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Cognitive Biology

Evolutionary and Developmental Perspectives on Mind, Brain, and Behavior

edited by Luca Tommasi, Mary A. Peterson, and Lynn Nadel

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12 Learning in Core and Noncore Domains

Rochel Gelman

Different researchers have different ideas regarding the domain-specific approach to learning and its implications for an account of early cognitive development and learning. This leads me to focus on the oft-repeated question: What is a domain? I start with this question, then I discuss the difference between core and noncore domains, and follow with the respective distinctions between domains that have an innate basis and those that do not. The distinction between core and noncore domains dispels the widespread interpretation that all domain-specific theoretical accounts imply a commitment to a new form of nativism.

The Notion of a Domain

I and other developmentalists hold that an area of knowledge constitutes a domain if it has a set of coherent principles that form a structure and contains domain-specific entities that are domain-specific and that can combine to form other entities within the domain (Gelman 1990; Spelke 2000). The domain of causality is about the kinds of conditions that lead objects to move and transform as well as how they move or change. It dominates several classes of items, including those that are separably movable and those that are not. Regarding the former, we can distinguish between those that move by themselves and those that do not.[1] These are of course the classes of animate and inanimate objects. Different considerations apply regarding both the nature of the object and its sources of energy. Setting aside machines, the energy for separably movable animate objects is from within or inside the organism, whereas that for inanimates is external. Importantly, the kind of material the object is made of and the material's composition and are yoked to these causal distinctions. As predicted, even preschoolers treat machines as a separate default category from either the animate or inanimate ones, given the ambiguity between machines' inanimate material and their seemingly self-generated motion (Gelman 2002).

The distinction between the classes of animate and inanimate objects that are separably movable goes hand in hand with the fact that animate objects are composed of biological matter and honor biomechanical principles as well as principles of mechanics, whereas inanimate objects are composed of nonbiological material and honor only principles of mechanics. Further, animate motions have a quality of purpose or function. This is a direct consequence of their governance by control mechanisms that make it possible for animates to respond (adjust) to environments—be these social or nonsocial—and adapt to unforeseeable changes in circumstances. Such considerations mean that the priors for learning about animates include principles that are social, including collaboration, reciprocity, and the capacity to perceive and communicate (Gelman et al. 1995; Gelman and Lucariello 2002).

The present definition of domain implies that different domains are organized according to different principles and include only those entities that are constrained by the given principles. So the entities of the causality domain are qualitatively different from those for the domain of language. The causality domain does not contain any basic linguistic elements that are combined to make a sentence. The principles for generating phonemes, morphemes, and sentences are organized by principles that constitute linguistic structures. It makes no sense to ask whether the "movement" of the word *how* in sentences (1) and (2) is due to internal biological energy or forces of nature.

1. He knows *how* to go there.
2. *How* does he know to go there?

For yet another domain, that of arithmetic and the subordinate principles that govern counting, still different entities and structures are involved. It does not matter how large an entity is when one engages counting principles to generate a cardinal value to add to or subtract from another quantity. Indeed, the to-be-counted entities need not even be objects. They can be imaginary playmates, good ideas at a conference, or cracks in the sidewalk. The entities generated by the counting principles are such that they can be combined to produce yet further examples of quantities within the domain.

To repeat: Whenever we can state that a unique set of principles serves to capture the structure of a domain of knowledge and the entities within it, either by themselves or ones generated according to the combination rules of the structure, it is appropriate to postulate a kind of domain-specific knowledge.

Core and Noncore Domains

Domains can either be based on innate skeletal structures or acquired later on in development. This is a crucial point. It is a mistake to assume that all domains of knowledge are based on innate skeletal structures. Indeed, thus far the discussion of what counts as a domain is neutral as to whether a given domain is innate or not. I call domains that benefit from biological underpinnings *core* domains (Gelman and Williams 1998), in way that is similar to Spelke (2000). Domains of organized knowledge that are acquired later are called *noncore* domains. Thus, I reserve the phrase *core domain* for domains that have an innate origin and noncore domain for those that require the acquisition of both the structure and related content. Examples of noncore domains include chess, sushi making, and all kinds of advanced fields in physics, mathematics, movie making, computer science, and so on. Importantly, it is a mistake to label information-processing operations—such as discrimination, attention, or classification—as domains. These are processes that are orthogonal to the distinction between core and noncore domains. They may or may not be variables that differ across domains. But, this is a theoretical position that remains to be tested.

We know from the literature on adult cognitive psychology that it is always much easier to learn more about a content domain if we already possess a coherent understanding of that domain. We also know that it is difficult to acquire new conceptual structures. One has to work at the goal of building a new domain of knowledge for many years, and it helps to have formal tutoring about what to learn and what to practice (Bransford et al. 1999). Often when one is exposed to a new domain it seems incomprehensible. For example, beginning chemistry undergraduates in their first class might think that the words "bond," "attraction," "model," and so forth are related to business and cannot imagine why these terms are being used in chemistry. These students surely are not in a position to understand the technical meaning of these terms as they are used in chemistry and therefore are at risk for misunderstanding them or even of dropping the course. We know from research that such knowledge is the kind attributed to experts and we know that it takes a great deal of work over many, many years to acquire expertise for any noncore domain (Ericsson 2006). A characterization of noncore domains is presented in a later section.

For young children, having some nascent mental structures for various domains means that they have a leg up when it comes to learning about the data that can put flesh on these early structures. A core domain's principles serve to outline the equivalence class of inputs that are relevant, that can nurture the acquisition of the domain-relevant body of knowledge. Of course the notion of "skeletal" is a metaphor meant to capture the idea that core domains do not start out being knowledge-rich or even complete. Nevertheless, no matter how nascent these mental structures may be, they are mental structures. And, like all bodily structures, they are actively used to engage with relevant environments—those that have the potential to nourish their growth. They accomplish this by directing attention and permitting the uptake into memory of relevant data in the environment. In this way, they provide a way to gather together domain-relevant memories within a common structure. This line of reasoning highlights the role of structure mapping as a fundamental learning mechanism.

More on Core Domains

Natural number arithmetic is an example of a core domain. Importantly, the principles of arithmetic (addition, subtraction, and ordering) and their entities (numerons and separate, orderable discrete and continuous quantities) do not overlap with those involved in the causal principles and their link to separably movable animate and inanimate objects. As a result, examples of relevant entities and their properties are distinctly different. For no matter what the conceptual or perceptual entities are, if you think they constitute a to-be-counted collection of separate entities, you can count them. It even is permissible to decide to count the spaces between telephone poles (a favorite game of many young American children) or collect for counting the temporary set of every person and writing utensil in a particular room. This is because there is no principled restriction on the kinds of items that can be counted. The only requirement is that the items be taken to be perceptually or conceptually separable. I later develop the evidence and argument that skeletal structures in the domain of positive natural number arithmetic benefit from nonverbal structures that define relevance regarding the verbal instantiation of counting and its related principles of arithmetic.

Now consider the domains of animate and inanimate causality. There is no question that the nature and characteristics of the entities really do matter. The way one plans to interact with an object is constrained by the kind of entity it is and its environment. If the entity is an animate object, when deciding whether to pet it or run away as fast possible I will take into account the object's size, how it moves, how fast it can move, whether it has teeth, and so on. If I want to move two desks, I have to take into account their size and likely weight as well as my own limits. I will do the same should I be asked to also lift the two men sitting in chairs. I know that I do not have the kind of strength it takes to lift and move the men, whereas I might be able to push the desks. So objects' material, weight, and size definitely do matter when I consider the conditions under which they move. This contrast accomplishes what we want–an a priori account of psychological relevance. If the learner's goal is to engage in counting, then attention has to be paid to identifying and keeping as separate the to-be-counted entities but not their particular attributes, let alone their weight.

Similarly, if the learner's goal is to think about animate or inanimate objects, then attention has to be given to the information that provides clues about animacy or inanimacy, for example, whether the object communicates with and responds in kind to like objects, moves by itself, and is made up of what we consider biological material. Food surely is another core domain. We care about the color of a kind of food, whereas we rarely care about the color of an artifact or countable entity. It is noteworthy that children as young as two years of age also take the color of food into account (Macario 1991).

Defining Core Domains

So how should we think about core domains? I offer the following of criteria.

1. Core domains are *mental structures*. To start, they are far from fully developed, which is why I use the metaphor of "skeletal." Despite their incompleteness, they are structures

that actively engage the environment from the start. This a consequence of their being biological, mental organizations that function to collect domain-relevant data and hence provide the needed "memory drawer" for the buildup of knowledge that is organized in a way that is consistent with the principles of the domain.

2. Core domains help us solve the problem of *selective attention*. They provide a way for us to avoid the common circular argument that selective attention is due to salience and salience directs attention. Potential relevant candidate data are those that that fit the equivalence class outlined by the principles of the domain, which define the relevance dimensions.

3. They are *universal*. One reason to say that core domains are universal is that they can support learning about any data sets that cohere as domain-relevant examples of the structure of the core domain. The particular set of examples of inputs can vary across cultures. There are no known restrictions of the possibility of adopting any healthy infant into any language culture. Children in different language communities all learn to speak in sentences that share the organization of Noun Phrase and Verb Phrase as well as key combination rules. In a similar way, children everywhere think about instances of animate and inanimate objects as belonging to separate categories, even though the particular examples vary from culture to culture. For these reasons, we can expect variability across cultures as far as the particular language that is spoken, the different instances of animals that will be known, and so on. Since the kind of data a given culture offers young children varies as a function of geography, urbanization, and other factors, it follows that the range of knowledge about the animate-inanimate domain will vary. Still, the organizing principles will be the same during early acquisition (Waxman et al. 2007).

Linguists who posit that there are universal principles supporting language acquisition do not expect children to learn their language in two days. The main idea is that the learning occurs on the fly and without formal instruction. The same considerations hold for other domains. We now know that even infants abstract and process numerical displays and reason about the effects of numerical operations (Cordes and Brannon 2006). They also make inferences about unseen causes (Saxe et al. 2006).

When we posit that young learners use universal innate principles to find relevant inputs, we end up with a challenge. Given that the learner's self-generated attention is a key contributor to what counts as relevant data, we no longer can assume that we know what inputs will or will not foster such active learning. Nor do we know how many examples or how much of each example is necessary. The challenge to is find the kind of theory of learning that accounts for early learnings that occur on the fly, without formal instruction and the extent to which these early acquisitions serve as bridges or barriers to later learnings. We also need to study the nature of relevant environments so as to develop a theory of supporting inputs for learning. At present, many assume that learning takes place whenever an organism is presented with sufficient examples of any kind of inputs.

Ethologists constitute a notable exception to this generalization. They take it granted that innate learning dispositions have to encounter environments that are examples of existing predilections. A given biological predisposition must encounter particular inputs for the behavior in question to develop. The terms "innate" and "learned" are not opposite nor mutually exclusive. (See Gelman and Williams 1998, for further discussion.)

4. Core domains are akin to *labeled and structured memory drawers* where data acceptable to the domain are incorporated. This provides an account of how it is possible to build up a coherent knowledge domain.

5. Core domains support *learning on the fly*. They support this type of learning because of the child's active tendencies to search for supporting environments in the physical, social, or communicative worlds offered by the environment. The fact that learning occurs on the fly and is a function of what the child attends to is why many students of young children's early cognitive development have moved in to postulate core domains. It also is related to efforts to enrich early learning with core domain examples of domain-relevant learning environments such as preschools and daycare centers (Gelman et al., forthcoming).

6. The principles of the structure and entities within a domain are *implicit*. They cannot be stated by an adult (not to mention an infant), any more than a nonexpert adult can state linguistic principles.

7. Children are highly *motivated to learn* in these domains. They ask relevant questions, including how a remote control works, why a parent says the car battery is dead, what number comes after 100, 1000, and so forth. I well remember a little girl in a schoolyard telling me she was too busy to talk. She had set herself to count to "a million." I asked when she thought she would get there. Her reply was, "A very, very, very long time." She pointed out that she needed to eat, sleep, and probably would be very old.

Many young children's inclinations to self-correct and rehearse are part of their overall tendencies to put into place the competencies that are within their purview. Examples of young children self-correcting their efforts or even rehearsing what they have just learned are ubiquitous in the developmental literature. A common report from parents has to do with their children asking, "What's that?" after the parents have answered the question many, many times. Such rituals can go on for days and, then, for no obvious reason, drop off the radar screen. In a related way, we are finding that the children from right across the socioeconomic spectrum in the preschools where we work are eager to have us ask more questions about unfamiliar animate and inanimate objects (Gelman and Brenneman 2004).

8. The number of core domains is probably *relatively small.* A core domain is only going to be as large as is necessary for each individual to possess universal shared knowledge without formal instruction. Just as the core domain of language supports the acquisition

of different languages in different language communities, different language-cultural communities favor differential uptake of the relevant data that they offer. Nevertheless, the underlying structure of the core domain should be common—at least to start.

On Early Learning

The Role of Structure Mapping

For me, the most important learning mechanism is *structure mapping*. Possessing an existing structure, the human mind will run it roughshod over the environment, finding those data that are isomorphic to what it already has stored in a structured way. It could be that an infant first identifies the examples of the relevant patterned inputs and then maps to the relevant structure. Subsequently further sections of the pattern are put in place. In any case, the details that are assimilated fit into a growing set of the class of relevant data that fill in the basic structure.

Importantly, input data may vary considerably in terms of surface characteristics as long as they are in the class of data that are recognizable by the domain's principles. This carries with it the implication that the input stimuli do not have to be identical; in fact, they are most likely to be variants of the same underlying structure. Multiple examples offer a number of advantages: They provide different ways of doing the same thing, opportunities to compare and contrast items to zero in on whether they are in the same domain. Given an existing structure, a child can self-monitor and self-correct, saying, "That's not right; try again." In fact, in our counting protocols, we have examples of children saying, "One, two, three, five—no, try dat again!" for five trials, then getting it right and saying, "Whew!" Nobody tells children to do this; they just do it. We see a lot of this kind spontaneous correction or rehearsal of learning that is related to the available structure.

Natural Number

There is a very large literature now on whether babies and young preschoolers count, can order displays representing different numerical values, and process the effect of addition and subtraction on an expected value. For a number of years the evidence did not favor this position. Instead it was held that infants respond to overall quantity variables that are confounds on numerosity, as might be the overall length or area of a display (see Mix et al. 1997). The tide has once again turned to favoring the view that infants do abstract number from dot displays (Cordes et al. 2007; see also Brannon and Cantlon, chapter 10, this volume).

The various studies that report the use of nonverbal counting as well as addition, subtraction, and ordering lend credence to our account of how these operations benefit beginning learners' acquisition of the language of counting and simple arithmetic.

It is crucial to keep in mind my view that counting principles are embedded in the domain of positive natural number under addition and subtraction. If so, the meaning of a count word does not stand alone. Given the fact that available structures can pick out isomorphs, the use rules for verbal counting can be mapped to the underlying nonverbal counting principles that young children bring to their verbal environment. Since people use their mental structures to find data that feed these structures, this means that beginning language learners are likely to attend to and start to learn the nonsense string of sounds that constitutes the verbal counting list ("one-two-three" etc.). Keep in mind that there is nothing about the sound "won" that dictates it will be followed by the sound "too" and so on.

The principled requirements for verbal counting lists are that the words follow some basic rules: (1) The *one-to-one* principle. If you are going to count, you have to have available a set of tags that can be placed one for one, for each of the items, without skipping, jumping, or using the same tag more than once. (2) The *stable order* principle. Whatever the mental tags are, they have to be used in a stable order over trials. If they were not, you would not know how to treat the last tag—the total amount. This relates to (3) the *cardinal value*, which is conserved over irrelevant changes. The relevant arithmetic principles are ordering, adding, and subtracting. Counting itself is constrained by three principles. If you want to know whether the last tag used in a tagging list is *understood as a cardinal number*, it is important to consider whether a child relates these to arithmetic principles; it helps also to determine how the child treats the effects of adding and subtracting.

Count words behave differently than adjectives, even when they are in the same position in a sentence. It is acceptable to say of a set of four round circles that "a circle is round" or to speak of "a round circle," but one cannot say "a circle is four" or speak of "a four circle."

What about addition and subtraction? A rather long time ago, I started studying whether very young children two and a half to five years keep track of the number-specific effects of addition and subtraction. In one series of experiments, I used a magic show that was modeled after discussions with people in Philadelphia who specialized in doing magic with children (Gelman 1972). The procedure is a modification of a shell game. It starts with an adult showing a child two small toys on one plate and three on another plate (see figure 12.1). One plate is randomly dubbed the winner, the other the loser. The adult does not mention number but does say several times which is the winner plate and which is the loser plate. Henceforth both plates are covered by cans and the child is to guess where the winner is. The child picks up a can, and if it hides the winner plate the child gets a prize to immediately to put in an envelope. If the child does not see a winner, he or she is asked where it is, at which point the child picks up the other one and then gets a prize. The use of a correction procedure is deliberate: it helps children realize that we are not doing anything unusual, at least from their point of view. This set-up continues for ten or eleven trials, at which point the children encounter a surreptitiously altered display either because items were rearranged or because they changed in color, kind, or number).

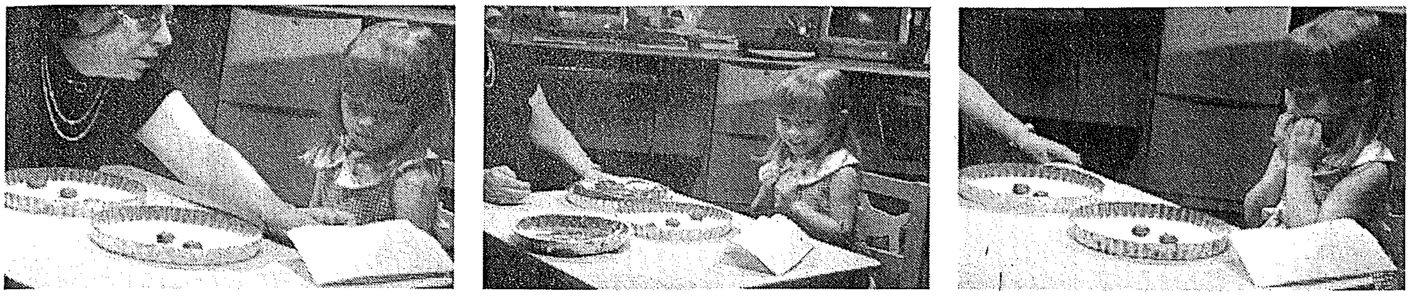

Figure 12.1
The three phases of the Gelman (1972) "magic game," shown from left to right. In phase 1, the child is shown uncovered displays and told that one is the winner, the other the loser. She is asked to identify each and told about winning prizes that will be stored in the envelope. To start phase 2, the displays are covered and shuffled for ten or eleven trials. When she picks up a winner, she gets a prize. In phase 3 she unexpectedly encounters the effect of a surreptitious change in the number on the winner plate. Notice the shift from her exuberant mood to one of puzzlement.

The effect of adding or subtracting an object led to notable surprise reactions (see figure 12.1c). Children did a variety of things such as putting their fingers in their mouths, changing facial expression, starting searching, and even asking for another object ("I need another mouse"). That is, they responded in a way that is consistent with the assumption that addition or subtraction is relevant, and they know how to relate them. When we show two-year-olds 1 vs. 2 to start and then transfer to 3 vs. 4 items, the children transfer greater-than or less-than relationship, whichever they learned about in phase 1. That is, we have behavior that fits predictions that follow from the description of the natural number operations.

In a more recent experiment, Hurewitz and colleagues (2006) asked children ranging in age from almost three to almost four to place a sticker on a two- or four-item frame, in one set of testing trials. In a second set of testing trial, they then placed stickers on a *some* vs. *many* frame. The children had an easier time with the request that used numerals than with the one that used quantifiers. This provides another example of early use of cardinal numerosity. The finding that the word "some" gave them the most difficulties in this task challenges the view that beginning language learners bootstrap their understanding of counting words off their earlier understanding of quantifiers (Carey 2001). Further examples of young children's facility with positive natural number can be found in Gelman (2006).

The Animate-Inanimate Distinction and Related Causal Principles

If young children benefit from available skeletal principles, they should be able to solve novel problems with novel stimuli. This led Massey and Gelman (1988) to show preschool children photographs of novel animates, vertebrates and nonvertebrates; statues selected to look like people and animals; wheeled objects; and inert complex objects such as an electric iron. Examples also included a photograph of an echidna, a large "bug," Chinese statues, and wheeled objects from the turn of the nineteenth century. Graduate students were asked to name the items, and when they could not do so it confirmed our expectation that these objects would be novel for young children.

The question put to three- and four-year-old children was a simple one: Could the depicted item go up and down a hill by itself? They judged that only the novel animates could do this. A wheeled object might go down a hill "by itself," given a push, but not up. And the complex inert objects would not be able to move in either direction. Children this age are not especially good at explaining their responses, but when they did so, their explanations were extremely informative. For example, one child said that a statue did not have feet, even though it did. We pointed this out and learned that the feet were "not real." Some children told us that the echidna could move itself because it had feet, even though we pointed out that none were visible. The rejoinder? The echnida was sitting on its feet. These kinds of responses have led us to find ways to show that young children yoke biologically relevant data with the capacity to move on one's own.

A different line of relevant work comes from the extensive collection of findings about infants' ability to assign animate agency to actors in videotapes (see Kulhmeier et al. 2003). The explosion of research like this is directly due to a number of investigators' commitment to a domain-specific theoretical agenda.

There will be many a debate about the findings, but one thing is certain: The domain-specific view has prompted researchers to design studies regarding the possible abstract levels of data interpretations on the part of the very young children.

The Nature of Noncore Domains

Noncore domains have six primary features.

1. Noncore domains are *not universal*; there is no representation of the targeted learning domain, and therefore an individual does not start with any understanding of the data of the domain.

2. Noncore domains involve the *mounting of new mental structures* for understanding and require considerable effort over an extended period time, typically about ten years.

3. Noncore domains are *not processes*, such as discrimination learning, attention, inhibition, and other terms that often serve as chapter headings in textbooks. These task or processe terms do not capture the notion of a body of organized, structured knowledge.

4. The number of noncore domains is *not restricted*. This is related to the fact that individuals make different commitments regarding the extensive effort needed to build a coherent domain of knowledge and related skills. Success at achieving the chosen learning goals depends extensively on individuals' abilities to stick with their chosen learning problem, their talents, and the quality of relevant inputs, be these text materials, cultural values, demonstrations, or the skills of a teacher or tutor. Some examples of masters of noncore domains include: CEO of a Fortune 500 company, chess master, dog show judge,

linguist, army general, composer, master chef, theoretical physicist, yacht racer, string theorist, sushi chef, and so on.

5. Learning about a noncore domain almost always depends on *extensive help from a teacher or master* of the domain—an individual who selects and structures input and provides feedback. Still, no matter how well-prepared the teacher might be, the learner often has a major problem if she is unable to detect or pick up relationships or at least parts of relationships that eventually will relate to other relevant inputs, for example, what characterizes a musical interval of a third, no matter what the key. The task can be even more demanding if one has to acquire a new notational system—for example, learn a new alphabet—which can be challenging in its own right.

6. Early talent in noncore domains *does not guarantee acquisition* of expertise. It takes around ten years of dedicated work to reach the level of expert for the domain in question, whether the domain is in the arts, athletics, academics, or a host of other areas (see Ericsson 2006 for a review and theoretical discussion).

Comparison of a Core Domain to a Noncore Domain

I will conclude by comparing two contrasting numerical concepts, one of which is part of a core domain and one of which is part of a noncore domain.

Successor Principle Is Easy; Rational Numbers Are Hard

Every natural number has a unique "next" number, and it is always possible to add one to a given very large number. The more formal way to put this is to say that the successor principle belongs to the core domain of natural number. By way of contrast, there is no successor principle for the rational numbers. There is an infinite number of rational numbers between any pair of rationals. Rational numbers are not the same as natural numbers, Each is obtained by dividing one natural number by another and therefore do not belong to the same domain.

Assuming that young children know that adding one to a given cardinal number produces a new higher one, we predicted that children in the early elementary grades would readily achieve an explicit induction of the successor principle. As expected, when Hartnett and Gelman (1998) asked children ranging in age from about six years to eight years of age if they could keep adding 1 to the biggest number that they could or were thinking about, a surprising number indicated that they could. Even when we suggested that a googol or some other very large cardinal number was the biggest number there could be, the children resisted and noted it was possible to add another to our number.

The successor principle is seldom taught in elementary school, even though children can easily comprehend it. Notions about rational numbers (also known as fractions) are, on the other hand, taught in elementary school. Still, it is well known that students have a very hard time coming to understand rational numbers (Hartnett and Gelman 1998). The fact that children benefit from a short overview about the successor principle but do not benefit from formal instruction about fractions and division contribute to my conclusion that the rational numbers constitute a noncore domain.

The problem with rational numbers might well be that the principles involved both contradict and are different from those for the domain of natural numbers. The successor principle does not apply. Further, the formal definition of a rational number introduces a new operation, this being division. The answer to a division problem need not be a third cardinal number. The odds are that there will be a remainder. Still, people have a clear tendency to throw away the remainder—that is, to turn a rational number into a cardinal number. This begins to give one the flavor of why I propose that the domain of rational numbers is a noncore domain that involves conceptual change. That is, one has to learn that there is a new kind of number and then assimilate the natural numbers to the rationals (100/100 = 1; 200/100 = 2, etc.).

To continue with the problem of rationals, I illustrate the kind of errorful but systematic patterns of responses we have obtained from school-aged children asked to place in order, from left to right, a series of number symbols, each one of which is on a separate card. The children were given pretest practice at placing sticks of different lengths on an ordering cloth. They also were told that it was acceptable to put sticks there of the same length but different colors and to move sticks. Then the test cards followed, until they were happy with their placement order. Careful inspection of the placements reveals that the children invented natural number solutions. For example, an eight-year-old started by placing each of three cards left to right as follows: 1/2, 2/2, 2-1/2, etc. What the child is doing is taking the first pair of numbers and adding them, and getting 3; the second and adding them, etc. The following interpretation captures these and all of his further placements. A bit of thought reveals that the child took the cards as an opportunity to treat the problem as a novel opportunity to apply his knowledge of natural number addition:

$$(1 + 2 = 3), (2 + 2 = 4), (2 + 1 + 2 = 5)$$

Other children invented different patterns, but all invented some kind of interpretation that was based on natural numbers.

One might think that students would master the placement of fractions and rational numbers well before they enter college. Unfortunately, this is not the case. When Obrecht and colleagues (2007) asked whether undergraduates made use of the law of large numbers when asked to reason intuitively about statistics, they determined that students who could simply solve percentage and decimal problems were reliably more able to do so. Those who made a lot of errors preferred to use the few examples they encountered that violated the trend achieved by a very large number of instances (Obrecht et al. 2007). This continues into college. If you want to know now why your students are horrified and gasp when they are faced with a graph, it is probably because a nontrivial percentage does not understand rational numbers and measurement.

Other Noncore Domains

Although young children rapidly learn a great deal about the difference between animate and inanimate objects as well as factors that are encompassed by these, it does not follow that it will be just as easy to learn Newton's laws. In fact, it is well known that many a college student who has taken physics comes away with her pre-Newtonian beliefs intact. It is hard to grasp that velocity and acceleration are different concepts, let alone that something at its resting place has zero velocity. These difficulties persist, despite the fact that Newtonian physics has been part of Western culture for several centuries. Similar comments apply to the task of learning modern biology. Conceptual changes do not come easily, a fact that needs to be taken into account in light of the persistent calls for upgrading the scientific and mathematical literacy of the citizens of the world.

Summary

Domains are bodies of knowledge that are organized by a set of principles or rules. They are not information processing operations such as attention, discrimination, inhibition, etc. Core domains constitute a small domain-specific, group of skeletal domains that are part of our endowment and support learning on the fly, all over the world. Of course, the relevant data must be part of the child's everyday environment, and preferably in multiple contexts. Absence of samples from the relevant equivalence class of supporting data might be akin to deprivation. Noncore domains differ by virtue of the fact that their acquisition requires the mounting of new mental structures as well as the body of evidence that the structures organize. Further, teachers or tutors create the relevant inputs and oversee the learning, while learners—even those with definite talents—do serious, concentrated work for many years.

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Note

1. A parallel distinction applies to objects attached to the ground. Now it is between things that grow and inanimate structures such as buildings, bridges, etc. These are not discussed here save to point out that the distinction living-inert embraces both separably movable and stationary object kinds. The higher-order classification is biological vs. inert.

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