

# WHY “CONCEPTUAL ECOLOGY” IS A GOOD IDEA

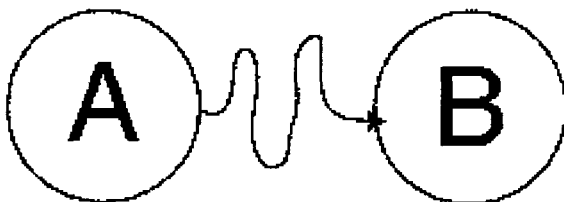
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**Abstract.** This paper motivates the idea of “conceptual ecology” by critiquing the current mainstream of conceptual change research. Most research on conceptual change suffers from too little theoretical accountability concerning the nature of the mental entities involved and too little use of the details of process data to support its theoretical view. Part of the consequences of these limitations is a vast underestimate of the complexity and diversity of conceptual change phenomena. In contrast, a conceptual ecology approach involves hypothesizing that conceptual change involves a large number of diverse kinds of knowledge, organized and re-organized into complex systems. To illustrate a conceptual ecology approach, we explain two very different kinds of mental entities, p-prims and coordination classes. P-prims are small and numerous intuitive elements that are often quite context specific in their activation. Coordination classes, by contrast, are large systems whose very existence entails a high degree of coordination across diverse contexts. We claim that both p-prims and coordination classes are much more explicit and precise in their assumptions than is typically the case, and they both survive substantial empirical test in the form of analysis of process data.

## 1. INTRODUCTION

My aim in this chapter is to provide a critique of the current state of conceptual change research and a brief account of how I believe better progress may be achieved. In particular, much prior research in conceptual change has taken a vastly oversimplified view of the process. Figure 1 provides a graphical backdrop on which to illustrate these oversimplifications. The figure shows a naïve concept, A, and its trajectory of development into expert concept, B. What could be wrong with such a picture?



*Figure 1. A graphic illustrating “conceptual change.”*

To begin, we must ask, what are the entities, A and B? The answer most often given is “concepts,” although other types of mental entities are sometimes given, say, ontologies (Chi, this volume), beliefs (Hofer & Pintrich, in press), models (Vosniadou & Brewer, 1992), or theories (McCloskey, 1983; Gopnik & Meltzoff, 1996). (To simplify exposition, for the most part I will use “concepts” as an exemplar type of mental entity, although my arguments are essentially unchanged if other types are substituted or if a few are added to a list of types.) To say A and B are concepts begs the question, what is a concept (or any of these other mental entities)? How do we know a concept when we see one? Might it not be necessary to distinguish different kinds of concepts? In this chapter I will strongly motivate the need for a significant variety of types of mental entities to replace the few listed in the literature. More significantly, I will argue that prior work has typically lacked theoretical accountability; it has, indeed, failed to tell us what concepts are, and how to distinguish them from other actual or possible types of mental entities.

Figure 1 shows only two examples of concepts, A and B. Might it not be true, however, that many mental entities contribute to the construction of B? Might it not be true that B is, in fact, a complex system consisting of many interacting parts? My belief is that it is essentially certain that scientific concepts are best considered as complex systems, and prior research has not systematically addressed this possibility seriously. For example, current practice in conceptual change research is far from being able to (and rarely attempts to) match system elements and processes against the details of student reasoning and learning data.

The logical extension of Figure 1 has exactly one naïve concept for every expert concept, and it does not make room for the distinct possibility that naïve concepts have rather different properties than expert ones. Empirical data with respect to these possibilities are easy to come by. Beginning students have many ideas that do not come close to matching expert ideas on a one-by-one basis. It well may be that the naïve conceptual ecology has no exemplar whatsoever that approaches the qualities exhibited by expert concepts.

With an impoverished view of the nature of concepts, it is no wonder that the long, winding path from naiveté to expertise has little exposed detail in the literature. Instead, one finds a variety of unhelpful, definition-begging and probably unfalsifiable terms, like “partial construction,” “mixed models,” and “confused ideas.” And yet, in the classroom, teachers easily find rich and complex intermediate states with which they have to deal; clinical interviews of students essentially always reveal a textured mix of naiveté and learned knowledge, which, however, has had few, if any, systematic descriptions to date.

Figure 2 shows a graphic—obviously simplified—that illustrates the view of conceptual change I advocate in this paper. The naïve state consists of a large number of conceptual elements of varying types. Those elements are modified and combined in complex ways, possibly in levels and into subsystems that, together, constitute the “final” configuration of an expert concept. For reference, I call this a “complex knowledge systems” view of conceptual change—informally, “conceptual ecology.”

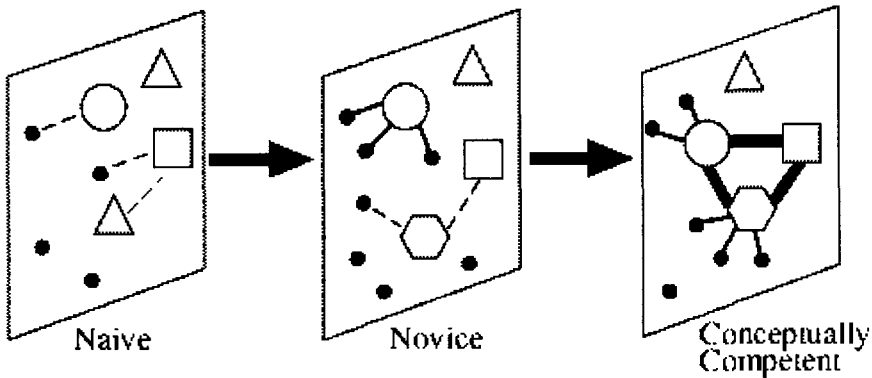


Figure 2. Illustrating a complex systems view, where many exemplars of many different types of knowledge develop and become reorganized in the process of "conceptual change."

An "expert concept" draws on many different elements of naïve knowledge (some not belonging to "the naïve concept") that get gradually changed, augmented with new elements, and organized into a new configuration.

The term conceptual ecology has been used by others. In particular, in their influential work on conceptual change, Strike and Posner (1992) speak of conceptual ecology in a similar spirit.<sup>1</sup> More generally, there have been other advocates and allies of the complex knowledge systems view, some implicitly in the details of their analysis of learning complexities, and some more explicitly in the richness of their theoretical framing (e.g., Thagard, 1992). Indeed, in a summary chapter for a section of book on reasoning (Vosniadou & Ortony, 1989), Bill Brewer reports his synthetic conclusion that "in the long run, a proper understanding of the human mind will require that we recognize a large number of very different forms of knowledge and associated psychological processes." (p. 537) Despite sporadic recognition of the importance of a complex systems view, the mainstream of conceptual change research has persisted with vague and oversimplified assumptions about the entities and processes involved in conceptual change. In addition, of course, I intend my contribution to point out particular ways of pursuing a complex systems view that I expect will be most fruitful.

The remainder of this paper elaborates and systemizes the difficulties I see in the contemporary landscape of conceptual change research. Following, I illustrate my approach to improving on the present state.

## 2. DIFFICULTIES ELABORATED

Broadly, I divide the difficulties in the core of contemporary conceptual change landscape into theoretical and empirical subsets.

<sup>1</sup> However, Strike and Posner did not seem to intend the level of detail in articulating and modeling knowledge types and architectures implicated here.

### 2.1. *Theoretical Considerations*

A lot could be said about the lack of cogent theoretical framing for the issue of conceptual change. However, in this chapter, I underscore only one issue: the lack of well-developed technical terms.

Dictionary meanings can almost never serve the purposes of science. Instead, whenever science is successful, it refines existing terms or adds supplemental ones that can bear a stronger burden. Everyday words are known to be polysemous, combining multiple senses in useful (if ambiguous) packages. Furthermore, even the various senses of everyday words serve only everyday purposes in everyday ways. “Concept” (or one of its various senses or connotations), in particular, seems clear and useful in common usage. However, in the following section, I argue that it is hopelessly vague, covering multitudes of kinds of mental entities with a common coat.

At this point in cognitive studies, we can hope to apply high analytical (as opposed to purely empirical) standards to our technical terms. We could, for example, attempt process models that explain technical terms. Although I won’t press far in this direction here, it is good to realize that the literature on conceptual change has rarely attempted process models, nor has it entertained substitute methods of making technical terms’ meanings precise.

Besides “concept,” other common candidates for useful technical terms suffer similar difficulties to varying degrees. We all have a vague sense of what a theory is. Yet, even if the term is sufficiently well-defined within the social conduct of professional science, in transporting the term to individual learning, a host of changes are likely necessary.<sup>2</sup> In particular, I believe there is convincing data that many naïve scientific ideas are inarticulate, are not easily expressible in words. This, alone, is a dramatic difference from professional science, where complex, careful and symbolically augmented expression (e.g., using algebra) is almost always evident. It seems indubitable that externalizing ideas is more than for archival purposes in professional science. Externalizing allows extraordinary reflective scrutiny and careful reformulation. In contrast, “naïve theories” are never seen directly in the words of subjects, or we might simply be able to ask students for their theories, the way we do with scientists.

“Ontology” has longstanding philosophical roots. To my knowledge, however, no researcher of conceptual change has attempted a process model of ontologies. I don’t need to criticize empirical work that implicates shifting ontologies to point out that such work is weakened unless we know what an ontology is, unless we understand how such mental entities may come to exist in some detail and how they function in reasoning and learning. For ontology, as well as for concept, we want to know how we can surpass images like Figure 1 in detail and cogency.

Unless we develop theoretically well-elaborated technical terms, major empirical problems follow. Unless we know what a theory is, how do we distinguish it from a small collection of concepts, or even from a sentence one may utter and toward which one might express some commitment? Tellingly, researchers preferring one

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<sup>2</sup> With regard to social vs. individual perspectives on theory development, see Harris (1989).

term of another (concept, theory, belief, ontology) essentially never use data to show students' reasoning and learning are inconsistent with other theoretical assumptions. diSessa & Sherin (1998) examine the literature of conceptual change. They argue that even the best and most widely-recognized researchers use inexplicit definitions that implicate ill-defined meanings, and they show what difficulties follow in attempting to interpret data in such vague terms.

The deep problems of conceptual change remain unscathed when we cling to vague, unelaborated terms. What aspects of "theory" are really critical in theory change, and why, after all, is conceptual change difficult when some kinds of learning proceed effortlessly?

In this chapter, I won't propose general criteria for cogency of technical terms in cognitive studies. However, I will illustrate steps toward more adequate terms with two categories among several I have developed in my own studies of conceptual change.

## 2.2. *Empirical and Quasi-Empirical Considerations*

This section views the current state of conceptual change research through an empirical lens. I will argue that researchers have used very weak empirical strategies that avoid the real complexity of conceptual change. In particular, I make the case that, without much effort, we can strongly motivate, if not prove, that the appropriate default approach to studying conceptual change recognizes diversity in mental entities.

Several trends that I take to be paths of improving our study of conceptual change will become evident in this section. The first, already mentioned, concerns *types*. In particular, I advocate a trend toward *multiplicity*, a greater number of (more accountable) types of mental entities. A second trend concerns *grain size*. Here, the trend should be toward *a greater number of smaller scale elements*. Concomitantly with the second trend, in investigating large-scale accomplishments like "conceptual change" we are necessarily studying *systems of interacting elements*. A final trend concerns increased care in dealing with *invariance*, that is, the issue of when two situations evoke the same conceptual elements. With a rich selection of knowledge elements, we are forced into much more specific consideration of context. If a conceptual ecology contains thousands of elements, certainly the issue of when which are activated is highlighted. In fact, we should expect a greater degree of *context dependency*. Combining trends toward increased contextual dependency, toward multiplicity and toward smaller grain size suggests that an application of a concept is likely to be better viewed as the selected activation of particular concept subcomponents, depending on context. This particular observation will become a core concern when we turn to one of my sample knowledge types, "coordination class."

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