

## Mental Models in the Formation of Scientific and Engineering Maps

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### Abstract

The mental models are formed according to the belief and they are applied for describing the situations and predicting them. The mental models are formed according to two principles: first, the mental models are as the belief structure which forms them in inside and indicates them in a reality form in outside. Second, the mental models are formed and made for doing many activities correctly. Behind each map or design, there is a group of mental models which form the decisions unconsciously and can be about doing a project. For example, what persons will be applied or what problems will be proposed and what works can be done? What is called "mapping" by many organizations can be a prediction for the future situation of their existing mental model. The mental models and their explanation and interpretation, according to the nature of semantic space embracing them, are the interpretive concept and the capacity and power of individual deduction. In the engineering works, having a correct mental understanding of the problem physic is very important. Therefore, in this article, we study the roots of the manner of forming the physical and engineering mental models in making the efficient models in the scientific and laboratory fields.

**Keywords:** Individual deduction, mental models, engineering models

### Introduction

The interaction of human is with a seemingly simple but complex system, a demonstration from that system is formed inside the mind. Such demonstrations are so-called the mental models. A mental model is a combination of internal feeling of the person, policy, imagination and understanding about the situation of a system. Among interactions which are formed between human and complex engineering systems, usually the mental models simplify the reality of a system by partitioning them in the form of degrees of their importance amount and they will simplify the problem degree of a theorem or argument by classification of them (Hertzum & Pejtersen, 2000; Moray, 1990). The studies indicate that most of the mental models are as the foundation of forming many relations and maps. Inference and comparison of such models clarify the key variables and infrastructures of a map. Discussion about the mental models for the first time was proposed by Craik (1943). In 1983, the phrase of mental model was repeated in two books with this same title. In each one of these books, the phrase of mental model was used for expressing different concepts (Craik, 1943). Laird Johnson (1999) expressed that mental models are as the manner of explaining a process that human applies for solving the problems through inductive logic. In another book, Michael and Dioden defined the conceptual model as a systemic work model that persons make it in their mind for facilitating the interactions. The psychology accomplished on the studies of people's mental models indicates this issue that people need to know that what factors are worthy to be considered in the complex conditions, in what form they should be trained in the real process and also they need to know some general principles for judgement about this issue that how some factors interact with other factors. Rouse et al (1992) have proposed and discussed about the shortage of mental models in the normal extent in gregarious work as the main reason of failure of a system.

Since the mental models can not be observed directly, the indirect methods were developed for extraction of them. Langan- Fax et al (2000) expressed eight normal techniques of this extraction in the form of following list :

- Cognitive interviewing technique
- Verbal protocol analysis
- Content analysis
- Visual card sorting technique
- Repertory grid technique
- Casual mapping
- Pair wise rating
- Ordered tree

In comparison between the models purposes systems, the mental models are in relation with a set of hypotheses and estimates of the probability of total influences of an occurrence (Tversky and Kahenman, 1974). The researchers concluded that the mental models of each person can be different. This difference may be ramified in the degrees of the skills of each person or difference in the argument method of a similar system. Therefore, some attempts were accomplished for understanding this issue that what methodologies make the mental models (Kaufman and Patel, 1988).

#### **Definition of mental model**

The mental models are as a reflection of beliefs, values and hypotheses which are formed inside a human. And, they are the infrastructures of reasons for doing some affairs which are accomplished (Kaufman & Patel, 1998). The mental models of a person as the engineer are formed according to two principles:

- 1) The mental models form the frame of belief and they may be indicated in the form of a behavior or reality in the environment around.
- 2) The mental models are formed for doing many activities correctly.

The mental models form the mind structure, while they have no intervention for doing the necessary calculations in different fields of engineering. The mental models often do not have stability (they do not have a stable form) and their structure is very sensitive and depends on the amount of their application. They are concluded from the experiences and do not have any specified boundary. Yet, the mental models provide the executive tools in description and explanation of realities in relation with a system and ability to predict the future behavior of system according to its current situation. When the mental models of a system become close to a reality of that system, its executive ability in doing it rises very much (Maani & Cavana, 2007).

#### **The importance and necessity of the mental models**

Undoubtedly, planning on the factors related to the increase of the engineering force productivity is one of the important aspects which should be considered in the education and management of engineers in the organizations specially. Increase of engineering force productivity can be seen from different attitudes. One of the most useful attitudes to this issue refers to the mental models views. For this purpose, necessarily the factors influencing on the mental models of engineering forces should be studied precisely; and by studying these factors, it should be attempted that the mental model about engineering forces to be defined.

Mental model mapping is accounted as a technique for analysis of the problems and it is according to the degree of learning and cognition. This technique also can demonstrate the experiences, understanding, hypotheses, knowledge, etc. The mental models often influence on the

behavior consciously. Solving the complex problems in the special maps in which considering the political and management factors is necessary, seeks a learning method. These problems can cause to create non-applicable knowledge, long disputes, delay or failure of project and reduction of trust in decision of an engineer. This gap between knowledge and decision is arisen from occupation of information and dispersion of relation which is between them. Therefore, the existence of correct understanding and open view to the details and execution of problem is needed to reach to a balanced and tolerable decision.

According to this, mental model mapping can be a hopeful tool for supporting the decisions and overcoming on this gap about management of a project. Generally, mental models are as an abstract of presentation of a situation or system in the mind of each person (Kraiger & Wenzel, 1997).

### **The environmental factors influencing on the mental models**

Human is a social creature that has been influenced from the society and influences on it mutually. The domains of influencing on person are also very various. But, what is related to the discussion includes the influence on the special part of the society and in the special frame of interactions. This special part of the society includes the persons of engineering force who have significant role in achieving the social, economic, political and cultural progress in the society. The factors influencing on the mental model of current persons can be classified in the following form:

- Scientific and theoretical ability
- Practical experience
- Ability to use of theoretical instructions in the practical problems (physical understanding of theories)
- Environmental influences and especially engineering group influences

According to this classification, the factors for the formation of mental model of an engineer can be almost classified well. These factors influence on each other and they have different internal interactions with each other. These factors are in general form and they only create the necessary conditions for impressionability on the mental model of a person as engineer. But the necessary and sufficient condition for the mental model of an engineer can not be only the environmental factors. This refers to the understanding and ability of a person and this issue that how he can explain the problem for himself. Training the imagination and hypotheses beside the casual relations make the belief and view of an engineer. These internal factors complete the structure of a person's bases for creating the mental models. Scientific and theoretical ability refers to an explicit knowledge that the person acquires during his academic education. Acquisition of scientific knowledge is accomplished since the outset of a person's learning and it is expanded in each stage of education and learning. But, most of the scientific knowledge of engineers is acquired in the university environment. Therefore, the universities have a main role in training the mental model of a person as engineer. Yet, the educational bases of each person before entering to the university have significant influence on rising the skill and effectiveness of education presented in the university. Therefore, the educational route that person has traversed before university such as lessons and educational methods has significant influence on his performance in the university. For pathology of scientific and theoretical abilities of engineer, necessarily the domains influencing on this factor of constituent factors of mental model must be identified well. Perhaps, these effective factors can be classified in the form of the educational foundations before entering to the university, educational strategy and educational methods. This specialized knowledge with regard to the kind of educational course of person, university of education place, educational chapters ... can have different influences on the

persons, mental models. For example, the students of technical-engineering courses have different mental models with students of human sciences and philosophy.

Another factor which will have much influence on the person's mental model is an environment that the person enters to it after exiting from university and entering to the work environment. If this environment is a dynamic and active environment, it will cause to form the person's mental model to the work environment in the positive and active form. While if such a person after graduation works in a lifeless environment, his environmental conditions after a while will cause to reduce his inquisitiveness and creativity morale. The environmental conditions also have very important part in formation of the persons, mental models. The persons, attitudes are different to the various issues and it is related to the environmental conditions and thought power of a person. The environmental conditions and influences that environment creates on the person in the habit form include behavioral and personal features that person indicates from himself in different situations and involuntarily. These features are influenced from familial, society, university and work environments of person to high extent. Incorrect environmental habits cause that person despite of having proper scientific skills and abilities not to have sufficient effectiveness in the work environment. For example, the excessive obsession of a mapper in doing the calculations which are not very precise causes to spend much time vs low value added. This affair is one of the main reasons of increase of cost and time of projects. The engineers, who estimate the security factors or management stores with abundant obsession and without considering the logical scientific principles, cause to impose intolerable costs on the projects. Also, the existence of such habits causes that sufficient proportion not to be established between scientific knowledge of person and also his technical and applicable skills. For example, a person who considers much value and credit for experience and empirical works, often does not consider the mapping calculations and executes the most of maps with change at the time of execution. The main reasons for creation of incorrect habits can be expressed in the following form (Forrester, 1992):

- Lack of creation of space and foundation of correct occupational habits in the university and educational environments
- Valid environmental conditions for training the incorrect behaviors and habits
- Disregarding a proper environment for giving up the incorrect habits and talents in the work environment

Human is a social creature and because of this, he is influenced from his around environment and he will influence on it. Therefore, the cultural environment around a person as the dominant aspect of his around environment will influence on his mental model and consequently his performance. The cultural factors influence on the formation of his personality since the outset of the person's growth period. Traditions, values, beliefs, etc cause to form the person's personality during the years. This influence can be also effective on the mental model and occupational personality of engineer unconsciously. In fact, it can be said that even important issues like the ability to establish relation with other adventure, etc will be also influenced from the cultural personality. Cultural environment can influence on the person's mental model through cultural features, customs, habits, common law, norms and other environmental parameters. The environment around the person in different levels influences on the person. Family is the first and most effective environment around the person and it has a great role in creating and forming the person's mental model. This environment has had abundant positive and negative influences on the person's mental model and forms this model since the outset of childhood. After family, an environment which influences on the person is society. Therefore, necessarily, this factor must be also considered as another factor influencing on the person's mental model and finally his

performance in it must be considered. Considering this factor with regard to the vastness of effectiveness domains isn't in the range of person's personality or special existence and amendment of the effectiveness of this domain needs consultation and alignment between the purposes of different sections of society, family, organization.

### **The place of mental models in creation of engineering maps**

The thought of a specialized person should become a completely formed model before mapping and consequently it should cover many probabilities. A lecturer before designing a dispute should observe the factors such as exaggeration in talking, scientific terms, its strategy for achieving the purpose, in order to execute his lecture. Sass (1991) expressed several forms of methodology related to seize the mental models generally that according to it, we can express that a person as the member of an engineering team for cognition of different mental models existing in the group acts in several forms.

The first form is related to the excessive reliance and trust in the information obtained from the members performance. This issue is not always acceptable, because the persons may do the correct works for the incorrect and reversed reasons. Therefore, it will cause the disturbance of the analysis system order. Reliance on the methods of mental models extraction in the artificial conditions is not also trustable, because probably it is affected by invalidity of ecology. Therefore, it is originated from there which is not considered on the person's interaction with system in the normal state. The third form is in relation with the models which are related to the process of producing thought with high voice. The significant point is this issue that this case can not be also trustable sufficiently, because the persons are informed of their works and activities subtly and due to this, they can not express all processes and routes which are related to execute a duty. Production of question according to a smart model, the speeches formed according to the mental models and comparison between them are in this form that the content of these questions should be placed concentrated on the titles existing in the disputes which are appeared in the mental models. These titles can include the important correct belief and even wrong imagination or views according to the wrong issues in the formalization of these questions (these wrong issues are more in the ages of 13 to 18 years that there is not anything for saying about these mental models disputes). For creation of a complete and precise question in order to produce a design (map), at first the mental model of it should be created and then with regard to the problem structures and covering its all aspects, the question content should be formed in the form of a model in the mind. These models are used for analogical, consequential and chronological deduction and in a time that we can rise the correctness of a decision in any situation (Johnson, Liard, 2001).

The frame of solving a problem is theoretical generally which expresses that which use of technique for mental models mapping can be applied for analysis of the problem as a hopeful technique. This frame is related to the mapping cycle with considering the management and political factors, modeling cycle or production of knowledge and a model as the connector between these cycles.

### **The place of the mental models in the decisions of an engineering team**

About gregarious works, it can be said that a team partakes in the determined form of existing information and sources that according to it, a kind of distribution of responsibility is established. Moreover, what is important in a team includes sufficient stability and relation of the members with each other which will cause more correct coordination. Due to this, the existence of a normal mental model among all members of team is important specially. Cannon-Bowers (1993) and Kraiger et al (1997) and many other researchers deducted in this manner that existence of more

similarity between the mental models of group members will cause very better performance of that group.

Modeling or mapping a design in the mind before its outset helps a lot. Division of this procedure into different stages and in each stage by asking questions and finding their responses in the mind, it can be completed more. These questions and responses are accomplished according to the mental models. In the gregarious works, this issue that we should reach to a tolerable result is wrong. Because all of these casual relations in each stage give correct response to complete the work. The reason of this issue that some weaknesses are seen in the gregarious works is often arisen from this issue that the person has a general view about the map form, and trains it ideally, while he doesn't have special regard to its stages and a mental model to all stages of doing the map. When a person as engineer in a gregarious work has complete mental model, with regard to the views of other persons can have management on doing it. The key factors in describing the control mechanism of a process are the used sources, casual relation and probable changes of each stage in a process. So, according to the difference among the mental models quantities of persons in a unique action, and/or the management performance during a process, necessarily a common method must be used in description of mental models.

### **Conclusion**

The mental models are a reflection of beliefs, values and hypotheses which are formed inside a human, and they are the infrastructures of reasons for doing some affairs which are accomplished (Maani and Cavana, 2007). The methods presented in some engineering fields like industries engineering, etc which are applied in the processes and systems that have been structured well, are very successful. Yet, when we chase the analysis and mapping of a controller system which includes unstructured processes, this issue can be seen that the managers and engineers are facing with a very different problem. This is correct especially in the systems in which the groups and persons have key role in the daily operations, monitoring and decisions. In these cases, the processes may be done by different persons in terms of the power of their understanding, belief, thoughts, views and the situation of their mental appeal which are specified in the form of the mental models of the system operator. In these conditions, understanding the system can indicate the key variables of the problem. The mental models describe and explain the problem and provide the prediction of future behavior of the system by presenting a set of hypotheses and estimates according to the base of primary understanding of problem. The correctness of decision can be deduced by this mental model accomplished. Analysis of deciding process expresses this issue that the selections are created in each stage of a process cycle of solving the intended problem which is according to the frame of the understanding and thought of the decision-maker. These structures which are formed according to the person's mental model have different frames and they are also change. A sample of unstructured process is the research and development phase (R &D). In such a state, engineer has an almost general freedom for selecting the conduction route of a determined process and the space for creativity exists significantly. Because the standard amounts for assessment in the unstructured processes are not clear completely or they have not been defined well. No optimum and impartial model can be developed for these processes. The questions are always proposed that their responses refer to the belief, understanding and in other words mental models. This issue that what factors cause the difference between two engineers in creating the map and model or between two scientists with equal scientific field in the amount of understanding or explaining a problem. Correct understanding of mental models and the manner of developing them give a powerful tool in the scientific and engineering field for better explanation and production of scientific maps.

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