KNOWLEDGE CREATION AND MANAGEMENT: INTEGRATED ISSUES

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SUMMARY

Knowledge is defined as what we already know. *Knowledge management* (KM) is the practice of making knowledge instantaneously available in a usable format and using it. *Knowledge creation* (KC) is what we know now that we did not know before.

The KM idea began with the realized need to convert the abundance of raw data available in organizations into database to be used to the business advantage. Present-day computers are the medium for this data synthesis. As a result, most of the emphasis on KM has been information technology (IT)-focused. An equally important issue needing attention is KC. There is a lack of published literature on this topic. Knowledge creation depends on: 1) the authenticity and completeness of data, 2) meaningful summaries of the data, 3) newly acquired knowledge when the summaries are viewed and interpreted with the aid of basic principles, and 4) circumstances surrounding a specific application that make the knowledge usable or unusable. Both knowledge creation and knowledge management are crucial components of the whole. Without an integrated approach, neither of them can create a strategic business advantage. In this paper, we will develop the link between KM and KC.

KEY WORDS

knowledge engineering

INTRODUCTION

In recent times, we have been experiencing an unprecedented movement of personnel from one organization to other. This will remain true in the foreseeable future. Knowledge that continually develops in an organization travels with the so-called knowledge worker. Even though the company and its products or services are relatively constant, its workforce is not likely to be so. Therefore, the emerging challenge is how to retain the knowledge that should surround products and services rather than the migrant knowledge worker. We used to hire knowledgeable employees who tend to remain in job positions for lengthy period of time. Presently, the trend is to hire transient knowledge workers who are skilled at developing and using the company's existing knowledge bases.

The resulting challenge is twofold: 1) how can we convert what we already know into useful knowledge base? 2) how can we continually update the knowledge base such that it remains current, accessible, and usable? We label the first challenge as knowledge management and the second challenge as knowledge creation. These two challenges must be met simultaneously, not sequentially.

We will explore specific examples and solution schemes from the perspective of knowledge management, knowledge creation, and finally, their integration.

CONTEXT OF KNOWLEDGE MANAGEMENT

We are most interested in the systematic use of existing knowledge. Our working premise is that we already possess the raw data that can be converted into knowledge. An innovative organization of existing data will create an inherent improvement as well as a substantial advantage over other organizations. There exists an unjustified belief that knowledge management includes both the creation of knowledge as well as the systemization of existing knowledge. However, KM solely deals with knowns. With KC, we are investigating unknowns. Success depends on the effective pairing of KM and KC. The following example will illustrate what knowledge management is and is not.

Example 1: A company collects data about many suppliers. Most of the data concern current suppliers; some of the data deal with potential suppliers. These data are utilized in choosing new suppliers as well as in monitoring the performance of current suppliers. The knowns include: 1) location, 2) contact information, 3) number of employees, 4) products, 5) years of history, 6) quality performance, 7) delivery performance, and 8) cost performance. From the KM perspective, all pieces of data are useful. However, from the KC perspective, only items 6, 7, and 8 are useful. All 8 pieces of data allow us to make a decision about a possible ongoing supplier relationship, whereas items 6, 7, and 8 enable us to examine supplier performance improvement. Items 6, 7, and 8, however, fall short because they act as problem indicators; they don't offer any solutions. The knowledge creation steps must be taken to develop the concrete solutions. The KM challenge is to create completeness of the raw data. The KC challenge is to actually solve the problem.

CONTEXT OF KNOWLEDGE CREATION

We are most interested in creating new knowledge. The fundamental belief here is that we can never claim to have sufficient knowledge. We need to continually replenish our knowledge base. This need is evidenced by many unresolved problems. Let us walk through various examples.

Example 1: We find posted signs on mechanized walks at the airport that read "walk on left, stand on right." Not many passengers pay attention and/or obey the signs. This has been a recurrent problem. There is no knowledge in existence that will solve this problem. In other words, there is no knowledge to manage. We must create the knowledge.

Example 2: Many car drivers casually turn left after the light has changed from yellow to red. It is impossible to have as many policemen as drivers to keep such behavior under check. This problem begs for a solution. Once again, there is no knowledge on how to solve this chronic problem. Therefore, there is no knowledge to manage.

Example 3: Certain automobile models experience the problem in which the electric window easily goes up, but will not come down. Engineers do not understand this phenomenon to the fullest. The interim solution is to change the electric motor that powers the window. The problem temporarily disappears, but intermittently reappears. Even though engineers understand several aspects of the window regulator mechanism, the problem basically remains. We need to understand the underlying physics, which is at the root of the problem. Successful understanding of the root causes will constitute the knowledge. The creation of practical knowledge occurs when a hardware solution that eliminates the physical problem is discovered. In this example, KC must be the horse that pulls the cart (KM).

Example 4: Cars are also known to undergo the problem of wind noise. This begins as very sensitive and costly issue when a brand new vehicle falls victim to wind noise. The only solution thus far attempted has been to reduce gaps between the automobile door and the automobile frame. In some instances, wind noise is experienced even when gaps are maintained within engineering specifications. Customer complaints end up being attended by readjustments of the door so that the symptom might disappear. The only test of successful adjustment is to drive a vehicle. In many instances, the effort to close the automobile door increases as a direct result of adjusting the door to reduce wind noise. The customer returns after a few days with the new complaint. The service person now must readjust the door for resolving the door effort complaint without adversely affecting the wind noise. This cycle of servicing continues until the customer ultimately rationalizes that he or she will have to live with the problem. This type of dilemma is called a problem of contradiction. Same sets of input variables act in opposite manners for arriving at acceptable levels of wind noise and door closure effort. There exist many actual unresolved problems of contradiction for which there is no knowledge. Once again, we can see that knowledge creation is an important prerequisite for knowledge management.

Table 1 summarizes the key differences between knowledge management and knowledge creation.

Table 1. Difference between the purposes of knowledge management and knowledge creation.

Element	***Knowledge management (KM)***	***Knowledge creation (KC)***
Purpose	We are most interested in systematizing the availability and use of existing knowledge. The fundamental premise is that we already have the knowledge. Systemization will create a substantial advantage.	We are primarily concerned with creating new knowledge. Fundamental belief is that we can never claim to have sufficient knowledge. We need to replenish our knowledge base continually. This fact is evidenced by many unresolved chronic problems.
	Integration	
	Integration means that we continually generate new knowledge, archive knowledge, and use knowledge. Without integration, we can only obtain a computerized version of current knowledge. To solve chronic problems or to develop future products, what we know now may simply be problem indicators, not the solutions.	

BUILDING BLOCKS OF KNOWLEDGE

The building blocks to knowledge are identified as data, information, knowledge, and wisdom in Figure 1 (English 1999). We will use these blocks to develop the issues and answers. We must recognize that each block is a subset of the previous.

DATA—KM PERSPECTIVE

Organizations typically collect huge amounts of raw data simply by the virtue of their daily activities. Generally, these data serve immediate needs. Afterward the data are archived for a number of years and ultimately discarded. A question from the knowledge management perspective is how to organize these data for long-term use. Here are a couple of examples to illustrate the point.

Example 1: A city periodically sends out water bills to the residents. The purpose of the bills is to collect the usage charges. Once the bills are paid, the copies are archived. Suppose the city wants to study the usage patterns for future planning. The bills can be studied over time to determine the usage patterns. The ultimate objective would be to determine how to provide uninterrupted water supply at the most economical prices. The computer capacity makes recording of these data possible and data are stored in an analysis-friendly fashion. The same procedures apply to electricity and gas usage.

Example 2: Manufacturing companies routinely collect massive amounts of product inspection data on a daily basis to serve quality control needs. The data are kept for a specified period of time and then discarded. Once again, a computer can store such data for learning about process capabilities, process controls, and overall process performance.

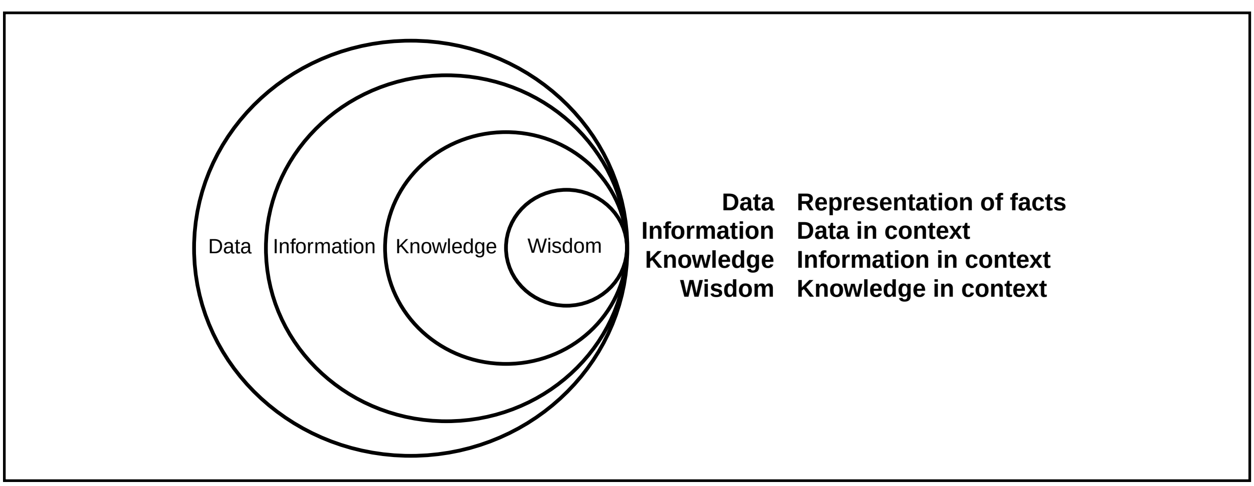

Figure 1. Building blocks of knowledge.

DATA—KC PERSPECTIVE

Our perspective of raw data is different from the knowledge creation basis than that of knowledge management. In KM, we ask how we organize raw data. During KC, we determine whether the data are trustworthy. The data can be considered dependable if it is complete, appropriate, and unbiased. Several examples will illustrate the considerations.

Example 1: This is an example of incomplete data. A team was involved in reducing nonconformance on a chemically coated glass screen. Ten distinct types of nonconformance were defined. The team wanted to focus on a single nonconformance for resolution. The company had some experience with knowledge management. They had computerized the nonconformance raw data for instantaneous retrieval and summary. However, upon in-depth examination, the team discovered that the inspector only recorded the first obvious screen nonconformance as opposed to all nonconformance that were present on a screen. Her rationalization was if the screen was going to be scrapped anyway, why bother recording all types of nonconformance. This is a typical example of incompleteness present in many companies.

Example 2: Here is another example of incomplete data. A company produces rubber material by mixing many ingredients. This rubber material is used for making an end product called the diaphragm. The process steps are: 1) weigh raw ingredients as per recipe; 2) mix ingredients for a set amount of time; 3) check properties of the mix; 4) if properties are within specification, accept the material for further use, otherwise add some ingredients, and continue mixing; 5) check properties of the mix again. This cycle continues until material properties are found to be within specification. Historically, on average, it takes four to five attempts before material is ready for further use. Records only indicate the ingredients of the first attempt and the ingredients of the last attempt. The rationalization for not recording transitional attempts is why should one record something that did not work.

Example 3: This is an example of inappropriateness of data. Many companies routinely collect statistical process control (SPC) data for multiple purposes. Generally, these data are collected at fixed intervals such as once a shift, once an hour, etc. A proper way of recording these data is to capture some systematic events as well as random events. Examples of systematic events are: beginning of a shift, change of a lot, change of a set up, before break, after break, after a maintenance event, etc. These account for known potential troubles. Random intervals capture all other unknowns. Thus, any data collected at a fixed interval is insufficient to convert into any business advantage.

Example 4: This scenario exemplifies biased data. That means the data collection is influenced by the beliefs of the data collector and the true picture is disguised. In one instance, a test engineer was collecting truck noise data on the proving ground. He had observed that during high wind speeds, the truck exhibited high noise levels. Therefore, he would only run tests when he observed low noise levels. Upon inquiry as to why, he responded that when the wind is blowing unfavorably he does not run the tests. His belief was that his assignment is to prove that the truck produces low noise. He could have recorded wind speed as a covariable during all the tests, but he did not. He did not think that the assignment was to determine the noise level of the truck.

Example 5: Here is another example of biased raw data. In this scenario, a test engineer is running a durability test. The design objective is to meet at least 1,000,000 cycles of well-defined laboratory fatigue loading. Most of the test samples exceeded 1,000,000 cycles. However, a couple of samples failed near 10,000 cycles. The test engineer would not include the low cycle data as a part of the analysis because it was nowhere near 1,000.000. His belief was that such low cycle failures are not part of a product design and therefore they cannot exist in the field.

Table 2 summarizes key considerations for raw data from the KC as well as the KM perspectives.

Table 2. Raw data considerations from KC and KM perspectives.

Element	*Knowledge management (KM)*	*Knowledge creation (KC)*
Raw data	Organizations typically have massive amounts of raw data simply by the virtue of their daily activities. Generally, this data serves immediate needs. Afterwards it is archived for a number of years and ultimately discarded. A question from the knowledge management perspective is how to organize these data for future use.	We know that raw data is one of the necessary raw ingredients for knowledge creation. From the knowledge creation perspective, we ask the question whether the data is trustworthy. The data can be considered reliable if it is complete, appropriate, and unbiased.
	Integration	
	Assure that raw data is trustworthy and it is archived in an instantaneously retrievable format. Without integration we cannot trust the quality of data and therefore, we cannot trust any information derived therefrom.	

INFORMATION—KM PERSPECTIVE

The information block is a subset of the data block. To convert data into information, we need to summarize it. We can list a set of summaries that the database can generate. The summaries can be in the form of pictures, numbers, or descriptions. There are common forms of number as well as pictorial summaries that are well described in the literature. Examples of number summaries are average, standard deviation, range, variance, skewness, maximum value, minimum value, kurtosis, coefficient of variation, correlation coefficient, coefficient of determination, etc. Examples of pictorial summaries include the pie chart, bar chart, frequency diagram, histogram, box-and-whisker plot, scatter diagram, time-series plots, control charts, multi-vari plots, distributions, concentration diagram, spider plot, etc. The information need not be in numerical or pictorial formats. The information can also be descriptive. The company can store descriptive information on good and bad practices based on actual experiences. This information could be made available on all new projects. We will explore a couple of examples to clarify the distinction between data and information.

Example 1: A cookie factory makes round cookies. A routine cookie inspection measures maximum and minimum diameters of cookie samples for making "accept" or "reject" decisions. The cookie diameter is a critical characteristic for packaging operation. Occasionally, some portion of the production gets rejected because the cookie sizes are not within specification. Suppose we wish to resolve this problem. We will need to understand the problem first. One can convert maximum and minimum diameters into a multi-vari chart. This chart will be an important pictorial summary to solve the problem. Thus, a multi-vari chart represents information. The raw data by itself is not very useful in searching for a solution.

Example 2: We return to the example in which the city periodically sends out water bills to the residents. The copies of the bills are archived. We made a case for computerizing these data for studying the usage patterns for future planning. To convert these data into information, we should be able to create summaries of water usage by streets, subdivisions, seasons, ambient temperatures, storms, and other coding parameters. These summaries can be utilized for deriving the knowledge necessary for future planning.

INFORMATION—KC PERSPECTIVE

From a knowledge creation perspective, information means much more than just summarizing data into either numbers or pictorial forms. We need to be able to combine summaries on demand. It is the combination of summaries that results in knowledge, not singular summaries by themselves. We should be able to combine number summaries, pictorial summaries, and descriptive summaries. Consider the following situations.

Example 1: The c chart is a summary of nonconformance per unit with respect to time. The Pareto chart is a summary of nonconformance in a categorized form. From the KM point of view, it may be sufficient to provide these two summaries. However, from the KC perspective, we should be able to combine the c chart and Pareto chart and display them as a single summary. A combined summary will allow us to select a problem that we can focus on. Individual summaries by themselves cannot achieve this purpose. To determine which problem to solve is a critical step in the knowledge creation process.

Example 2: A company has a 6-station machine. Box-and-whisker plots summarize the output of each station. From the KM perspective, this may be adequate. However, from the KC perspective, we want to compare the outputs of all six stations on a single diagram for a problem resolution. Therefore, we must make a provision for combining multiple box-and-whisker plots on a single display.

Table 3 summarizes the key distinction between KM type information and KC type information.

KNOWLEDGE—KM PERSPECTIVE

There are two elements that are critical while converting information into knowledge. The first element is related to retrieving information compatible with current circumstantial variables. Sometimes circumstances will be different than those in the past requiring further analysis of information. In some situations, current circumstances will be so different that it will require the KC viewpoint—because past information is obsolete.

The second element is to pose questions to stored proven experiences. The answers to these questions may result in usable knowledge. We will look at two examples.

Table 3. Knowledge management type versus knowledge creation type information.

Element	***Knowledge management (KM)***	***Knowledge creation (KC)***
Information	To convert data into information, we need to summarize the data. The summaries can be in the form of pictures, numbers, or descriptions. Examples of number summaries are average, standard deviation, range, variance, skewness, kurtosis, coefficient of variation, correlation coefficient, etc. Examples of pictorial summaries are pie chart, bar chart, frequency diagram, histogram, box-and-whisker plot, scatter diagram, time-series plots, control charts, concentration diagram, spider plot etc. The information can also be descriptive. The company can store information on good and bad practices based on actual experiences and make it available on all new projects.	From a knowledge creation perspective, information means much more than just summarizing data into either numbers or pictures. We need to be able to combine summaries on demand. It is the combination of summaries that results in knowledge, not singular summaries by themselves. We should be able to combine number summaries, pictorial summaries, and descriptive summaries. For example, we should be able to combine the c chart and Pareto chart and display as a single summary. Or, we should be able to combine multiple box-and-whisker plots and show on a single diagram.
	Integration	
	Provide facility to combine different set of summaries upon demand as well as generate variety of summaries. Without integration we get standardized summaries. If you do not have provisions that can blend, we may not be able to convert information into knowledge.	

Example 1: An injection-molding machine is experiencing a problem of short shots (a common defective condition observed on injection-molded parts). The information database revealed that the root cause was cold material in the hopper on a previous occasion. From the KM perspective, this is very useful information. This knowledge directed an examination of the raw material condition in the hopper. Upon investigation, we discovered that the material in the hopper was not cold. At this point, we need the KC viewpoint, because existing knowledge did not reveal the contributing cause.

Example 2: A company is involved with an ambitious plan of opening 200 franchise stores in one year. The business involves all-purpose printing. The company caters to corporate as well as individual customers. So far they had the experience of opening seven franchise stores. The major problem has been to deliver specialty paper orders on time. The company manually analyzed the data available from seven stores to arrive at the minimum inventory levels of specialty papers that would eliminate all delays. The analysis also suggested that a single specialty paper source would be better compared to having multiple sources. Based on this knowledge the company instituted a new franchising procedure that included maintaining the minimum inventory levels of specialty papers and name of the local specialty paper source. This example demonstrates how prior information is useful in planning for future success.

KNOWLEDGE—KC PERSPECTIVE

While talking about knowledge management, our viewpoint is more deterministic. That is, we examine information in light of well-known principles of physical and social sciences. However, when we consider knowledge creation, we change the viewpoint to the probabilistic inquiry. The probabilistic approach is designed to enhance the existing level of deterministic knowledge. A knowledge management approach would assume that once upon a time we resolved a similar problem. Therefore, we should be able to retrieve and synthesize past information to solve the current problem. The knowledge creation approach, on the other hand, is more interested in building knowledge, and therefore, it would seek answers to more diagnostic questions. These questions would be based on probabilistic principles. The results of diagnostic questions will not directly create knowledge but will reduce the field of investigation for developing new knowledge. Let us look at two examples.

Example 1: Let us say we are facing many problems on an assembly line. The routine daily inspection generates data on nonconformance. We wish to focus on only one type of nonconformance for developing knowledge. We want to use Shewhart and Pareto principles to make this choice. In this instance, we wish to synthesize information in a c chart—Pareto chart format. Together, these charts examine stability versus instability as well as majority versus minority. The use of the c+ Pareto chart narrows the field of investigation from many types of nonconformance to one type of nonconformance.

Example 2: At the engine test stand we are experiencing a 10% loss of engines. We have learned from the information database that all the key characteristics have Cpk values in excess of 1.5. It is possible that the off-target problem is responsible for 10% loss. This possibility can be examined by determining the values of (Cp – Cpk). Once again, we can see that synthesis of individual information (Cp and Cpk) creating new knowledge.

Table 4 describes the distinction between the need for existing knowledge versus new knowledge.

Table 4. Distinction between needs of existing knowledge and new knowledge

Element	*Knowledge management (KM)*	*Knowledge creation (KC)*
Knowledge	There are two elements that are critical while converting information into knowledge. The first element is related to retrieving information, which corresponds to the circumstantial variables present. Information must be analyzed before it can become knowledge. The second element is to pose questions to the stored proven experiences. The answers to these questions may result in usable knowledge.	While talking about KM, our viewpoint is mostly deterministic. That is, we examine information in light of well-known principles of physical and social sciences. However, when we talk about KC, our viewpoint is mostly probabilistic. The probabilistic approach is designed to enhance the existing level of deterministic knowledge. The KM approach would assume that once upon a time we resolved a similar problem. Therefore, we should be able to synthesize past information to solve the current problem. The KC approach, on the other hand, is more interested in building knowledge, and therefore, it would seek a response to more diagnostic questions. These questions would be based on probabilistic principles. The results of diagnostic questions will not directly create knowledge but will reduce the field of investigation for developing new knowledge.
	Integration	
	There are some instances when past information is directly useful in offering solutions for a given set of circumstances. Whenever there is a mismatch between a current scenario and the past, we need to derive new knowledge. Thus, integration of KM and KC perspectives will permit us to ask probabilistic questions as well as deterministic questions to develop the necessary knowledge.	

WISDOM—KM PERSPECTIVE

We want to act based upon knowledge. However, actions taken in the past may not be possible under current circumstances. Actions may be considered expensive, lacking empowerment, or risky. Two examples will illustrate this point.

Example 1: The problem of electric window not coming down was resolved with a new electric motor design considerably more expensive than the past design. This was a solution applied in desperation without understanding root causes. The knowledge base contains this information. However, this knowledge cannot be applied to the current circumstance because the cost of using a new motor design violates the economics of selling a product.

Example 2: A frontline airline employee is confronted with 180 passengers from a cancelled flight. The next flight, on which some of the passengers can be accommodated, is 3 hours from now. According to airline policy, the passengers should get a dinner coupon when the delay exceeds two hours. The employee waits until the crowd thins out ultimately delivering only about 8 coupons. Did the employee save money for the airline? Did the employee act wisely?

WISDOM—KC PERSPECTIVE

Here we are talking about new knowledge, unlike knowledge management, where we talked about existing knowledge. To implement new knowledge requires creativity rather than repeated actions from the past. We are most concerned with permanency and economics of actions. We do want to achieve highest permanency at the affordable price. Table 5 makes the distinction between KM-based actions versus KC-based actions.

Table 5. KM-based versus KC-based Actions.

Element	***Knowledge management (KM)***	***Knowledge creation (KC)***
Wisdom	We want to act based upon knowledge. However, actions taken in the past may not be possible under current circumstances. Actions may be considered expensive, one may not be empowered to act, or the action may be risky.	Here we are talking about new knowledge, unlike knowledge management, where we talked about existing knowledge. To implement new knowledge requires creativity rather than repeated actions from the past. We are most concerned with permanency and economics of actions. We do want to achieve highest permanency at the affordable price.
	Integration	
	From the KM perspective, applicability of past successful actions must be examined against current constraints. From the KC perspective, new actions must be examined from the viewpoint of maximum affordable permanency.	

Table 6. Distinction between KM and KC needs.

	Knowledge management	***Knowledge creation***
Data	Collecting raw data with the intent . to recall	Collecting raw data with the intent to recall summaries
Information	Instantaneously retrieving data related to current interest.	Instantaneously retrieving summaries of data.
Knowledge	Examining previously successful solutions to fit a newer set of circumstances.	Investigating new solutions based on probabilistic queries.
Wisdom	Examining validity of past actions against present economics.	Installing permanency of newly discovered actions.

CONCLUSION

Possession of knowledge is always an indication of power. However, there is no guarantee that knowledge will be used in solving chronic problems or creating new products and services. Use of knowledge has been informal in many companies. Rapidly changing circumstances such as, increasing computer power, changing technology, and migrant knowledge workers force us to think about treating knowledge more formally.

The knowledge must surround products and services and be stored accessibly rather than travel with individuals. Knowledge must be continually created, stored in an instantaneously retrievable form, made available in a suitable format upon demand, and interpreted to create a business advantage.

There are two facets of knowledge: 1) knowledge management, and 2) knowledge creation. Knowledge management emphasizes efficiency in using what we know. Knowledge creation, on the other hand, focuses on generating a new knowledge. Table 6 summarizes the distinction between KM and KC needs. We need to integrate KM and KC to create a strategic business advantage. Without integration, we get a fancy computer program with a very large storage of information that cannot be put to use in solving future problems.

REFERENCE

English, Larry P. 1999. "Information Quality in the Knowledge Age." *DM Review* (October): 36.