

UNDERSTANDING CONCEPTUAL CHANGE: A COMMENTARY

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Abstract In this essay, I compare and contrast four views of conceptual change--Vosniadou's *synthetic meaning* view, Chi and Roscoe's *misconception repair* view, diSessa's *knowledge-in-pieces* view, and Ivarsson, Schoultz, and Säljö's *sociocultural* view. In particular, I compare these four views in terms of what changes during conceptual change, who changes, how the change occurs, where the change takes place, the role of prior knowledge, and whether there is research evidence. As a conclusion, I offer a proposal for reconciling alternative views of conceptual change.

1. INTRODUCTION

How does a learner come to understand how force and motion work, how the human respiratory system works, or how gravity keeps objects on the earth? In each case, the learner undergoes a process of conceptual change in which he or she builds a coherent mental representation capable of explaining the target phenomenon.

Conceptual change is the mechanism underlying meaningful learning. Conceptual change occurs when a learner moves from not understanding how something works to understanding it. For decades scholars have recognized that conceptual change is at the heart of meaningful learning. Over the years, conceptual change has been represented as a process of achieving structural insight, accommodative learning, understanding of relations, deep learning, or--more recently--mental model building (Mayer, 2000).

Conceptual change has long been recognized as a fundamental aspect of science learning, and as a key process in learning in other domains. If scholars could understand how conceptual change works they would make important contributions both to learning theory and to educational practice. Throughout the first half of the 20th century researchers sought to build general theories of learning that could account for all forms of learning, but by mid-century it became clear that such efforts had failed (Mayer, 2001). Instead, today scholars focus on domain-specific theories of learning, such as trying to understand how people learn how something works or how to carry out a given procedure. Gone are the days when grand theories of learning dominated psychology and education, replaced today with more focused

4. DISESSA'S KNOWLEDGE-IN-PIECES VIEW OF CONCEPTUAL CHANGE: CHANGE AS ORGANIZING

What changes? In diSessa's view--expressed in his chapter and elsewhere (diSessa, 2001)--the learner organizes many fragments of naive knowledge into a structured mental representation of complex system. Learning involves the construction of what diSessa calls a *complex knowledge system* (or *conceptual ecology*) consisting of a large number of different kinds of conceptual elements that are modified and combined in complex ways such as levels and subsystems. What changes, then, is the way that knowledge is organized--from fragmented to structured.

Who changes? Learners are knowledge organizers who strive to build connections among the diverse elements in their knowledge base.

How does change occur? The process of conceptual change relies on mentally reorganizing one's knowledge: "Conceptual change involves a large number of diverse kinds of knowledge organized and re-organized into complex systems." Learners begin with intuitive knowledge called *p-prims* (for *phenomenological primitives*)--small, simple, plentiful, natural-feeling pieces of knowledge used to help understand one's experience. For example, in intuitive physics, a p-prim is the idea that "induced motion just dies away", that is, an object in motion requires a force acting on it to stay in motion. However, in the course of conceptual change, p-prims are integrated into more complex explanatory systems. P-prims no longer function as isolated monolithic explanations but rather become part of a larger system. DiSessa notes that "many p-prims find useful places in the complex system" and might "come to be known as an effective special case of a scientific principle." Thus, the mechanism underlying conceptual change is not a simple process of deletion or replacement of p-prims, as in contrasting views of conceptual change, but rather a complex process of integration and reorganization.

Where does change occur? Conceptual change is a cognitive process that occurs in the learner's mind.

What is the role of prior knowledge in conceptual change? Prior knowledge--such as p-prims--form the basis for conceptual change. Prior knowledge enables conceptual change because conceptual change involves organizing existing pieces of knowledge.

Is there research evidence? The supporting empirical evidence for diSessa's argument comes from selected segments of the protocol of a structured clinical interview about physics problems with one child called J. However, diSessa correctly warns that "I don't intend to prove or demonstrate here."

5. IVARSSON, SCHOULTZ, AND SÄLJÖ'S SOCIOCULTURAL VIEW OF CONCEPTUAL CHANGE: CHANGE AS TOOL APPROPRIATION

What changes? In conceptual change, learners appropriate intellectual tools (i.e., agreed-upon concepts such as the concept of gravity) and physical tools (i.e., agreed-upon representations such as maps and globes). The authors claim that cognition is the use of tools, so conceptual change involves the development of tool-

and modest theories of learning. The search for a research-based theory of conceptual change represents a major component in this focused strategy.

My assignment in this piece is to compare and contrast four views of conceptual change: Vosniadou's (this volume) *synthetic meaning* view, Chi and Roscoe's (this volume) *misconception repair* view, diSessa's (this volume) *knowledge-in-pieces* view, and Ivarsson, Schoultz, and Säljö's (this volume) *sociocultural* view. In each of four respective sections, I analyze the views in terms of what changes during conceptual change, who changes, how the change occurs, where the change takes place, the role of prior knowledge, and whether there is research evidence. Finally, in the last section, I attempt to synthesize a vision of conceptual change based on the ideas in these four views.

2. VOSNIADOU'S SYNTHETIC MEANING VIEW OF CONCEPTUAL CHANGE: CHANGE AS SYNTHESIS

What changes? In Vosniadou's theory, the learner seeks to build a coherent explanatory framework (or mental model) of how some system works. In short, what changes is the learner's mental model.

Who changes? In Vosniadou's theory, learners are synthesizers who attempt to reconcile inconsistent models of how something works. The learner is a model builder who creates conflict by acquiring inconsistent new knowledge but who seeks to build internally consistent models.

How does change occur? Learners build a mental model by integrating new material from science instruction with their existing explanatory frameworks: "Information received through instruction seems to become assimilated to the initial explanatory framework creating synthetic or internally inconsistent models." Conceptual change begins with the learner's existing explanatory framework, that is, a naive theory of how something works based on personal experience: "Children construct a narrow but coherent explanatory framework that guides the process of acquiring knowledge about the physical world from early on." The next step in conceptual change occurs when learners are exposed to science instruction that is inconsistent with their existing mental representations; as they assimilate this new knowledge with existing mental representations they form synthetic meanings that lack coherence and stability. The final step is to resolve the internal inconsistencies, so "conceptual change occurs from the need to solve internal inconsistencies." This process of resolving internal inconsistencies in the learner's knowledge is a gradual one which can result in a progression of mental models. Rather than involving sudden replacement of misconceptions, conceptual change involves assimilating new scientific knowledge to existing explanatory frameworks, thereby creating internal inconsistencies that must be gradually reconciled. Rather than involving the process of organizing isolated knowledge fragments, conceptual change is a process of assimilating knowledge to existing structures, which must then be reorganized.

Where does change occur? Vosniadou presents a cognitive account of conceptual change in which the changes occur within the learner's mind.

What is role of prior knowledge in conceptual change? In Vosniadou's view of conceptual change, prior knowledge is both an obstacle for change--because it must be revised--and a vehicle for change--because new conflicting knowledge is assimilated to it.

Is there research evidence? In an exemplary study, kindergarteners, 4th graders, 6th graders, and 9th graders were asked in an interview to answer a series of questions about force. For example, in one question they were shown a drawing of a stone standing on the ground and asked, "Is there a force exerted on the stone? Why?" For most of the students, it was possible to classify their answers as consistent with one out of a small number of mental models of force. The most common model for kindergarteners was *internal force*, the idea that objects have internal force based on their weight or size. The internal force model is an example of an initial explanatory framework based on personal experience. The most common model for 4th graders was *internal and acquired force*, the idea that objects have internal force based on their weight or size, but there is also an acquired force within moving objects only. There is an internal inconsistency in the synthetic meaning of combining internal force and acquired force. The most common model for 6th graders was *acquired force*, the idea that there is an acquired force within moving objects only. The reliance on acquired force, which is another explanatory framework, can be seen as an attempt to resolve the inconsistency inherent in the internal and acquired force model. The most common model for 9th graders was *gravitational and other forces*, the idea that forces in objects come from gravity, from being pushed or pulled, and from moving. Students appear to be assimilating Newtonian concepts within their existing framework based on acquired force. By adding the force of gravity and the force of push/pull to the force of movement, learners create various synthetic meanings that eventually need to be resolved.

3. CHI AND ROSCOE'S MISCONCEPTION REPAIR VIEW OF CONCEPTUAL CHANGE: CHANGE AS REPLACEMENT

What changes? In Chi and Roscoe's view, the learner seeks to construct an accurate mental model of how something works. When mental models initially are based on incorrect conceptions (as in *naive knowledge*), these conceptions must be replaced: "All naive knowledge needs to be repaired in order to promote deep understanding." Thus, what changes is the learner's mental model and the conceptions from which it is built. In particular, a misconception is defined as a miscategorized concept, so what changes is the placement of a concept from an incorrect category to a correct category. The resulting mental model changes from being flawed to being correct.

Who changes? Learners are fixers who repair erroneous conceptions in their mental models. Learners engage in the repair process by recognizing misconceptions (i.e., miscategorized concepts) and creating or finding new categories into which the miscategorized concepts can be placed.

How does change occur? Conceptual change occurs when a learner identifies a faulty conception in his or her mental model, and repairs it. Learners begin with naive knowledge--or existing conceptions--that are often incorrect. Naive knowledge

can consist of *preconceptions*, which easily can be revised or removed through instruction, and *misconceptions*, which are misunderstandings that persist even when confronted with focused instruction. In short, “cognitive change is the process of removing misconceptions.” The mechanism by which misconceptions are repaired involves recategorizing a concept from an incorrect category to a correct category: “Misconceptions are, in fact, miscategorizations of concepts” so “conceptual change is merely a process of reassigning or shifting a miscategorized concept from one ... category to another.” To accomplish conceptual change, learners must become aware that they have miscategorized a concept and must invent or find an appropriate category to which it can be reassigned. Conceptual change means to change from a flawed (or incomplete) mental model to a correct mental model through assimilation (i.e., adding new pieces of knowledge) and revision (i.e., correcting pieces of knowledge). This is an incremental process--of changing many small pieces of knowledge--rather than a process of sudden accommodation.

Where does change occur? Conceptual change is a cognitive process that occurs within the learner's mind.

What is the role of prior knowledge in conceptual change? Prior knowledge--when it contains misconceptions--is an obstacle to conceptual change: “Naive knowledge ...often (but not always) impedes the learning of formal knowledge with deep understanding.”

Is there research evidence? First, Chi and Roscoe describe previous research on 8th graders' preconceptions about how the human circulatory system works (Chi, 2000). Based on in-depth interviews, a collection of incorrect conceptions was identified (such as “all blood vessels have valves”). Then, students read a text about the human circulatory system and were interviewed again as a post-test. Many of the preconceptions that were addressed in the text were correctly revised on the post-test (such as “veins are the only vessels to have valves”), but those not addressed in the text were not correctly revised on the post-test. This research shows that some incorrect conceptions can be changed easily through instruction--namely, preconceptions.

The authors also describe a more recent study in which students read a text about the human circulatory system and explain to themselves what various sentences mean. Interviews with students show that the self-explanation process fosters incremental revisions of individual propositions about how the human circulatory system works, enabling students to change from a single loop model (in which only the heart is involved in pumping oxygen to the body) to a double-loop model (in which the lungs and heart are involved). This research shows that what appears to be a major conceptual change (from a single-loop to double-loop model) can be created by repairing individual pieces of knowledge about the circulatory system.

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