Alternative conceptions, memory, & mental models in physics education

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Abstract. There are two somewhat independent research traditions, which converge to suggest a form of students' knowledge: alternative conceptions and mental models. However we have little literature that explains what they are different from each other and from memory. This study tried to describe these issues with some thoughts about how cognitive psychology and science education approaches can be best synthesized in order to approach these questions.

INTRODUCTION

Research in cognitive psychology, science education, and developmental psychology during the last decade has shown that students construct intuitive understandings of the world, which are based on their everyday experience. Although different terms have been used to refer to this type of knowledge-such as alternative conception, preconception, misconception, folk theory, naïve theory, intuitive theory, mental model- there is general agreement that this intuitive knowledge provides explanations of natural phenomena which are frequently different from the currently accepted scientific explanations and which tend to be resistant to change. Especially, the term 'alternative conception' has been preferred by many researchers as students' intuitive understandings in science education [1].

In physics education, alternative conceptions (or misconceptions) and mental models are familiar terms for researchers and educators with other terms (e.g., p-prims, facets, coordination class, etc.). However, as a result, different terms are employed, sometimes leading to confusion. As Redish [2] mentioned, it is important to develop a theoretical frame, which is a shared language and shared assumptions and through which different theoretical models of student thinking can be compared so we can accumulate, evaluate, and refine what we learn.

This study is the first step for developing a theoretical frame. Thus, the purpose of this study was to compare three major terms (alternative conceptions, mental models, and memory), which are used for representing students' ideas in physics and to find the relationship among them. For this, we reviewed related literature and tried to synthesize the reviewing results from both cognitive psychology and science education approaches.

ALTERNATIVE CONCEPTION, MEMORY, AND MENTAL MODELS: IN THE PROCESS OF LEARNING

There are two somewhat independent research traditions, which converge to suggest a form of students' knowledge: alternative conceptions and mental models. In the 1970s, in the area of science education a number of researchers published papers describing 'alternative conceptions' in students' understanding of a variety of natural phenomena [1]. There are significant knowledge claims emerging from the research on students' alternative conceptions. Some of these knowledge claims are: "Students come to formal science instruction with a diverse set of alternative conceptions concerning natural objects and events. The alternative conceptions that students bring

to formal science instruction cut across age, ability, gender, and cultural boundaries. Alternative conceptions are tenacious and resistant to extinction by conventional teaching strategies" [1].

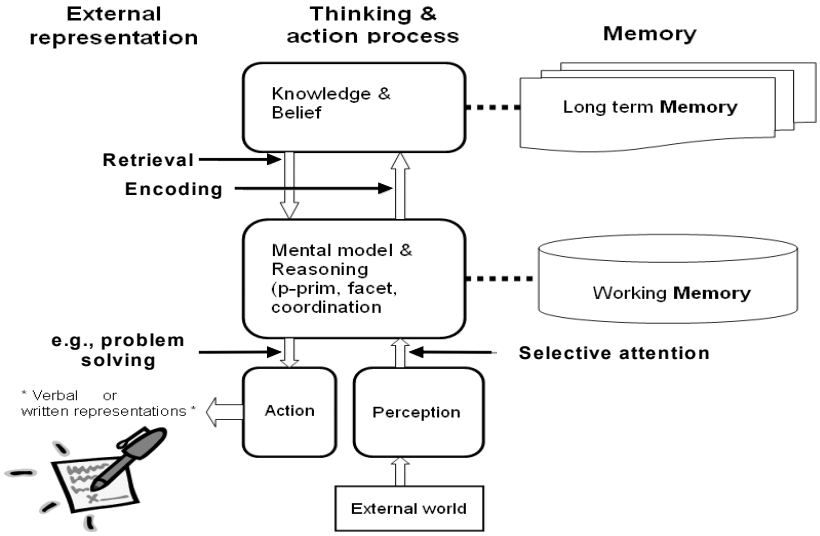
In cognitive psychology, Johnson-Laird (1983) introduced the term 'mental model' to refer to a form of mental representation [3]. The notion of mental model has been used in research in different areas with different meanings [4]. For some researchers a mental model is just a representation of some aspects of the world, whereas for others it is an analogue of objects in the world. Mental models serve as means with which to explain the relation between one's cognitive activity and the world. In this view, mental models are unstable, naturally evolving and incomplete. The views adopted by most researchers may be seen as delimited by these two extreme positions [4].

Recently, one of the main features of science education research is the increasing importance of the concept of 'mental model'. It appears that, with the concept of mental model, science educators are attempting to overcome some limitations of the Alternative Conceptions Movement (ACM), such as: "the frequently context specific character of alternative conceptions; the difficulty of the ACM in developing overall interpretations for domain-specific alternative conceptions; the difficulty in offering theoretically dense approaches to an understanding of such educational phenomena" [5].

Where do mental models (and alternative conceptions) come from? In order to answer this question, at first, we should know what memory is because memory is the place where our knowledge is stored and is activated. Memory can be divided into two primary components: working memory and long-term memory. Working memory is the temporary storage and processing of information that can be used to solve problems, respond to environmental demands, or achieve goals. Working memory is rapidly accessed and severely limited in capacity. Many theorists portray working memory as playing a central executive role, in essence controlling and monitoring an individual's overall memory processes. In a nutshell, working memory is the component in which "thinking" occurs: therefore, we might think of it as the "awareness" or "consciousness" of the memory system [6].

Long-term memory (LTM) is the part of the memory system that retains information for a relatively long period of. It includes both memory for specific events and knowledge that has been gleaned from those events over the years time [6]. Types of memory (in LTM) can be distinguished by the kind of knowledge stored and the way this knowledge is retrieved and expressed [7]. There are two kinds of knowledge, declarative and procedural.

Since conceptions are the principal units of knowledge organization, we can say that students' alternative conceptions are one of the principal units of knowledge as a part of their LTM. There is little literature that explains how alternative conceptions are constructed even though some researchers suggested several sources [8]. Some examples are sensual impression, everyday language, innate structures of the brain, learning in students' social environments, and instructions.



* Researchers usually call external representations as **alternative conception**, misconception, **mental model**, etc.

FIGURE 1. The relationships among alternative conceptions, memory, and mental models in the process of learning

On the other hand, mental model theory has tried to explain students' intuitive understandings of the world from integrated perspectives. For example, Vosniadou [9] explained the construction of mental models using conceptual structure. According to her, mental models are constructed in conceptual structure, which has presuppositions (epistemological, ontological) and beliefs from observations in cultural context. Mental models are constrained by a set of presuppositions which are derived from everyday experiences and which are consistent with their beliefs about physical objects.

Mental models are dynamic representations through integrating external information recognized and individual knowledge. In terms of memory, mental models are constructed in working memory, which involve mental representations of words or images themselves reflect interactions between current sensory data and stored knowledge from LTM. Based on these ideas, we developed a theoretical framework for synthesizing our understandings about mental models (See Fig. 1).

Figure 1 shows the relationships among alternative conception, memory, and mental model in the structure and process of learning. Mental model construct is related to perception processes and to knowledge structures. In fact, perception and knowledge are generally recognized as the principal sources of mental models [10]. The perception of visual, auditive, tactile, or haptic information marks one side of higher cognitive processes that is sometimes called 'bottom up' or 'data driven'. Mental models are contingent on external information insofar as the incoming data as a cue to particular analytical or synthetical subprocesses [11]. Knowledge, on the other hand, marks the other side of higher cognitive processes; the one that is sometimes called 'top down' or 'schema driven'. Mental models depend on individual knowledge insofar as the incoming data are interpreted with respect to context and experience, that is, to results of earlier processing.

Beliefs are also the components of LTM. They serve to constrain the types of knowledge and inferences a person may hold in their mental models. For example, Vosniadou and Brewer [9] stressed the role that epistemological and ontological beliefs play in the formation of mental models. For example, epistemological beliefs include the criteria individuals use to judge what constitutes a phenomenon, the assumptions that phenomena require an explanation, and that causal explanations can be used to explain physical phenomena. Ontological beliefs include the basic beliefs about the nature of objects such as physical objects are solid, stable, and if not supported, will fall down. In this, epistemological and ontological beliefs constrain conceptual knowledge that individuals may acquire from their observations and experience in the cultural context by limiting the inferences individuals make about their observations.

Pintrich [12] extend the logic of Vosniadou and Brewer's theory with suggesting that motivational beliefs about self and learning can play the same role in terms of being a resource to support or constrain the formation of mental model. He argued that "motivational beliefs, as presuppositions or theories about the self and learning, they may influence the types of inferences and belief formation that take place as students acquire knowledge and build their mental models". As Pintrich [12] have noted:

> *For example, certain types of motivational beliefs may inhibit certain types of cognitive processes from occurring, whereas other motivational beliefs may facilitate cognitive engagement. These motivation beliefs and various cognitive and metacognitive strategies are assumed to be "resources" that students can bring to bear on the task at hand to help them to learn (p.34).*

Thus, we believe that mental models depend on individual knowledge insofar as the incoming data are interpreted with respect to various beliefs.

Classroom context can be other factors that affect the formation of mental model since knowledge and beliefs are embedded in various classroom contexts. For example, the task, as a context, that students are confronted with can activate motivational beliefs and related knowledge in problem solving situation. According to the pattern of the activation of knowledge and/or beliefs, there might be different inferences and linked knowledge in the process of mental model formation.

Mental models guide action through reasoning and decision making process. For example, when students read, talk, write, something or take exams, mental models are always involved in that situation preserving information about and interpretations of objects and events in the world.

In summary, we can think about an example of how we form a mental model with figure 1. If we were confronted with an event (like a test), our knowledge and beliefs would be activated. After that, through problem solving, as thinking process, we will form mental model(s) in working memory. Finally, by action (like talking, writing, etc.) we present mental

model(s). They become the external representation. In an interview or test situation, we can only see (or listen) the external representation, which students represent. Using the external representation, we can speculate what the students' conceptions, or mental model(s) are in their minds.

We should recognize the differentiations between the external representation, internal/mental representation (that is, mental models), and conceptual knowledge (that is, students' conceptions, alternative conceptions, misconceptions, etc). The places where each term locates are as follows (see Fig. 1, too),

- External representations: in words or graphs on papers, talking, gestures, etc

  (We can see or listen to them. However they are not exactly what students have in their minds)

- Mental models: in working memory

  (We cannot see or listen to them. We can only speculate them from external representation)

- Students' conceptions (alternative conceptions, misconceptions, etc): in long-term memory

  (We cannot see listen to them. We can only speculate them from external representation)

CONCLUSION

"The concept of mental representation is as fundamental to cognitive psychology as force is to physics" [13]. Mental models are dynamic mental representations through integrating external information recognized and individual knowledge. Within physics education, the mental model notion has been invoked in math education, psychology, linguistics, artificial intelligence, etc. Now, mental models have been a crucial term for explaining students' intuitive theory not only because it is located at the intersection of various disciplines but also because it can provide physics education researchers and teachers with valuable information about learners' conceptual framework, that is, their underlying knowledge structures from an integrated perspective.

In this study, we tried to answer the questions, "What mental models are?" and "How mental models are different from other terms, especially, alternative conceptions and memory?" Figure 1 shows our theoretical framework for answering the questions even though this study is the first step to develop the theoretical framework. In the future, we need to further develop our theoretical frame continually by conducting case studies and addressing new theoretical issues.

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