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Constructing and Using Conceptual Competence

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There is much agreement between Sophian's and my views of constraints, competence, and performance. Differences are often due to what Sophian and I take to be my position on early conceptual competence. I therefore concentrate on my views about conceptual competence (or incompetence) and the mind's learning tools. To anticipate, I do not, and have not maintained that conceptual competence is frozen at Point A in developmental time, so that "Either children (of given age) have a target competence or they do not (Sophian, p. 286)." My search for conditions under which young children reveal competence has not been motivated by an all-or-none belief in early conceptual competence. Instead, the effort is due to the need to have data in order to compare and contrast what younger and older children can and cannot do. As argued elsewhere (Gelman & Gallistel, 1978, ch. 1; Gelman, 1978), when we only characterize early points in children's cognitive development in terms of what capacities they lack, there are no constraints on the kinds of transition mechanisms we postulate in accounts of how knowledge acquisition proceeds. There is an infinite number of ways to account for shifts from a state of no competence to one of full competence.

Unexpected levels of conceptual competence were revealed in young children as researchers developed tasks that were suitable for them. In those days preschoolers were prelogical, preconceptual, always perception bound, unable to think abstractly under any conditions, and so on (Gelman, 1978). As data of this kind accumulated, I was led to rethink the position I was working within, one that was very much within the empiricist camp. I saw a need to find a way to attribute *some* conceptual competence and develop a systematic account of the variables that differentiated early, as opposed to later levels of performance. It would not do to conclude that initial competencies carried with them an ability to generate perfect solutions to all and any tasks, settings or problems. I eventually hit upon the metaphor of skeletal structures in order to work on a theory that grants some innate

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mental structures. As discussed in Gelman and Williams (in press), the idea is that our young benefit from skeletal structures for a small set of *core*, as opposed to *noncore* domains. I hold that core domains are universal, in the sense that initial skeletal structures are used to actively engage and interact with the domain-relevant learning paths the environments offer them. Of course, different cultures might well offer different examples of relevant learning paths, just as they offer different language inputs for universal linguistic structures. Further discussion of the *core noncore* distinction is presented in Gelman and Williams (in press).

The notion of skeletal domains embodies the assumption that learning is required if a coherent body of knowledge is to develop. Existing skeletal mental structures are but potential knowledge sources. Like all biological structures, the potential cannot be realized without opportunity to interact with, influence, and be influenced by supporting environments. Otherwise, there will be no fleshing in of the structure or instantiation, let alone change, of the principles that serve to outline the structure of the domain.

My evolving account of cognitive development is always driven by my own and others' data on the *performance* of children who differ in their developmental status. The patterns of evidence of how animals, infants, children and adults perform in different number tasks and settings (again, see Gelman & Williams, in press) is what has moved me toward the adoption of a rational-constructivist theory of concept acquisition and theory of learning that is consistent with this approach. The search therefore is for a new learning theory, one that explains knowledge acquisition as a function of experience (Gelman, 1993; Gelman, in press).

A conceptual competence theory of learning is no more or less falsifiable than is any other class of theories, be they S-R associationist or information processing in form. Discussion of ways to approach the problem are presented in Gelman and Greeno (1989) and Gallistel and Gelman (1992). These include the working out of detailed computational models that can be tested either as computer simulations or against fine-grained analyses of the sources of variability. Gelman and Greeno (1989) present an example where the attempt to model observed performance is based on a simulation that does or does not include a given kind of conceptual competence. Gallistel and Gelman focus on the need to obtain variance measures in order to test alternative models of preverbal numerical and arithmetic competence (Gallistel & Gelman, 1992).

The reader might well ask: but how does learning occur within a rational-constructivist account? For me, the key is in the mind's proclivity to apply its existing structures. As Gelman and Williams (in press) point out, rational-constructivists' theories of learning are qualitatively different from ones based on association theory; nevertheless, they are *learning theories*. It simply is not the case that the phrase "learning theory" is uniquely defined within an associationist framework, no matter how strong current theoretical tendencies might be to assimilate the meaning of terms like *learning* and *innate* to this framework

and its related assumptions about the nature of knowledge acquisition and storage.[1] In order to expand on these and other points presented above, I turn to what I mean by the notion of domain.

I define a domain of knowledge in much the same way that formalists do, by appealing to the notion of a set of interrelated principles that constitute a structure. A given set of principles, the principle's rules of application, and the entities to which they apply together constitute a domain. Neither tasks like discrimination learning or general structures like schematas constitute a domain. Both core and non-core domains are learned as a result of the mind's active use of learning tools, the paramount one being structure mapping. However, epigenesis in a *core* domain is privileged. There is a straightforward reason for this: The mind has an ever-present tendency to apply existing structures, no matter how skeletal the initial structures in core domains might be. Since they constitute structures, nascent structures are available to search for, find, attend to, and store examples of data sets from relevant learning paths, that is, ones that map structurally to each other and that of the domain.

Domain-relevant knowledge in a core domain becomes part of the domain's conceptual competence when it maps to the existing structure that outlines the domain (Gelman, 1991, 1993; Gelman, in press; Gelman, Durgin & Kaufman, 1995; Gelman & Williams, in press). In the case of non-core domains, for example, chess, the learner has the double task of assembling the structure and a domain-relevant data base. Learning under these conditions is known to be difficult; that is, it is extremely hard to attend to what counts as the relevant data in the absence of a knowledge structure that outlines the pieces of input that should be assembled together. Put differently, it is not easy to learn about things we know nothing about.

The foregoing covers some of my reasons for insisting that the nature of conceptual competence is not frozen at Point A in developmental time and why the presence of some conceptual competence does not, indeed cannot, imply perfect performance. Other reasons follow from my views on what roles are played by conceptual competence. When conceptual competence is well-developed, it provides a set of enabling conditions, potentiates relevant components for assembly into a plan of action for a goal, and a model for finding relevant data and checking outputs of an executed action sequence. The enabling conditions of conceptual competence serve either to identify actions that are consistent domain-relevant goals or set conditions on the assembly of a plan of action that has the potential to satisfy the conceptual constraints of the task and its setting (Gelman & Greeno, 1989). But these factors do not suffice to guarantee the generation of a plan of action to be competent, or its successful execution. The planner must also take into account the way tasks and their settings interact with conceptual competence.

[1] I intentionally use the term "storage" given the current debates as to whether there are any representations, let alone domain-specific structures, at any point in cognitive development.

Even if conceptual planning and interpretative competence are at their highest levels and lead to the generation of a competent plan of action for its goal, it is still possible that performance will be errorful. Information processing demands could be greater than those available. In addition, as any pianist knows, the best-intentioned plans can go astray because the requisite component acts are fragile, novel or are hard to integrate with the existing representation.

Self-initiated practice trials can function to bring together and expand the conceptual and coordinate action required for successful performance. I take it that these considerations apply as much to infants' performances on object permanence tasks as they do to the young white-crown sparrow learning the variant of the adult song that goes with his skeletal knowledge and to young children learning to use a verbal tagging list to apply counting principles (Gelman, 1993; Gelman & Williams, in press). Indeed, it is hard to resist comparing the young white-crowned sparrow's learning path (Marler, 1991) with examples of children's learning. One case that seems especially pertinent comes from beginning language learners' efforts to master the count list of their language.

The evidence is that children zero in on the relevant list and kinds of words extremely quickly (Gelman, 1990; Shatz & Backscheider, 1991; Wynn, 1990). Yet it will be quite a while before they are able to master even the first ten words in the list and use this verbal knowledge without error (Fuson, 1988; Hartnett, 1991; Miller, Smith, Zhu & Zhang, 1995; Wynn, 1992a, 1992b). Karmiloff-Smith and Inhelder's (1974/5) microgenetic analyses of children's block-balancing show similar developmental patterns, from seeming trial-and-error-like efforts to systematic, rule-governed actions. I am cautious about labeling these early counting and block-balancing efforts as examples of "trial and error," for even this variable performance is domain-relevant and far from random. Siegler and Crowley's (1994) experiments on how 5-year-olds achieve arithmetic solutions by converging on the use of a novel strategy, and how 10-year-olds learn to succeed at tic-tac-toe, are particularly relevant in this regard. Yes, they provide elegant demonstrations of the importance of paying special attention to learners' goals and abilities to attempt non-random solutions en route to a successful solution. But they also highlight the fact that goal sketches for a given setting do not stand alone. Just as a successful plan has to embody constraints that reflect the domain of knowledge, so does the use of goal sketches interact with the problem solver's existing knowledge of the domain and domain-relevant strategies that have or have not worked before.

Conceptual competence develops as it is being used in supporting environments and with supporting learning tools. Therefore, variability will be the rule, not the exception (Gelman & Williams, in press; Kuhn, 1996; Siegler, 1996). It should be apparent that my notion of conceptual competence, a set of domain-specific interrelated principles, is yoked to the Piagetian idea that structures are self-feeding, self-modifying, and even accommodating—given that they interact with and are influenced by relevant social, physical and mental environments. I have moved

toward a learning theory that is compatible with the assumption that our young have mental structures, some of which are innate skeletal ones. Learners, be they novices or otherwise, cannot help but actively put these structures to work at finding relevant learning paths in the environment. In turn, supporting environments on these paths nurture conceptual competence. The effect is that the mental structures of the mind either spiral forward or detour, depending on whether these are consistent or inconsistent with incoming data. This means that developmental learning functions are almost always protracted and that variability in performance is the rule, as opposed to the exception (Gelman, 1972, 1993; Gelman & Greeno, 1989; Gelman & Williams, in press). The challenge is to characterize the learning process, the systematic contributions to variance, and the nature of supporting environments that move conceptual competence in a forward domain.

Sophian correctly points out that those who would attribute competence must be concerned with performance outcomes that reflect false positives and findings of negative evidence (from the theorist's viewpoint) in the literature. The problems of accepting positive data without scrutiny and forgetting negative records are nontrivial for a cognitive developmentalist, physicist, historian, politician, doctor, lawyer, or a young child. All minds interpret data in ways that are consistent with existing mental structures and their related beliefs, a fact that puts us at risk for running our mental structures roughshod over novel inputs. Fortunately, there are ways to deal with this danger. One is to return to the empirical questions we asked at an earlier time, now with the advantage of being able to place them in the context of reports of conflicting studies and advances in the literature. Another is to make an effort to marshal converging lines of evidence. Of course, still another is to change one's theoretical commitment.

I have been concerned with the role of false negatives, that is the tendency to say those who fail a task are incompetent regarding the target domain of knowledge or language understanding and use. Perhaps less obvious is a parallel concern of mine about the possibility of over-attributing competence and accepting false positives. For example, my colleagues and I have repeatedly cautioned against the conclusion that the "magic show" (Gelman, 1972) shows that three- to five-year-olds can conserve number. We did not show conservation, that is, the "magic show does not reveal the ability to use the logical definition of one-to-one" correspondence to decide whether two sets either are equal or not for reasons discussed in a variety of sources, including Gelman & Gallistel (1978, ch. 11). The text of the Gelman and Meck (1982) conservation training study makes it clear that we were surprised to have to conclude that successful training with counting uncovered unexpected competence for at least implicit understanding of one-to-one correspondence.

The Gelman and Meck (1982) paper is pertinent to another argument in the present Sophian discussion—conceptual competence theorists have no way to accept or reject their theory. In fact, the outcome of the study changed our ideas about what is or is not conceptual competence in the early preschool years. In a related way, considerations of others' reports of very young children's failure to use principled counting (e.g., Fuson, 1998; Wynn, 1990; 1992b) led us to redouble our efforts to study the acquisition of domain-relevant conceptual knowledge. Studies of the learning involved in moving from a preverbal to a verbal level of understanding constitute one line of work in my lab (Gallistel & Gelman, 1992; Gelman, 1993; Gelman & Brenneman, 1994). Questions of how early conceptual competence either does or does not facilitate the learning of new principles, and therefore *expanded* conceptual competence, organizes another line of work (Hartnett & Gelman, in press). These efforts have led us to conclude that learning about new principles moves forward at a rapid pace when their structure is consistent with the structure of existing conceptual understanding in a domain. If there is inconsistency, then learning depends on the ability to find local structural commensurates between the known and to-be-learned principles. Although these serve as mental stepping stones, they are nowhere as effective as structural isomorphs can be. This is a straightforward consequence of a learning account that gives a central role to the active application of existing structures of mind.

My lab's concern for discrepancies between our and others' conclusions has led us to discover that the How Many? task is no better at leading adults to state the cardinal value of a set after they count than it is at leading young preschool-aged children to do so (Gelman, 1993). This, in turn, has sent us back to watch for settings in which young children generate competent counting and arithmetic solutions for numerical problems (Gelman, 1993; Zur, 1995), to consider input conditions (Gelman, Massey & McManus, 1991), take advantage of the opportunity to interview members of groups who are said to lack principles of counting and arithmetic (See Gelman, in press, for an example), and other lines of possibly converging or diverging lines of support.

Sophian and I agree: It is true that conceptual competence must change as a function of learning and development—a position that has and will continue to organize my theoretical and research efforts. I take it as given that concept learning must take place in supporting environments that can nurture the growth and change of conceptual competence. I also take it as given that, be we young children or members of the cognitive developmental community, all of us interpret our environments on the basis of our existing conceptual models. The odds are high that these differ for different theorists. It follows that there is a nontrivial risk that we will interpret what we encounter in ways that differ from the one intended by others, not because the intent is ill-motivated but because of the way our constructivist minds work.

My long-term goal is an account of the epigenesis of knowledge, especially regarding cognitions about mathematics and the nature of the causal conditions that organize concepts about the animate and inanimate worlds. The search is for the kind of acquisition model that can deal with the facts about: (1) the sources of both initial and subsequent knowledge structures, what Gelman and Williams (in press) call core and non-core domains, respectively; (2) the ways conceptual structures foster learning; (3) the characterization of relevant inputs for both early and subsequent learning; (4) the characterization of the sources of those structured inputs, including the physical and sociocultural environment; (5) the nature of the individual's active participation in the elaboration of their knowledge structures; (6) the mechanisms of change which relate initial learning to later learning; (7) the variability in performance levels during learning, across tasks and cultures; and (8) the existence of cross-cultural universals of cognition. In developing this account, Gelman and Williams (in press) rely heavily on the notions of structure, structure mapping, and other content-specific, structural learning tools.

To say that there is early conceptual competence is not to say that it springs full-blown in a fixed form. To do so would be to go against the very important fact that the mind is made up of adapting biological structures, ones that depend on supporting environments and that change as a function of efforts: to assemble a plan of action that is responsive to the constraints of the structure, to try out a plan, and to adjust the plan, if need be. With rare exception, any genetic program carries with it extensive requirements for interactions with those kinds of environments that can nurture, support, and channel the differentiation of adult structure. In the absence of those environments, the program will almost certainly fail. The same is surely true for skeletal mental structures; the existence of an innate input-structuring mechanism does not guarantee that domain-relevant knowledge is waiting to burst forth the moment the individual encounters a single example of the requisite environment. Without opportunities to interact with, learn about, and construct domain-relevant inputs, as well as to practice components of relevant action plans, the contributions of skeletal structures will remain unrealized, or even lead to atypical developments. It follows that learners must encounter opportunities to interact with and assimilate relevant supporting environments (cf. Scarr, 1993). It also follows that variability is a characteristic of any learning, be it about core domains that benefit from skeletal structures or non-core domains that do not.

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