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Mathematical Model of Knowledge Management System in an Organization

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In many situations the quality of decisions made is very important; overcoming the deficiencies of human judgment is an important issue in the scientific community.

In this study, we have proposed a mathematical model for knowledge transfer in order to make knowledge management mechanism or system take root in an organization and to obtain guidelines to make it work.

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Mathematical Model of Knowledge Management System in an Organization

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In many situations the quality of decisions made is very important; overcoming the deficiencies of human judgment is an important issue in the scientific community.

In this study, we have proposed a mathematical model for knowledge transfer in order to make knowledge management mechanism or system take root in an organization and to obtain guidelines to make it work. It was realized that as the felicitous difference becomes bigger, it becomes less likely for an institution to make use of the knowledge realized. Based on this model which consists of the earning and the expenditure, if the earnings are bigger than the expenditure, knowledge transfer will actively take place whiles there is likelihood of little knowledge been transferred if the earning is smaller than the expenditure from the provider and the recipient.

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I. Introduction

Organizations are the pillars of human societies [2]. They can be seen as living entities composed of individuals who execute a set of activities. These activities are the result of the collective work of the members of the organization in order to achieve an organizational objective. To perform each individual activity it is essential to own appropriate domain knowledge. Nowadays most companies work in complex application contexts which create huge amounts of information. The whole knowledge used by an organization for its functions, forms the so-called organizational knowledge. Moreover, the markets and their competitive pressure are continuously growing, the organizations must react quickly to changes in their domain; information loss may lead to a missed opportunity.

In each organization, the application of analytical systems for decision-making has gained increased attention in enterprises since they can provide insights to find solutions that help businesses to remain competitive in the current environment of globalization of markets.

For this reason, organizations are constantly searching for new solutions to adapt to new conditions in order to survive in these increasingly competitive environments. This is why KMS have been introduced in many enterprises. However, we can find only a few successful cases. We have also experiences of failures. For example, a system could not accumulate enough volume of knowledge because of low sense of participation of users. And another system could not utilize accumulated knowledge because the users didn't understand the knowledge well enough to use it.

In order to fully understand what actually the Knowledge Management System is, it is essential to comprehend the concept of knowledge and its features. Knowledge is defined by Davenport and Prusak [4] as a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information. It originates and is applied in the mind of knowers'. In organizations, it often becomes embedded not only in documents or repositories but also in organizational routines, processes, practices, and norms.

A common mistake is to identify with the term knowledge, that is, only information or merely data. This usually leads us to consider the KMS as a simple data manager or information system. In order to avoid confusion it is necessary to understand the evolution process that leads data to become knowledge as shown in Figure 1.1 below

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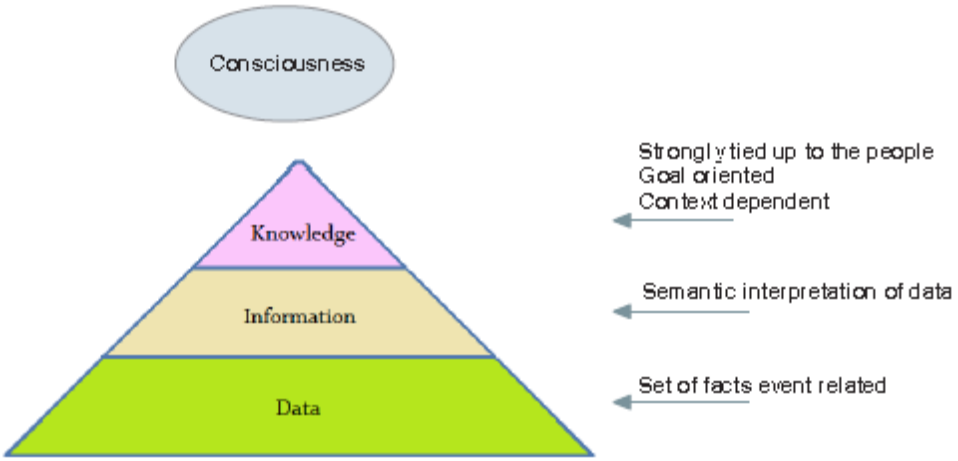

Figure 1.1 : Knowledge Pyramid [4]

The data are symbolic representations of facts, events related without meaning, so they do not constitute a basis for any kind of action. When a data is linked to a context, the context enriches the data of the meaning. The data thus is turned into information. Knowledge comes from the information and evolves by means of individuals. It is the result of experience and it is strongly related to expert skills. The shift from information to knowledge involves two processes: the selection of information and integration with the domain of knowledge already gained. The selection process of the information is handled by the objectives of the knowledge. So the information are reviewed and retained in proportion to help us to achieve the goal of knowledge. The selection process is followed by the integration process, through which the information is integrated into the knowledge domain of the individual. Unlike the information, knowledge has implications for decision-making, in other words who knows is able to act in certain circumstances within a given context.

There is no generally effective formal Knowledge Management analysis technique, which can be used to judge whether the Knowledge Management mechanism and system will work well before introducing them into the organization as such we have repeated similar failures. Jun Ma, et al, studied influences of organizational structure on knowledge transfer in organization and showed that knowledge transfer happens more in organization with a flat structure than in organization with a hierarchical structure. However, their work only treats the organizational structure so it is not enough to use it to analyze a KMS mechanism in an organization.

[8], established a model to show how knowledge transfer takes place in spirited relationship based on game theory and made some suggestions about its management.

But the model explains a specific situation where the relationship is competitive, and the model doesn't cover the many practical enterprise situations.

In order to solve the above problems we have proposed a mathematical model for knowledge transfer. The model is based on our experiences applying KMS to enterprise environment, and one of the purposes is to obtain guidelines to make a KMS take root in the organization and to make it work well. The model shows how a knowledge transfer takes place depending on the balance between earning and expenditure on the provider and the recipient.

II. Related Works

According to [3], the term of KM was first introduced in 1986 in the European management conference (American Productivity and Quality Center, 1996). The concept of KM then expanded rapidly and attracted the attention of many parties, and also reaped a lot of criticism. Nilmini Wickramasinghe & Dag Von Lubitz explained that the activity of knowledge centered on individual psychology processes such as experience, perception and emotion. In organizations there are four main activities of knowledge, which are (1) knowledge acquisition, which refers to the internalization of information, (2) knowledge creation, which are related to the creation of new knowledge (3) knowledge distribution, which is the phase distribution of knowledge within the organization, and (4) knowledge application, which refers to the use of knowledge in the practical work, [6].

The same thing was suggested by [1], which stated that within the knowledge life cycle, there are several processes undertaken by the organization. Phases of the KM life cycle process can be divided into creation, capturing, organizing, refining, and transfers. The phase of creating is a new phase of knowledge creation from both a research as well as the phenomenon of certain events. The phase of capturing is the phase of collecting and comprehending knowledge which is documented or not. The next phase is the phase of organizing, which is the phase of organizing knowledge so that it can be searched easily

and reused by individuals within the organization. Method of organizing knowledge can be done with indexing, clustering, cataloging, filtering, codifying, ontology, etc. The phase of refining is an activity in which the organized knowledge is refined for example data mining. The final phase is the phase of transferring / disseminating, which is a phase that exchanges the knowledge which either can be procedure, tutorial or guide.

Knowledge Based System: The Knowledge Base represents the knowledge container, whose relations and concepts are described using an ontological structure of instances suitable for application purposes of a specific domain. A Knowledge-Based System is able to represent specific domain knowledge and to apply it to solve problems through inference processes. The main components of Knowledge - Based System [2] are the following (Fig. 2.1):

- The Knowledge Base is the passive component of a Knowledge-Based System. It plays a role similar to a database in a traditional informative system.

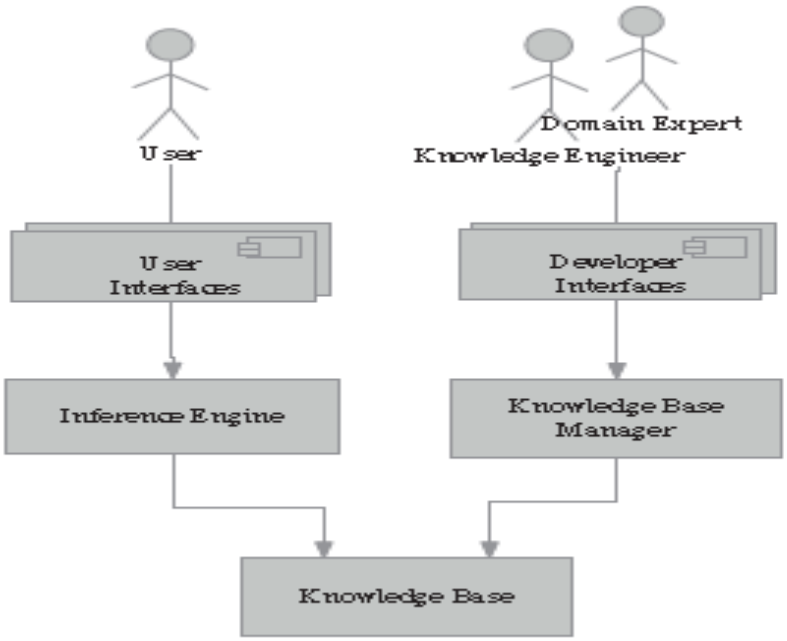

Figure 2.1 : Knowledge Based System Architecture [2]

- The Inference Engine is the core of the system. It uses the Knowledge Base content to derive new knowledge using reasoning techniques.
- The Knowledge Base Manager manages coherence and consistency of the information stored in the Knowledge Base.

a) The SECI Model

According to Nonaka et.al [7][8][9][10], the evolution and creation process of organizational knowledge is a spiral that crosses two levels: individual and collective level. In each level, the knowledge takes two dimensions: tacit and explicit dimension.

The tacit dimension of knowledge, seen in figure 2.2, is characterized by the fact that it is strictly linked to the people and therefore hard to formalize and communicate. The tacit knowledge is constituted by experiences, personal skills and know-how and it comprises both cognitive and technical elements. The cognitive element refers to an individual mental models consisting of mental maps, beliefs, paradigms and viewpoints. The technical component consists of concrete know-how and skills that apply to a specific context. The explicit dimension of knowledge, on the other hand, is the knowledge that is simply transferable, as previously seen. While in the individual level the knowledge is created by an individual, the collective knowledge is created by the collective actions of a group. Human beings acquire knowledge by actively creating and organizing their own experiences. So, the Knowledge Management requires continuous knowledge conversion processes that permit to capitalize information, experiences and expertise.

Nonaka and Takeuchi [6] defined a dynamic model, the SECI Model, based on the principle that organizations create knowledge through the interactions between explicit knowledge and tacit knowledge. The interaction between these types of knowledge is achieved through four modes namely socialization (from tacit knowledge to tacit knowledge); externalization (from tacit knowledge to explicit knowledge); combination (from explicit knowledge to explicit knowledge) and internalization (from explicit knowledge to tacit knowledge), as shown in Fig. 2.2 below.

Figure 2.2 : The SECI Model. [6]

[5], proposed a model named Relational Model Theory (RMT) and suggested that there are four fundamental relation models to which people refer to generate social action, understand and evaluate other's social behavior as well as coordinate, plan, encode and remember social behavior. Based on Fiske's perspective, Boer [11] proposed the relation models of knowledge sharing and asserted there are four fundamental models, which are Communal Sharing (CS), Authority Ranking (AR), Equality Matching (EM) and Market Pricing (MP), coexisting within the relationship structure of individuals while they share knowledge with each other. Further they claimed that with the combination of these four relation models, it could provide comprehensive and overall interpretation for the dynamics of knowledge sharing.

III. Mathematical Model of Knowledge Management System

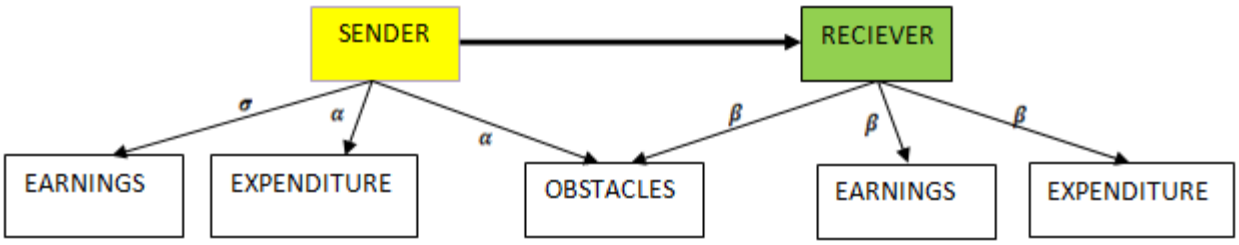

Figure 3.1 : The Compartmental diagram of Knowledge Management System

According to [12], the *sender* is anyone who wishes to convey an idea or concept to others, seek information, or express a thought or emotion. The *receiver* is the person to whom the message is sent. The sender encodes the idea by selecting symbols with which to compose a message. The message is the tangible formulation of the idea that is sent to the receiver. The message is sent through a channel, which is the communication carrier. The channel can be a formal report, a telephone call, an e-mail message, or a face-to-face meeting. The receiver decodes the symbols to interpret the meaning of the message."

a) Earnings

From figure 3.1, the Sender's Earnings $(\boldsymbol{\sigma E})$ include Approval, Incentives, Intelligence of input, Achievement and Fulfillment. The direct gain of the sender is the improvement of his own skills, etc. whereas the Receiver's Earnings $(\boldsymbol{\beta E})$ includes improvement and progress in work efficiency as a result of receiving the knowledge, etc.

b) Expenditure

The Sender's Expenditure $(\boldsymbol{\alpha S})$ required for providing and receiving knowledge includes time required for creating documents and explaining the documents to his customers whereas the Receiver's Expenditure $(\boldsymbol{\beta S})$ includes the work to interpret or convert the received knowledge into useful information.

Felicitous difference $(\boldsymbol{d})$ is considered as the major factor that influences the expenditure. Felicitous here means the background of the knowledge that is whether the transferred knowledge can fully demonstrate power at its destination, such factors

includes implicit knowledge, organizational culture and environment.

[5], proposed the term *Partially Correct Construct* (PaCC), as a general term for constructs that only partially match the corresponding mathematical knowledge elements that underline the learning context. Obviously one cannot expect that a sender will construct every aspect and meaning of a knowledge element. In this sense, knowledge is always partial. Thus, discussion of PaCC's requires clarifying with respect to which whole entity a construct is partially correct.

Therefore the expenditure can be regarded as an increasing function of the felicitous difference between the sender and the receiver. This means the greater the felicitous difference is, the more work it takes. For example, chances are, your customers have less technical knowledge than you do therefore one needs to be extra careful when explaining things to them. If you use acronyms, be sure you identify what the acronym means. The same acronym can mean different things. For example within an IT context (ASP can refer to "Application Service Provider" or "Active Server Page"). Be careful that you don't make two opposite mistakes: either talking over their head or talking down to them. Keep your eyes on customers when you talk to them and be alert to clues indicating that they don't understand. Ask them whether they understand what you're saying, if necessary.

For instance, according to [12], if you compare the case where one tries to convey the knowledge about a sales activities in one industry sector to a member belonging to the same team with the case where one tries to convey it to a team engaged in sales activities to a different customer in a different industry sector, the latter clearly requires more explanation for knowledge transfer compared with the former. On the other hand, when the felicitous difference between a sender and a receiver is large, the earning obtained from the knowledge tends to fall in general.

As the felicitous difference becomes bigger, it becomes less likely for an institution to make use of the knowledge realized. Based on this model which consists of the earnings and the expenditure, if the earnings are bigger than the expenditure, knowledge transfer will actively take place while there is likely to be little knowledge transfer if the earning is smaller than the expenditure. However, generally, the condition alone does not seem sufficient to promote knowledge transfer. For example, simply giving incentives to increase earnings does not drive people to actively provide knowledge to others. It is suspected that a factor other than the earning and the expenditure is involved. In this paper, we assume the factor as the obstacle and define it as follows:

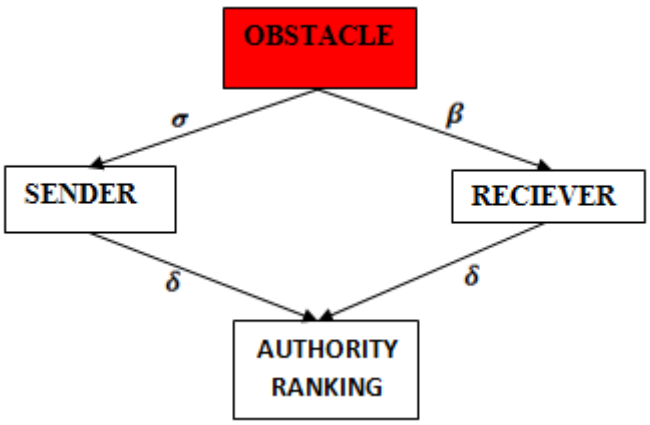

Figure 3.2

c) Obstacle

Obstacle is defined as an action or situation that causes an obstruction; there are different types of obstacles, physical, economic, biopsychosocial, cultural, political, technological or even military, but from figure 3.2 our definition of obstacle here is something that influences knowledge transfer in an organization. Its effect is either positive or negative influence on the motivation to provide or receive the knowledge.

The obstacles on the sender side ($\boldsymbol{\sigma B}$) includes the level of trust in the knowledge sender, competitive relationship, sense of discomfort, success or failure experiences, human relationship with the sender, etc.

The obstacles on the receiver side ($\boldsymbol{\beta B}$) includes factors that affect the motivation to acquire knowledge, such as the level of trust competitive relationship, sense of discomfort success or failure experiences, human relationship with the receiver about the knowledge, extravagant behavior etc.

Authority Ranking (AR) ($\boldsymbol{\delta}$) relationship is based on a model of the asymmetry among human, therefore people in such relationship have distinctive hierarchical

ranks based on formal power, expertise or age [5]. Knowledge is perceived as a means to display rank difference and knowledge sharing is motivated by power differences. People in higher rank would like to share knowledge with their inferiors to show their nobility and largesse and in that way they could also get authority, respect and status in return. People in lower rank would like to share their knowledge to please and have better relationship with their superiors. Also in reality, superiors have power over their subordinates and can demand their subordinates to share knowledge with them. To sum up, the major elements of AR include: authority, power, demand and control and obey. [2], found the power centralization and formalization of an organization will elevate the intention of free riding behavior (i.e. not share or withheld effort or knowledge). The empirical study of [5] also confirmed that we introduced into our model the parameter δ as the Authority ranking parameter

IV. Model Derivation

We let $\boldsymbol{\alpha E}$ = Sender's Earning
$\boldsymbol{\beta E}$ = Receiver's Earning
$\boldsymbol{\alpha S}$ =Sender's Expenditure
$\boldsymbol{\beta S}$ = Receiver's Expenditure
$\boldsymbol{\sigma B}$ = Sender's obstacle
$\boldsymbol{\beta B}$ =Receiver's obstacle
$\boldsymbol{\delta}$ = Authority Ranking parameter
$\boldsymbol{d}$ = Felicitous difference
Phase I: Case where knowledge is accessible

$$[\boldsymbol{\alpha E} - (\boldsymbol{\alpha S} \times \boldsymbol{d})] > (\boldsymbol{\alpha B} + \boldsymbol{\delta})$$

Where $[\boldsymbol{\alpha E} - (\boldsymbol{\alpha S} \times \boldsymbol{d})]$ is the sender's earning and expenditure, we represent it as Accessible Value $(\boldsymbol{AV})$ and represent $(\boldsymbol{\alpha B} + \boldsymbol{\delta})$ as Obstacle Value $(\boldsymbol{OV})$.
Phase II: Case where knowledge is received

$$(\boldsymbol{d\beta E} - \boldsymbol{d\beta S}) > (\boldsymbol{\beta B} + \boldsymbol{\delta})$$

Where $(\boldsymbol{d\beta E} - \boldsymbol{d\beta S})$ is the receiver's earning and expenditure, we represent it as Earned Value $(\boldsymbol{EV})$ and represent $(\boldsymbol{\beta B} + \boldsymbol{\delta})$ as Obstacle Value $(\boldsymbol{OV})$.

The above expressions mean that, if more earnings than barriers remain after the cost are deducted from the earnings, knowledge transfer will occur.

a) Data Collection

Assessment and evaluation are essential components of teaching and learning in Mathematics. Without an effective evaluation program it is impossible to know whether students have learned, whether teaching has been effective, or how best to address student learning needs. The quality of the assessment and evaluation in the educational process has a profound and well-established link to student performance. Research consistently shows that regular monitoring and feedback are essential to improving student learning. What is assessed and evaluated, how it is assessed and evaluated, and how results are communicated send clear messages to students and others about what is really valued, what is worth learning, how it should be learned, what elements of quality are most important, and how well students are expected to perform.

The study was based on collection of primary data; an interview schedule was designed for the study. The draft questionnaire was tested with 50 teachers in the study area for three months (1st August 2015 to October 22, 2015). The questionnaire was modified and rearranged according to the experience gathered in pre -testing of questionnaire. A combination of questionnaire interview and Participatory Rural Appraisal (PRA) tools such as Focus Group Discussion (FGD) and crosscheck interviews were conducted. All the collected information were accumulated and analyzed by Microsoft - Excel.

b) Model Analysis

In the analysis, 70 cases of information and ideas were accumulated. The provision of knowledge was done on the trial basis without any incentives except for a request for entries only twice in a week and done as an activity separate from the participants' main business. Still, within 24 hours of registration of each knowledge, approximately 85% of them received feedback of 4 or more comments as a result of reviewing.

The reviewed process was carried out in three phases;

In phase one 10 people received the knowledge daily, and then in phase two another 10 review the received knowledge then in the final phase the knowledge is then processed into a useful information.

However, in this trial, we only evaluated our model under the experimental environment. This is because there were no opportunities to utilize the design model in other sectors with the trial period being 3 months.

c) *Graphs*

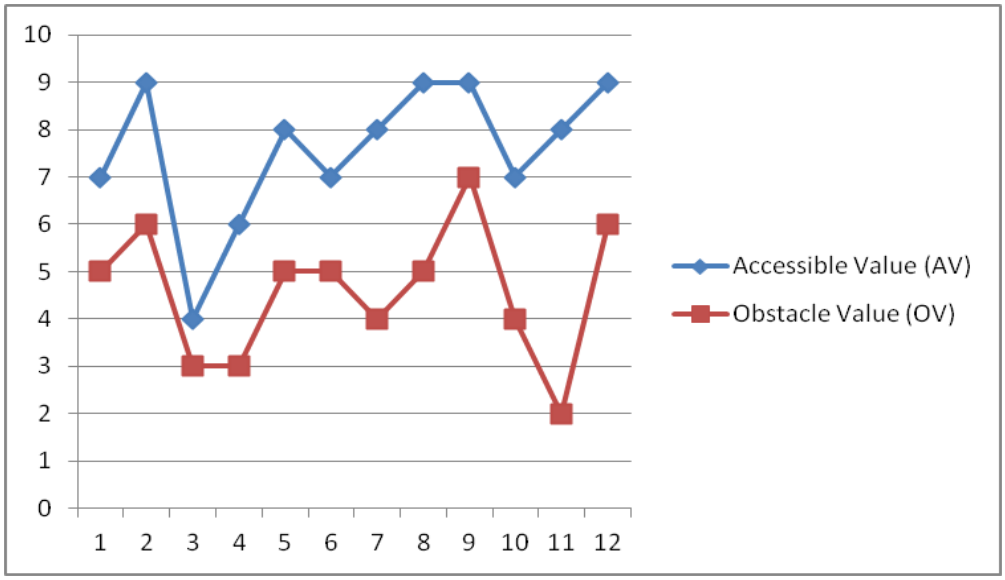

Figure 3.3 : Trend of Available Knowledge

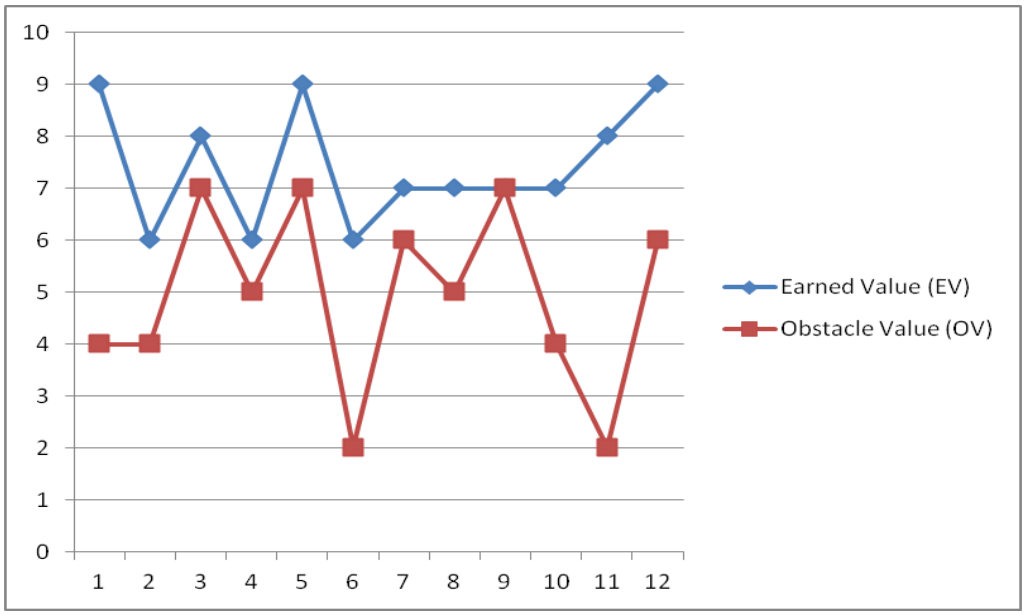

Figure 3.4 : Trend of received knowledge

(Note: Microsoft Excel Solver was used to calculate the parameters).

As a result, from figure 3.3 and figure 3.4 above it was observed that the design guidelines derived from the mathematical model were functioning successfully for knowledge provision. This has allowed us to demonstrate that the mathematical model could be used as guidelines to make the KM system function successfully.

V. Conclussion

In this study, we described the outline of the mathematical model of Knowledge Management System in an organization.

We have successfully demonstrated that it is possible to derive the design guidelines using the model and that the guidelines are valid.

In our model, knowledge transfer is defined using three factors (earnings, expenditure and obstacle). Knowledge transfer actively takes place when the remainder after subtracting the cost from the earning is greater than the obstacle. Furthermore, the felicitous difference between the provider and the recipient of the knowledge affects the expenditure and the earning on the recipient side and serves as a parameter of the knowledge transfer.

Based on the analysis with the model, we derived two operation guidelines:

- Mutual reviewing to increase the sense of participation;
- Establishment of the criteria to evaluate the background information about the knowledge to be shared.

As a result, it is shown that the mathematical model derived makes the KM system function successfully.

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