4) Knowledge management requires a knowledge contract.
(5) Knowledge management benefits more from maps than models, more from markets than from hierarchies.
(6) Knowledge management means improving knowledge work processes.
(7) Sharing and using knowledge are often unnatural acts.
(8) Knowledge management is expensive.
(9) Knowledge access is only the beginning.
(10) Knowledge management never ends.

INNOVATION

What is innovation? One of the problems in managing innovation is variation in what people understand by the term, often confusing it with invention. In its broadest sense the term comes from the Latin *innovare* meaning ‘to make something new’. Drucker [4] defined innovation as the specific tool of entrepreneurs, the means by which they exploit change as an opportunity for a different business or service. It is capable of being presented as a discipline, capable of being learned, capable of being practiced. Porter [5] said "Companies achieve competitive advantage through acts of innovation. They approach innovation in its broadest sense, including both new technologies and new ways of doing things." We think that innovation is a process of turning opportunity into new ideas and of putting these into widely used practice. Industrial innovation includes the technical design, manufacturing, management and commercial activities involved in the marketing of a new (or improved) product or the first commercial use of a new (or improved) process or equipment.

Innovation is the use of new technological and market knowledge to offer a new product or service to customers, as shown in Figure 1. The product is new in that its cost is lower, its attributes are improved, it now has attributes it never had before, or it never existed in that market before. Often the new product itself is called an innovation, reflecting the fact that it is the creation of new technological or market knowledge, or it is new to customers. The new technological or market knowledge that is used to offer the new product or service can underpin any of the chain of activities that the firm must perform in order to offer the new product. It can be in the design of the product or in the way the product is advertised. The knowledge is new because the firm has never used it before or because it used it but only for applications unrelated to the one for which the new product is earmarked.

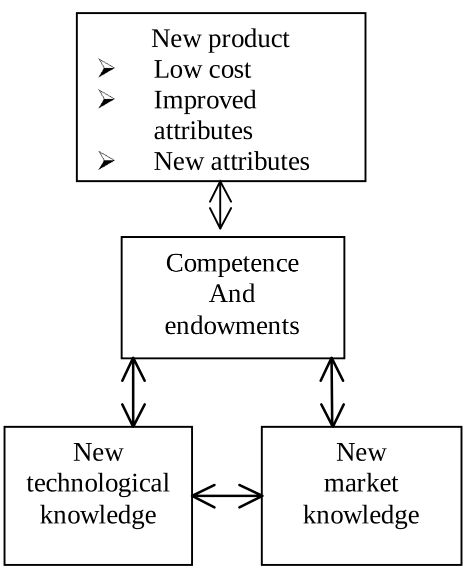

FIGURE. 1
THE SYSTEM OF INNOVATION

Although industries know that innovation is very important and try to reinforce their ability of innovation, many of them still misunderstand innovation. Failure to understand fully the process nature of innovation leads in practice to what might be termed 'one-dimensional management', that is, focusing only on those parts which are perceived as important. Table I provides an overview of the difficulties which arise if we take a partial view of innovation. To find the core abilities in managing innovation in industries, we also make a survey of some companies in Taiwan. Table II shows a list of basic abilities in managing innovation and its related contributing routines.

ENGINEERING INNOVATION LOGIC

To investigate the management of innovation and engineering logic in industries, a survey on some engineers in some manufacturing companies in Taiwan was made. According to the summary of that survey, the innovation logic of engineering focuses around three kinds of activities: invention, design, and problem solving. Invention is the activity of creating a new technology. Design is the activity of creating the form and function of products, production processes, or services. Technical problem solving is the activity of making technologies work and work well.

Technological invention

Often, in design or in solving a technical problem, an engineer needs to invent a new way of doing something. Invention is the creation of new technology. The logic of invention is an idea that maps functional logic to physical morphologies. Invention is always new to the person inventing it. Invention need not be new to everyone, as long as the invention solves the immediate technical problem. But if the invention is new to everyone, it may be patented.

Design

In design, the essential logic is to create morphological and logical forms to perform function. Form and function are the basic intellectual dichotomy of the concept of design. The logical steps involved require, first, determining the performance require for the function for the customer and then, creating an integrated logical and physical form for fulfilling the function.

TABLE I

PROBLEMS OF PARTIAL VIEWS OF INNOVATION

If innovation is only seen as…	…..the result can be
Strong R&D capability	Technology which fails to meet user needs and may not be accepted
The province of specialists in white coats in the R&D laboratory	Lack of involvement of others, and a lack of key knowledge and experience input from other perspectives
Meeting customer needs	Lack of technical progression, leading to inability to gain competitive edge by anticipating future needs
Technology advances	Producing products which the market does not want or designing processes which do not meet the needs of the users or which are opposed
The province only of large firms	Weak small firms with too high a dependence on a few large customers
Only about 'breakthrough' changes	Neglect of the potential of incremental innovation. Also an inability to secure and reinforce the gains from radical change because the incremental performance ratchet is not working well
Only associated with key individuals	Failure to utilize the creativity of the remainder of employees, and to secure their inputs and perspectives to improve innovation
Only internally generated	The 'not invented here' effect, where good ideas from outside are resisted or rejected
Only externally generated	Innovation becomes simply a matter of filling a shopping list of needs from outside and there is little internal learning or development of technological competence

TABLE II

CORE ABILITIES IN MANAGING INNOVATION

Basic ability	Contributing routines
Recognizing	Searching the environment for technical and economic clues to trigger the process of change
Aligning	Ensuring a good fit between the overall business strategy and the proposed change-not innovating because it is fashionable or as a knee-jerk response to a competitor
Acquiring	Recognizing the limitations of the company's own technology base and being able to connect to external sources of knowledge, information, equipment, etc. Transferring knowledge from various outside sources and connecting it to the relevant internal points in the organization
Generating	Having the ability to create some aspects of technology in-house, e.g. through R&D, engineering groups
Choosing	Exploring and selecting the most suitable response to the environmental triggers which fit the strategy and the internal resource base/external technology network
Executing	Managing development projects for new products or processes from initial idea through to final launch. Monitoring and controlling such projects
Implementing	Managing the introduction of change-technical and otherwise-in the organization to ensure acceptance and effective use of innovation
Learning	Having the ability to evaluate and reflect upon the innovation process and identify lessons for improvement in the management routines
Developing the organization	Embedding effective routines in place-in structures, processes, underlying behaviors, etc

In product design, the first logical step is to establish customer needs. This is a list of:

(1) The customer's applications of the engineered product
(2) The functional capability of the product for these applications
(3) The performance requirement for the applications
(4) The desired features of the applications
(5) Size, shape, material, and energy requirements for the applications
(6) Legal, safety, and environmental requirements for the product
(7) Supplies for and maintenance and repairability of the product
(8) Target price of the product

Once the customer needs list is established, the next logical step is to establish a "product specification set." These product specs translate customer needs into technical specifications that guide the engineering design of the product.

The third logical step is the design of the product, using ideas from previous product designs along with innovative new design ideas to create a product that meets the product specs and customer needs.

While these logical steps sound sequential, in practice, successful design requires concurrent interactions with marketing and finance and redesign loops as the both the needs and specs get refined into design details. Thus, in a large organization, design occurs in groups of designers and goes from a conceptual design stage into a detail design stage and back and forth until a final design is realized that is ready for testing.

After a design goes into testing, the design must often be modified to correct flaws in the product's design. Once a tested design is ready to be produced, then the design must again be altered to become manufacturable in volume with high quality and to meet target costs. (As much of the manufacturability criteria as possible should be brought early into the design process, to minimize redesign for manufacturability.)

Technical Problem Solving

Engineers make the technologies that a firm uses work, and all technologies are touchy. Nature is always more complicated than the use we make of it. Simplifying nature to make it mostly work for us technologically always stimulates technical problems, which engineering must solve. The logic of problem solving includes:

(1) Recognition of a problem
(2) Identification of the problem
(3) Analysis of the problem
(4) Solutions to the problem
(5) Testing of the solution
(6) Improvement of the solution and / or redefinition of the problem

In a large organization, problem recognition may not be simple. This requires leadership realizing that there is a problem and acknowledging the existence of the problem. If leaders will not recognize that a problem exists, personnel cannot work on solving the problem. Problems may not be recognized because the leadership does not have the expertise to recognize the problem or because it is politically inconvenient or embarrassing to leadership to acknowledge that a problem exists.

Once a problem is recognized, the next logical step is to identify the nature of the problem, its location, and the client to whom it causes difficulties. Identification of a problem can then logically be followed by analysis of the problem, its sources, and its causes. Once the source and cause of the problem are known, then solutions to the problem can be diagnosed or invented. The proposed best solution can then be tested to see if it solves the problem. If testing shows that the problem is still not solved, then further refinement of the solution or alternative solutions may be tried and tested. Sometimes, the problem even requires redefinition, if testing shows that the problem was not properly understood initially.

Problem solving is also an essential aspect in the design and invention activities of engineering. There will always be problems in inventions and in new designs that are found only after use in the field. For example, von Hippel and Tyre [4] examined problem solving in two cases of designing new process equipment. They found that, in about half the problems encountered, information about the potential problem did exist with the users but were not communicated to the designers, as they were not thought to be relevant. In the other half of the problems, the problems appeared only after use of the new equipment in the field.

Since technical problem solving is a major activity of engineering, understanding of the nature of problems and solutions for problems is a critical skill of engineers. This is why science is a base knowledge for engineering, because science provides knowledge of nature that underlies technology problems.

CONCLUSIONS

This study investigate the requirements of introduction of knowledge management into engineering education systems from the point of industries. We provide some summaries from the survey of several manufacturing companies in Taiwan. When an educators want to design engineering courses about knowledge management or innovation, he can refer to these summaries. Finally, we suggest some knowledge management activities for engineering education systems:

(1) Knowledge capture, i.e., creation of documents and moving documents onto computer systems
(2) Adding value to knowledge through editing, packaging, and pruning
(3) Developing knowledge categorization approaches and categorizing new contributions to knowledge
(4) Developing information technology infrastructures and applications for the distribution of knowledge
(5) Educating teachers or students on the creation, sharing, and use of knowledge.

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