ASSESSMENT OF LEARNING IN COMPLEX DOMAINS[1]

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ABSTRACT: There is no tool directly measuring how the process of learning at complex domains however this research study proposes that the use of concept mapping and casual influence diagram methods have impacts in assessment of learning in complex domains. Subjects in this study use a web-based casual influence diagram and concept mapping tool to explain what they understand from a problem scenario and how they solve the problem. Even though the cognitive scientists propose that internal conceptual systems are not easily observable, the assessment tools of the study can help to interpret individuals' communications and representations of own knowledge about their internal conceptual systems.

KEYWORDS: Assessment of learning, problem solving strategies, mental models, learning in complex domains, problem based learning.

INTRODUCTION

Psychology provides viewpoints about how people present knowledge; philosophy does the same about how knowledge is presented. There are innumerable ways to present what people know and their mental structures. Mental models reveal the individual's ability at transferring their mental processing and knowledge to novel and familiar situations. How the brain works productively, how concepts are organized in the human mind, how people use these concepts in problem solving, are all explained by cognitive strategies. The answers to these questions studied by cognitive psychologists are important for

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development of “meaningful learning” techniques. The individual develops cognitive strategies such as concept grouping, mental picturing and symbolization when constructing knowledge (Erdoğan, 2000). These cognitive strategies are used during mental modeling efforts. Out of the two existing forms of memory, short-term memory tends to record the events occur at consciousness level; whereas long-term memory tends to store knowledge. Concept mapping and causal interaction diagram methods help to the storage of knowledge in long-term memory (Anderson, 1982; Öztürk & Karayağız, 2006). This method accelerates the individual’s processes of structuring and organizing of knowledge (Anderson, 1982). When knowledge is regularly stored in long-term memory, “meaningful learning” takes place. Therefore the study of evaluation of mental models intends to develop a methodology which investigates how the individual structures and organizes knowledge in long-term memory, and to utilize this methodology in assessment and evaluation of learning in complex domains.

“Meaningful learning” occurs when knowledge is regularly stored in long-term memory. Thus this methodology can be used in planning and assessment of learning-teaching activities while supporting “meaningful learning”. “Meaningful learning” should possess the following qualities:

- Newly acquired concepts and premises should be similar to those that exist in the cognitive structure.
- Knowledge should be formed hierarchically in the cognitive structure.
- The method of contemplation, discussion and interpretation should be adopted instead of memorization (All, Huycke, Fisher, 2003).

There are a number of methods that demonstrate how people perceive and express knowledge and present what people know and their mental structures, such as concept mapping, causal integration diagram, conceptual frames and knowledge model. These models are based on Ausubel’s Assimilation Theory (Ausubel, 1968). Mental Model researchers (Seel, Al-Diban, Blumschein, 2000) have used concept mapping and causal interaction diagram as tools to obtain experts’ comments on various scenarios. Even though these methods provide the outline for transforming internal knowledge into a visual form, they cannot solve

the compensation and adaptation difficulties created by novel problems. A number of institutions and researchers have developed software tools to extend especially the use of concept mapping. For example, NASA uses concept maps to textually describe the information on spatial events and to present a richer content in space projects. Studies in Turkey, which philosophically analyze computerized modeling in cognitive science (Urgen, 2007), emphasize four basic elements in understanding models' place in science: installation of models, operation of models, representation of models and forms of learning from models. The model discussed in these studies is the Q-Soar model, which is created with Soar architecture and represents a particular group of model. These studies discuss that generalizations can be made for computerized cognitive models (Urgen, 2007).

The present study uses a Web-based program. Students' knowledge about the content of a problem and how they present this knowledge are investigated by this method, and evaluated by comparing to the expert's presentation of knowledge. The elements required to improve students' ability to solve complex problems and increase their domain knowledge, can be investigated as a result of this evaluation.

PURPOSE

Problems in complex domains have ambiguous sources and many different factors have to be simultaneously contemplated in order to solve the problems (Spector & Koszalka, 2004). Solution of this type of problems necessitates thorough comprehension of the subject and consideration of all of the factors of the problem from all possible viewpoints (Spector & Koszalka, 2004; Suzuki & Harnisch, 1995). Diagnosis and treatment of a medical problem can be given as an example to this. In these kinds of problems more than one solution can be proposed. Problems we encounter in school are well-defined, but problems in reality are not so. The goal is to raise individuals who have the ability to solve the problems encountered in real life, which are not as well-defined as those in school. This study aims to investigate the mental models of individuals at the time

of expression of what they think of the given problem scenarios and thus to assess learning in complex domains.

This project considers the process of learning as gaining expertise in problem solving. Therefore, experts' mental models are compared with the mental models of individuals getting education on the path to becoming an expert. This method was used in the National Science Foundation (NSF)-supported NSF 02-34 DEEP project entitled *"Enhanced Evaluation of Learning in Complex Domains"* and termed as Dynamic Evaluation of Enhanced Problem Solving – DEEP methodology. It was demonstrated that the DEEP methodology is a reliable and valid method in the studied areas but the fact that the ideas of this methodology are still new and need to be developed was emphasized (Gogus, Koszalka, Spector, 2009). Moreover, the DEEP methodology has not been tested in the area of mathematics yet. Therefore, mathematics is determined as a study domain in this research.

It has been observed that in mathematics, students have difficulty in solving problems that require making connections between concepts and equations even though they can mechanically learn the definitions (Şahin, Macaroğlu, Gürdal, 1994). On the other hand, individuals with enhanced mathematical thinking have a solid viewpoint and an objective approach towards problem solving (Umay, 1996). It has to be emphasized that mathematical thinking is the problem solving method, the efficacy of which is recognized in almost all areas of the culture (Yıldırım, 1998). Problem solving is one of the most important indicators that a certain level has been reached in mathematics education (Erdoğan, 2000). The common aspects of the known problem solving processes are the identification and symbolization of data. The following steps are the perception of the formula and the solving of the problem. This is what deems problem solving difficult (Umay, 1996). This study also aims to investigate how individuals anticipate the formulae. Therefore, in this study it is believed that it will be helpful to use open-ended problems instead of practical problems. How the problem is comprehended, what kind of a model is constructed, how this model is critiqued, the processes of reversion, the formulae utilized and how the solution is explained are all examined. The web-based

program planned to be used in this study is user-friendly, and enables the student to easily express what he/she comprehends from the whole and the substructures of the problem.

In order to develop a reliable and valid methodology for evaluation of mental models and promote the use of this methodology in the present and following research studies, this study compared four previously developed four basic methodologies. These four methodologies developed for the evaluation of the mental models by using concept map and causal interaction diagram are *Analysis Constructed Shared Mental Model – ACSMM*, *Surface, Matching, and Deep Structure - SMD*, *Model Inspection Trace of Concepts and Relations - MITOCAR*, and *Dynamic Evaluation of Enhanced Problem Solving – DEEP* (Johnson, O'Connor, Pirnay-Dummer, Ifenthaler, Spector, and Seel; 2006).

METHOD

The method that will be used for evaluation of mental models requires the analysis of the schemas that show individuals' cognitive frames and the investigation of the existence of common or different cognitive models by comparing these schemas. This project considers the process of learning as gaining expertise in problem solving (Ericson & Smith, 1991) and therefore aims to compare the mental models of experts and non-experts. This comparison has three dimensions:

1) Analysis of the schemas that show the cognitive frames of individuals within a group and the investigation of the existence of common or different cognitive models by comparing these schemas;
2) Comparison of the models of the two groups, evaluating the reasons underlying the differences and examining them within the context of performance outputs;
3) Examination of the changes within the individuals' and groups' models over time, and evaluating the reasons underlying the differences within the context of learning outcomes.

The causal interaction diagrams, concept maps and qualitative data collection methods that will be used in this study to elicit individuals' mental models will enable the individuals reveal what they know and what they conceive about the solution of a problem.

This study has three main research questions:

1) Can a significantly common mental model be elicited for the expert sample?
2) Can a significantly common mental model be elicited for the non-expert sample?
3) Do samples with different levels of expertise have different mental models? If so, how different are they? Why?

The main hypothesis of the study is that the developed methodology can be used as a tool in evaluation of mental models and assessment of learning in complex domains. The study has three sub-hypotheses:

1) Significantly common mental models can be elicited for samples.
2) Level of expertise in a domain, that is, rate of learning in a complex domain can be assessed by comparing mental models.
3) Mental models develop in time through learning in parallel to gaining expertise in a subject domain.

Data will be collected from expert and non-expert samples and compared to each other in order to test these hypotheses.

Data will be collected from faculty members whose expertise lie in the area of mathematics and from their students. The sample will be the students of Mathematics classes at Sabancı University and faculty members teaching mathematics.

DISCUSSIONS

This study of assessment of learning in complex domains requires analyzing and comparing individuals' mental models and problem solving strategies and capturing shared models of groups. Subjects use a web-based casual influence diagram and concept mapping tool to explain what they understand

from a problem scenario and how they solve the problem. The research study is at the stage of validation of the methodology.

This research is significant in terms of presenting how problem based learning approach and causal interaction diagram methods could be applied to an educational research. In this research, learning is considered as becoming an expert on a subject therefore the differences and similarities between experts and non-experts are compared according to their knowledge, experience, and problem solving skills.

One of the problems frequently experienced in education field is that the learning theories are well taught theoretically but the practice of learning theory is constrained. The gap between the practice, and the theoretical information in the literature of the methodology which is planned to be developed and implemented and mental models' evaluation, is intended to be reduced. Producing a methodology that can have international and national acceptance has vital value in terms of its usability by various sciences in practice. Therefore the methodology of mental models evaluation, an internationally popular study subject, may considerably contribute to the science and education researches conducted in both Turkey and around the globe.

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