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On Conceptual Metaphor and the Flora and Fauna of Mind: Commentary on Brookes and Etkina; and Jeppsson, Haglund, and Amin

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I have been asked to comment on two papers appearing in this special issue. The first paper is *The Importance of Language in Students' Reasoning About Heat in Thermodynamic Processes*, by David T. Brookes and Eugenia Etkina. The second is *Varying Use of Conceptual Metaphors Across Levels of Expertise in Thermodynamics*, by Fredrik Jeppsson, Jesper Haglund, and Tamer G. Amin.

I will begin with my top-level comment: I found both of these papers to be very congenial, in the sense that their overall thrust is in line with my own core beliefs about how science is learned, and how it should be taught. These core beliefs that I share with the authors are—to use my own vocabulary—that (1) science learning must build on everyday resources that students possess prior to formal science instruction and that (2) successful science learning requires the coordination of these everyday resources and new resources acquired during formal instruction. The authors of both papers are very clear that they share these core beliefs with a range of prior work that includes, in particular, the work of diSessa (1993), as well as my own work on symbolic forms, which they graciously cite (Sherin, 2001).

If these papers are in such good alignment with work that is over 20 years old, then that raises the obvious question: What's new here? Are there ways in which this newer work adds to, or even departs from, for example, the program laid out in diSessa (1993). The short answer is that there are certainly substantial novel contributions in these papers. I cannot fully summarize these contributions, given the small space allotted to me, so I will simply highlight what is most exciting to me.

Over the past 20–30 years, our field has seen substantial research that documents how less expert students understand (and misunderstand) science. However, there

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has been much less work that examines advanced populations, particularly as they wrestle with truly difficult subject matter. The work described in diSessa (1993), for example, was based on interviews with novice physics students, working only on relatively elementary subject matter, though diSessa speculates about the trajectories from novice to expertise.

In contrast, the work in these papers begins to flesh out the longer term trajectory of science learning. They look at more expert participants, working on notoriously difficult subject matter—the thermodynamic notions of heat and entropy. The authors of these papers make a compelling case that the development of expertise in physics subject matter requires the weaving together—coordination—of old and new knowledge resources. With relatively few exceptions, there has been little research that makes this case in such a compelling way (for one of these exceptions, see Clement, 1994). It is worth pointing out that there are still scholars in our field who argue that there are scientific conceptions, such as heat and entropy, that depart so much from our everyday conceptual apparatus, that their understanding cannot be built on existing conceptual resources (Chi, 2005).

To this point, I have been painting a picture in which the work described in this program can be seen as a logical continuation of work begun decades ago. However, the authors of these papers do not see themselves as merely fleshing out a research program that was begun 20 years ago by diSessa and others. Instead, they see themselves as advancing a new perspective, one that aligns with the themes of this special issue, conceptual metaphor and embodied cognition. Furthermore, I believe that there are some respects in which this new perspective is not compatible with the older program—or, at least with my own take on that older program. In the rest of this paper, I will lay out these incompatibilities, and let readers make of them what they will. To lay my cards on the table, the reader will see that I harbor some skepticism regarding the newer perspective of which embodiment and conceptual metaphor are a part.

Locating These Papers

I want to start with how the authors position their work in relation to longer term trends in the field. Brookes and Etkina, I believe, see their particular focus on language as something that sets them apart from older work. I agree. It is not that researchers such as myself ignored language; we certainly listened to what participants said. But to a great extent we looked *through* language rather than *at* language. We used the speech of our participants as a window into their thinking, but we did not focus as closely on the window itself.

I take more issue with how Jeppsson et al. position their work with respect to longer term trends in the field. I will start by quoting some text from their introduction:

> Early work on expertise focused on the differences between novices and experts, identifying the important role of abstract principles in the latter, absent in the former (Chi,

> 2006a, 2006b; Chi, Feltovich, & Glaser, 1981; Chi, Glaser, & Rees, 1982). Another line of work has focused on continuity between novices and experts by focusing on non-propositional knowledge structures such as imagery, image-schemas (abstractions from sensorimotor schemas) and mental models (Clement, 2009; diSessa, 1993; Hammer, 2000; Smith, diSessa, & Roschelle, 1993). This latter approach can be seen as reflecting a kind of "embodiment turn" in research on scientific expertise and science learning. (Jeppsson, Haglund, & Amin, 2015)

Throughout their paper, Jeppsson et al. describe researchers such as Chi as identifying 'propositional' knowledge, and they see this propositional knowledge as aligning with the formal knowledge taught in textbooks. In contrast, they describe work in the diSessa line as non-propositional and embodied.

I want to take issue with some core aspects of these characterizations. First, I do not believe that that we can so straightforwardly say that researchers such as Chi and diSessa are identifying knowledge that differs in *kind*. For example, Chi's problem categories can, I believe, be rightly thought of as problem *schemas*, with all of the potential fuzziness of schemas, such as those associated with p-prims. Second, I do not believe that diSessa and his colleagues (among whom I include myself) would be entirely comfortable with being part of the 'embodiment turn'. (I will say more about this below.) Thus, in sum, aligning non-propositional knowledge with the embodied perspective, and propositional with formal physics knowledge, is just too crude a gloss.

There is a larger issue here, and it is a problem that I think characterizes much of the literature on embodied cognition. Namely, there is a tendency to want to subsume too much into the embodied cognition perspective, and to grant too little to the alternatives. I will quote one other passage from Jeppsson et al. that allows me to make this point dramatically:

> Cognitive science has traditionally relied on the analogy of the mind to a computer, and that our cognition can be modelled fruitfully in terms of propositional representations made up of arbitrary symbols and processing that involves the manipulation of those symbols modelled as formal logic (e.g. Larkin, McDermott, Simon, & Simon, 1980). Embodied cognition has evolved as a diverse movement, which nonetheless unites around the critique of this traditional approach to cognitive science. (Jeppsson et al., 2015)

Even where it relies very heavily on the mind–computer analogy, cognitive science has never been only about propositional representations, or formal logic. One of the earliest and most fundamental discoveries of cognitive science was the heuristic nature of thought (Glaser & Chi, 1988; Newell, 1976); another was the fuzzy nature of such mental constructs as categories (Medin, 1989). So I do not see how these can be features that are critiqued in cognitive science, let alone insights that can be claimed for embodied cognition.

Conceptual Metaphors

A core feature of both papers is their focus on identifying conceptual metaphors. Indeed, when I read work from the embodied cognition perspective, the identification of

conceptual metaphors is where I learn the most. Uncovering tacit knowledge is never easy, but both of these papers—like much other work from the embodied cognition perspectives—display a genius at seeing the tacit structure in the speech of their participants.

A core question, from my point of view, is how conceptual metaphors relate to the sort of theoretical constructs identified in earlier work—constructs such as p-prims or my symbolic forms. Both sets of authors suggest that what they are describing is a new kind of resource, which supplements, rather than supplants, the list of resources identified by prior research. The primary conceptual metaphor identified by Brooks and Etkina is the caloric metaphor, which they describe as a 'linguistic resource'. Jeppsson et al. are also clear that what they are identifying is something additional, and is not intended to supplant resources described in earlier research. They say: 'We have suggested that conceptual metaphor may be added to the list of productive intuitive resources that contribute to science learning.'

Still, I come away with the sense that a great deal gets subsumed within the construct of conceptual metaphor, and that it unnecessarily breaks down boundaries that should be left up. Contrast, for example, the view laid out by Dedre Gentner across a wide range of articles. For Gentner, there have always been many types of 'domain comparisons' including 'abstraction' and 'analogy' (Gentner, 1983). In a later work, she opened up this taxonomy even more, describing a broad space of types of similarity relations (Gentner & Markman, 1997). Whether or not we accept Gentner's take on these issues, it is clear to me that not all domain comparisons are created equal. Let us consider one example from Brooks and Etkina. They talk about 'tunneling' as a metaphor that is used to describe how a quantum mechanical object can pass through a boundary. Are we certain that it is appropriate to describe this as a metaphor? There might instead be a common abstract structure (an abstraction) shared by many phenomena, and for which there is no particular source domain.

Perhaps the authors would object that what I am calling 'abstraction' is indeed covered in what they mean by 'conceptual metaphor'. My response is that this is precisely the problem: I am concerned that they are trying to make the notion of conceptual metaphor cover too many disparate reasoning phenomena.

In my own view, there is a diverse flora and fauna of entities of mind, and that we should be cautious about attempting to capture them all with a single theoretical construct that loses some of this diversity. To cite one example from the work of Jeppsson et al., the authors talk about conceptual metaphors associated with the levels of engagement of the speaker with the problem they are solving, for example, 'A Problem Solver Is an Owner/Observer of a System'. But I think we should ask ourselves whether these conceptual metaphors are really the same sort of beast as the other conceptual metaphors identified by the authors, such as 'Change of State Is Forced Movement'.

I have one last note about conceptual metaphors. I must admit that I do not understand how we are supposed to know when we have correctly identified a conceptual metaphor. How do we know that 'Change of State Is Forced Movement' is the right rendering in these instances? Part of the answer seems to be that the authors make specific bets about the level of abstraction and generality at which these conceptual

metaphors live; there are theoretical assumptions that guide them. I also suspect that some sort of triangulation is required, but that it is not described in the papers because of limitations of space.

The Body

At the start of this essay, I stated that I thought too much was being subsumed within the 'embodiment turn'. In particular, it seems that, according to Jeppsson et al., discussions of mental entities such as mental model, p-prims, and perhaps even symbolic forms are all part of the 'embodiment turn'. I want to officially raise my objection to being included as part of the embodiment turn (even though it would put me in very, very good company).

There are foundational questions at issue here, and there are limits to what I can say in this short essay. Researchers such as Lakoff claim that a mechanism such as conceptual metaphor is needed to solve the 'grounding problem' (Lakoff & Johnson, 1999). The idea is that, for us to truly understand something, it must be reducible to some common set of elements. It also helps greatly if these primitive elements are shared among humans. Though this view is not explicitly stated in the two papers, I believe it is at least tacit. At the very minimum, the authors have been strongly influenced by a research tradition built on this assumption.

In short, I do not see any need for, or any particular benefit in, any grounding of this sort. I do not see any problem with the notion that mental entities get their meaning from how they participate in a web of relations among themselves, and how they function in human action. In my view, there is no need for a special class of elements associated with the body. Note that this is in line with my more general view that there are a diverse flora and fauna of mind—a weaving together of diverse entities—with no single class that has a wide special importance.

A Central Role for Language

I conclude with some comments on language. As I noted earlier, I believe that the attention to language is one of the important contributions in these papers, and one that distinguishes this work from much earlier work. Of course, the relationship between language and thought is fraught, and it is a relationship that has been wrestled with at least for decades, if not for centuries or millennia. Here, the authors are appropriately cautious, with particular attention paid by Brookes and Etkina. They say:

> With our data and methodology, it is not possible for us to make causal assertions about the impact of the caloric metaphor on students' reasoning, whether reasoning is being driven by language choices, or if students' underlying conceptions of heat are influencing their choice of language. What we observe from our data is that the caloric metaphor is connected to reasoning about heat that appears as state-function-like reasoning. (Brookes & Etkina, 2015)

The question to ask ourselves is whether Brookes and Etkina have made any progress in teasing apart this fraught relationship. Ultimately they say that the relationship must be 'bi-directional'. They also cite Jay Lemke as saying that 'concepts do not

exist independently from their representations, and it is the representations themselves (graphs, equations, spoken/written language etc.) that constitute the concept itself' (Brookes & Etkina, 2015).

As I conclude this essay, I cannot resist adding my own thoughts on this issue that has consumed so many thinkers. I do not think we need to go as far as Lemke, and give up on a notion of concepts that sees them as located in the mind of individuals. Instead, my view is that we should see our knowledge and representational tools as having co-evolved, both phylogentically and ontogenically. This means that our knowledge is adapted by and for symbol use. Thus, we should expect to find many and multifarious ways in which knowledge and our representational tools will be finely tuned so as to work well with each other. We can expect no less. But, as far as sweeping claims go, we can say no more.

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No potential conflict of interest was reported by the author.

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