Reframing Research on Intuitive Science Knowledge

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Abstract: Education research has devoted significant effort to understanding the intuitive knowledge students bring to bear in reasoning about formal science. In addition to documenting the specific content of students' conceptions in particular domains, some researchers attempt to make more general claims, both within and across domains, about the nature of intuitive knowledge. These attempts involve an implicit assumption that the character and function of all intuitive knowledge is the same – that there is a single kind of thing called "intuitive science knowledge" that can be singularly characterized. The purpose of this work is to call that assumption into question, and we present examples to highlight our concerns. We propose a theoretical framework that provides a way to more carefully frame our research on intuitive science knowledge and demonstrate how it can be used to bring additional clarity to current discussions in the literature.

Research on Intuitive Science Knowledge

Both science education researchers and instructors have long held an interest in identifying and understanding students' prior conceptions. Work in a variety of domains has characterized students' understanding of science topics ranging from the shape of the earth (e.g., Vosniadou & Brewer, 1992) to elementary mechanics (e.g., McCloskey, 1983) to biological categorization (e.g., Carey, 1985). This research is often motivated by the belief that students possess intuitive knowledge of science content – knowledge gained outside of formal instruction – that impacts how they learn formal science content. It is hoped that finding out more about the intuitive knowledge itself will help make classroom instruction more effective and meaningful.

The desire to understand more about students' intuitive knowledge of science has largely been translated into research agendas that seek to document the specific contents of intuitive knowledge as it relates to particular scientific domains. For example, in their work on the shape of the earth, Vosniadou and Brewer (1992) describe the particular alternative models possessed by students. However, in some cases, researchers have attempted to address questions that have broader import. They have attempted, for example, to describe the *character* of intuitive knowledge in particular areas. Even more broadly, some researchers have attempted to draw conclusions, which span domains, about the nature of intuitive science knowledge. For example, the literature is rife with arguments over the form of intuitive knowledge – whether it is more theory or model-like or whether it is fragmented (e.g., diSessa, Gillespie, & Esterly, 2004). In attempting to draw conclusions that span domains, there is an assumption that the character and function of all intuitive knowledge is the same – that there is a single kind of thing called "intuitive science knowledge" that can be compared straightforwardly across all domains, and can be singularly characterized.

The purpose of this paper is to call this assumption into question. We argue that the various attempts to document student conceptions have often been focused on different kinds of knowledge, with very different origins, function, and character. As a result, many attempts to draw conclusions about intuitive knowledge that span domains are, at best, incoherent. As a remedy to this situation, we propose a framework that we hope can bring new clarity to attempts to draw more general conclusions about intuitive science knowledge. In what follows, we first lay out some reasons for concern. Then we describe our new framework. Finally, we show how the framework can be applied to help bring clarity to some of the major debates in the research literature.

Our approach in this brief paper will be purely theoretical. We will not present any new data, although we will draw on brief examples from the literature to illustrate some points. We believe that the issues are clear and dramatic enough that extensive reference to data is not needed. Instead we see this paper as a chance to step back and reflect on some of the fundamental assumptions of research on intuitive science knowledge.

Reasons for Concern

We believe that there are good and fairly clear reasons to doubt the assumption of domain uniformity of intuitive knowledge. In this section, we will take the reader on a brief tour of three sets of examples. Each of these sets of examples makes it clear that, at the least, there are reasons doubt the assumption of uniformity.

The Issue of Domain Size

First is the issue of domain "sizes." The domain of *mechanics* within physics seems much larger than the domain of *phases of the moon.* The first encompasses a wide range of physical situations and knowledge whereas the second is an extremely narrow slice of phenomenology. Which of these is the appropriate size to consider a domain? Can we consider both domains and still imagine their relevant intuitive knowledge base to be the same kind of thing?

It is likely that students' intuitive knowledge relevant to these two differently-sized domains differs in its scope and range of applicability. Consider part of a student explanation for what happens when a ball is tossed into the air - a task from the domain of mechanics.

> J: When you throw it, you're giving it a force upward, but that force can only last so long… So you give it this initial force, and its going up just fine, slower and slower because gravity is pulling on it and pulling on it. (diSessa, 1996, p. 720)

Here, J uses intuitions about forces, competition between forces, the effect of forces, and the strength of forces. This same knowledge (or some closely related knowledge) could also function to answer questions about projectile motion, objects moving in space, and objects moving along the ground. In contrast, consider the line of research that attempts to characterize student knowledge of phases of the moon (e.g., Stahly, Krockover, & Shephardson, 1999). The following student describes how we see the moon.

> A: Like, over here's the sun [refers to lamp] and then how the moon turns around [moves the Styrofoam moon around the Styrofoam earth] and it goes… and what we see from the… see the sun's not over here [indicates unlit side of the Styrofoam ball], it's right here [points to the lit side of the Styrofoam ball] so that makes a shadow. (Stahly et al., 1999, p. 167)

A uses knowledge about the relative locations of the sun, moon, and earth as well as intuitions about light and shadows. Though some of it is fairly general, A's knowledge does not need to – and sometimes cannot – answer a wide range of questions; the domain is much smaller in that it consists of this single task.

As we hope to make clear, this issue of domain "size" is reflective of a more general problem with domains, and what we mean when we speak of "intuitive knowledge of Domain X." It may be non-trivial to draw boundaries around a domain. For example, *mechanics* encompasses many sub-domains (e.g. *linear, freefall, and projectile motion)* and overlaps with other domains (e.g. *chemistry*) in complicated ways. It is not clear which aspects of mechanics to consider part of that domain and which to exclude.

Even if it were possible to cleanly define domains, assigning student intuitive knowledge to a particular domain poses further problems. For example, while Stahly et al. (1999) interpret A's reasoning as providing insight into her intuitive knowledge of *phases of the moon*, we might also just as easily claim that this excerpt gives data about her knowledge of the domain of *light and optics*. The knowledge she uses here might be more general knowledge that would fit equally well into a variety of domains; it does not cleanly or exclusively map onto a single science domain. diSessa et al. (2004) describe many of these concerns with domains – including fuzziness, overlap, and scope – in reference to knowledge *contextuality*.

Variability in Form and Genesis of Knowledge

Obviously the content of students' intuitive knowledge varies from domain to domain. But it also seems, at least intuitively, that the knowledge can be of very different types, both within and across domains. Consider two examples from intuitive physics. It is likely that some students possess a relatively elaborated mental model of what happens when an object is tossed in the air, including forces and velocities and how they change. At the same time, students might possess knowledge in the form of facts, perhaps as not much more than a slogan such as "gravity is always constant." Furthermore, it is possible that the intuitive knowledge associated with some domains might lean more heavily on knowledge of one form or another. For example, students may have a coherent impetus theory of mechanics (McCloskey, 1983) whereas their knowledge of nutrition may be built from individual facts (Kantor, Sherin, & Lee, 2006). Such great differences in the form of knowledge means that we must be careful in drawing general conclusions about intuitive knowledge both within and across domains.

These differences in the form of knowledge in part arise because intuitive science knowledge can have a wide variety of kind of origins. In some cases, for example, an individual might develop the knowledge by directly abstracting it from their own experience. For example an individual might develop an understanding of how a tossed ball works by tossing balls and watching what happens. In other cases, intuitive science knowledge might be acquired when children hear pop-science at home or on the radio. For example, knowledge of nutrition likely comes from hearing doctors or TV personalities talk about what's good for you.

The Repurposing of Knowledge

In some cases, it seems as though students apply intuitive knowledge from one domain in order to reason about another domain. This again makes it unclear what we can mean by "intuitive knowledge of Domain X." Consider again J's explanation for a tossed ball – a problem from the *mechanics* domain.

J: When you throw it, you're giving it a force upward, but that force can only last so long… So you give it this initial force, and its going up just fine, slower and slower because gravity is pulling on it and pulling on it. (diSessa, 1996, p. 720)

J's intuitions about force and motion in tossing a ball might well have been abstracted from similar experiences pushing and pulling on objects. The knowledge was developed for navigating the physical world and is thus directly applicable to questions about macro-object phenomena in the formal domain of Newtonian mechanics. In contrast, the following excerpt comes from a student discussing why a lamp lights when it is plugged in – a question from the domain of *electricity*.

D: …the electricity goes into the cord for the appliance, for the lamp and flows up to – flows – I think of it as flowing because of the negative to positive images I have, and also because… a cord is a narrow contained entity like a river. (Gentner & Gentner, 1983, p. 99)

D uses intuitions about "flow" and "containment" that, similarly to J's intuitions about force and motion, likely originated from everyday experience. He explicitly states that he is using knowledge of a common physical phenomenon – flowing rivers. However, unlike J, D's experience is not directly applicable to the question posed to him. Instead he must put his knowledge that was developed for reasoning in one context (the behavior of rivers) to use in answering questions from another context (reasoning about electric circuits).

A Framework for Studying Intuitive Science Knowledge

Together, the above issues suggest a need for care and clarity in our descriptions of intuitive science knowledge. We need a way to organize our thinking about intuitive knowledge relevant to different domains so that, when we begin to make general conclusions within and across domains, we can avoid the problems illustrated above. In what follows, we attempt to provide such a "meta-framework" that can guide our analyses of intuitive science knowledge. We begin by describing a simple framework and then successively elaborate it to account for more of our concerns.

Simple Frameworks

We start with the simple notion, shown schematically in Figure 1a, that there are science domains and distinct bodies of intuitive knowledge that align, one-to-one, with each domain. Domain X is entirely separable from Domain Y and the intuitive knowledge of Domain X is separable from the intuitive knowledge of domain Y.

(a) (b)

Figure 1. (a) A simple framework and (b) a slightly elaborated framework for describing intuitive knowledge.

In Figure 1b, we begin to acknowledge some of the complexity outlined in our "reasons for concern." We first highlighted the difficulties associated with defining domains due to domain overlap and sub-domains. To begin to account for this concern, Figure 1b shows the formal science domain as made up of sub-domains. For example, the domain of *biology* includes sub-domains such as the theory of evolution and classification systems for living things. We next highlighted some of the variation in the form and genesis of students' existing knowledge. We represent that variability in Figure 1b by acknowledging that existing knowledge is made up multiple sub-systems, consisting of many elements of varying kind.

An Elaborated Framework

While the above conceptions account for some of our concerns, it leaves others unanswered. There is still the problem of varying domain size, and adding sub-domains does not necessarily help in better defining domain boundaries. In addition, we still have the difficulty of how to represent knowledge that is repurposed and applied to domains outside its domain of origin. Figure 2 shows a final elaboration that helps resolve some of these remaining issues.

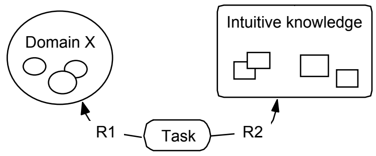

Figure 2. A fully elaborated framework for describing intuitive knowledge.

We point to two changes that help overcome our concerns. First, instead of separating intuitive knowledge into different spaces each associated with a domain, we place all of students' intuitive knowledge together; we do not attempt to distinguish between intuitive knowledge of domain X and intuitive knowledge of domain Y. In this single intuitive knowledge space we find elements such as knowledge of living things (relevant to the domains of *biology* and *chemistry*), knowledge of macro-objects (relevant to *mechanics*, *phases of the moon*, and *electricity*), and knowledge of rivers (relevant to *ecology* and indirectly relevant to other domains). Considering all intuitive knowledge together frees us from having to assign elements to particular domains, a task that may be difficult when domains themselves are not clearly defined. For example, we do not have to decide whether knowledge of lunar phases belongs to the domain of *cosmology*, *phases of the moon*, *physics,* or *light and optics.* By not designating particular knowledge to a particular domain, we are perhaps more open to look for overlap – places where knowledge relevant to one domain might be fruitfully repurposed to make sense of other domains.

Second, this conception explicitly includes the research task – the particular questions used to probe student science knowledge. These tasks may be questions that researchers pose in clinical interviews or on written evaluations or they may be classroom activities given by teachers to elicit student knowledge. We use the task, instead of the domain, as the organizer for describing intuitive knowledge. Doing so eliminates concerns about characterizing knowledge relevant to differently-sized domains since we always answer questions about the form, origin, and purpose of knowledge in relation to a single task. Thus we might compare the knowledge students use in answering the tossed ball question and the lunar phases question instead of comparing students' knowledge of the domain of *mechanics* to the domain of *lunar phases*.

The insertion of the research task as an intermediary also draws our attention to the two relationships shown in the figure, R1 and R2. It draws our attention to the relationship between the task and the intuitive knowledge (R2). We do not assume that the intuitive knowledge is directly applicable to the domain but allow for the possibility that it has been repurposed. It also draws our attention to how representative the research tasks used to elicit students' intuitive knowledge are of the science domain (R1). It may be that the tasks researchers select are representative of tasks that are fundamental to the domain. Alternatively, they may be only trivial or peripheral. If the latter is true, then the knowledge that students bring to bear in the task may give the researchers very little information about the students' intuitive knowledge that is related to tasks in the domain.

3.3 An Illustration of the Elaborated Framework

To quickly illustrate the application of this framework to data, we use the episode presented earlier in which J describes a ball toss.

> J: When you throw it, you're giving it a force upward, but that force can only last so long…
> So you give it this initial force, and its going up just fine, slower and slower because gravity is
> pulling on it and pulling on it. (diSessa, 1996, p. 720)

First we examine R1 – the relationship between the task and the domain of *mechanics.* Professional physicists likely do not sit around discussing the forces present when a ball is tossed into the air. However, a large part of the domain of *mechanics* is describing and explaining various physical phenomena using the unifying theory of Newton's Laws. Thus this task is at least reasonably representative of a part of the domain. It is important to note however that there are other kinds of tasks (e.g., prediction) and tasks tapping other content (e.g. kinematics or circular motion) relevant to the domain. We certainly should not presume that once we have identified the character of the knowledge J uses in this task we will necessarily have mapped out her intuitive knowledge pertaining to the entire domain of *mechanics.*

We next examine the character of the knowledge J applies to this task. First, the content of J's intuitive knowledge involves notions of forces and balance. From this one excerpt, it is difficult to tell the form of that knowledge – it may, for example, be small pieces of general abstracted knowledge (diSessa, 1993) or it may reflect a more systematic theory of motion (McCloskey, 1983). Whatever its form, the knowledge J employed here likely originated from her experiences navigating the physical world and is thus directly applicable to tasks of this sort. Thus R2 – the relationship between the knowledge and the task – seems relatively direct. J is using knowledge of motion in the physical world to answer questions about the same type of phenomenon; it is unlikely that she has repurposed that knowledge.

Notice what the framework does for us in this example. First, it forces us to focus on the manner in which the task relates to a formal scientific domain. We must ask: Is this task representative of my domain of concern? Of what parts is it representative? It also forces us to be more reflective about the particular bodies of intuitive knowledge drawn upon, including what that knowledge might look like, and where it might come from. More generally, it forces us to be more circumspect, and to follow certain strictures in drawing conclusions about "intuitive knowledge relating to Domain X."

Example Applications of the Framework to the Research Literature

To demonstrate the usefulness of the framework, we show how its application can bring additional clarity to two ongoing lines of research in the conceptual change literature. In what follows we carefully attend to the research tasks from this literature and use the constructs of R1 and R2 to reframe the discussions. Specifically, we address:

1) Coherence vs. fragmentation of intuitive knowledge – Conceptual change researchers are divided over whether students' intuitive science knowledge is "theory-like" and coherent or less consistent and more fragmented. We analyze research on students' intuitive knowledge of cosmology, namely their understanding of the shape of the earth. In this conceptual arena, Vosniadou and her colleagues (Vosniadou & Brewer, 1992; Vosniadou, Skopeliti, & Ikospentaki, 2004) advocate coherence while work by researchers in the UK and Australia (e.g., Nobes et al., 2003; Siegal, Butterworth, & Newcombe, 2004) suggests fragmentation.

2) Task selection – Research on the nature of intuitive biology spans many academic cultures, from science education to psychology to anthropology (e.g., Carey, 1985; Medin & Atran, 1999). Within this varied work, however, there is a consistent tendency to almost exclusively probe students' understanding of issues of categorization. We analyze the consequences of this narrow focus for science educators interested in tapping students' intuitive knowledge relevant to biology.

Coherence vs Fragmentation: Intuitive Cosmology

Research in a variety of conceptual domains has sought to describe the character of students' intuitive science knowledge (e.g., Carey, 1985; diSessa, 1993; McCloskey, 1983; Vosniadou & Brewer, 1992). Two major contrasting theoretical positions regarding the nature of that knowledge have emerged from this work. One position – "coherence" - contends that "intuitive knowledge can be conceptualized as consisting of a coherent and systematic set of ideas which deserve to be called a theory" (Vosniadou & Brewer, 1992, p. 527). These "naïve theories" held by students are said to be comparable to those held by scientists, at least in their coherence and consistency. The "theory" position attributes to students stable units of cognition for particular areas of thought that always govern how the student thinks about a set of circumstances (Hammer, 2004). In contrast, the other position – "fragmentation" - claims that "naïve ideas are many, diverse, and not theoretical in any deep sense" (diSessa et al., 2004, p. 845). In this view student knowledge is made of a large number of individual elements that are differentially activated in various contexts (diSessa, 1993). Each of these positions has a number of advocates in the conceptual change literature.

Here we focus on intuitive cosmology (or observational astronomy) - one domain where proponents of these opposing views of intuitive knowledge have sought to resolve the coherence/fragmentation debate. A variety of studies have attempted to characterize students' knowledge of the *shape of the earth* - a topic about which students are assumed to have both rich everyday experience and extensive cultural information to draw on. Generally, this research involves interviewing students of several ages using a variety of prompts each designed to give evidence about how they imagine the earth to be shaped. For example, students are asked both directly "What is the shape of the earth?" as well as questions such as "If you walked for many days in a straight line, would you fall off the edge of the earth?" During the interviews, students are also asked to create images (either 2D or 3D) of the shape of the earth or to select among images given to them.

On the coherence side, Vosniadou and her colleagues (Vosniadou & Brewer, 1992; Vosniadou, Skopeliti, & Ikospentaki, 2004) find that "there are a small number of well-defined alternative mental models of the earth which are used by children in a consistent fashion" (Vosniadou & Brewer, 1992, p. 575). They individually interview students using a 48-item questionnaire. Early in each interview students are asked to draw a picture or create a clay model of the earth; subsequent questions reference the students' own drawings. Through their analysis of student responses and drawings/clay models, Vosniadou and her colleagues identify five coherent models of the shape of the earth that students possess.

In response to these studies, other researchers use similar methods to probe student understanding of the shape of the earth (Nobes et al., 2003; Siegal et al., 2004). However, instead of having students construct their own representations, students are presented with three possible models for the shape of the earth (spherical, dual hemisphere – one for earth and one for sky, flat pancake) and asked to choose which is the correct shape. The rest of the questions in the interview either directly or indirectly make use of the model that students choose initially. Their analysis for this set of tasks reveals "little or no consistency occurring in the children's responses" (Nobes et al., 2003, p. 81) which supports the claim that students' "underlying knowledge structures of properties of the earth are fragmented" (Nobes et al., 2003, p. 83).

Each of these groups of researchers directly question the methods and results of the other group. On one side, Vosniadou et al. (2004) critique the forced-choice method of questioning and the use of non-student generated models, claiming that these methods "biased children in favour of the scientifically correct responses and masked the existence of synthetic models" (p. 205). In addition, they suggest that the Nobes et al. (2003) and Siegal et al. (2004) studies only test "whether children are able to recognize scientific information" (p. 207) and not the students' "ability to use this information generatively" (p. 208).

On the other side, Nobes et al. (2003) suggest that the analysis methods used by Vosniadou and her colleagues (what diSessa et al. 2004 call "model mapping", p. 861) to classify students' mental models are biased towards finding consistency. Both Nobes et al. (2003) and Siegal et al. (2004) question Vosniadou and Brewer's (1992) original study in which students drew their own representations of the earth, pointing to studies where results were heavily dependent on whether model selection or model generation was used. Siegal et al. (2004) criticize Vosniadou and Brewer's (1992) use of open-questioning, saying that it may mask student competencies.

Our framework can help us in teasing apart the issues of consequence in relation to this debate. First we note that we are dealing here with a domain of small "size." Even if we can agree on the character of intuitive knowledge relevant to this domain, we must be very circumspect about drawing conclusions about other domains, especially those that differ greatly in size.

Sticking within this small domain – the shape of the Earth, our framework tells us that there is likely not a *single* answer to the question of whether intuitive knowledge of cosmology is coherent or fragmented. Instead, we expect only to be able to answer the question of the form of intuitive knowledge *in relation to the tasks* used to probe that knowledge. The interview task gives us a window on student knowledge; we can look at particular tasks and see what knowledge they cue that might be relevant to the overall domain. Using this window allows us to be more careful about the knowledge claims we make than describing the entire domain.

Let us consider how orienting our analysis around the interview task plays out for the intuitive cosmology debate. Vosniadou and Brewer's (1992) interview is based on the task of generating a description for the shape of the earth. Their work suggests that this task draws on intuitive knowledge that is relatively coherent (form) and are likely generated both from everyday experience and from cultural pop-science (origin). Nobes et al. (2003) and Siegal et al. (2004) use a different type of task - selection among competing models. Their results indicate that this task draws on different intuitions than those identified by Vosniadou and Brewer, namely more fragmented piece-meal knowledge (form) that may have similar origin. These authors use different types of tasks (description vs selection) that have different content (providing models necessarily provides more content). As such, we are not surprised that they yield different pictures of intuitive knowledge.

We suggest that these different characterizations of knowledge arise not because one methodology got it "right" and the other got it "wrong," but instead because the knowledge that one accessed is in fact different from the knowledge the other accessed. Neither side can claim to have accessed students' "true" knowledge of cosmology; each side has gained some understanding of the knowledge students use *in particular tasks*.

These different tasks each give us insight into the different kinds of knowledge that students might bring to bear in reasoning in this domain. We could imagine both Vosniadou and Brewer's mental models and Nobes et al.'s fragmented elements contributing to students' understanding of astronomy concepts. An appropriate line of research might be to study how each of these types of knowledge contributes to learning the formal science domain.

4.2 Task Selection: Intuitive Biology

Research on intuitive biology presents another interesting case for us to consider. As with many science domains, intuitive biology has been a focus of research in science education. But intuitive biology is perhaps unique in the extent to which it has been a subject of interest to researchers in other fields. It has been studied by psychologists interested in more general issues of cognitive development (e.g., Carey, 1985), as well as by anthropologists and psychologists interested in the folk biological knowledge of various cultures (Medin & Atran, 1999).

Here we discuss one small slice of this varied research in order to illustrate the type of considerations that arise in applying our framework. Many of the tasks that are employed to study intuitive biology seem to hinge on issues of *categorization.* For example, children have been probed as to what things in the world eat, breath, sleep, etc. The results of these studies suggest that young children answer these questions very differently than older children. Young children seem to answer questions for specific animals by comparing those animals to humans whereas older children answer by making deductive inferences from category membership (Carey, 1985; Hatano & Inagaki, 1999). This difference is taken as an indication of a broad shift in children's thinking. For example, Hatano and Inagaki describe this change as reflecting a shift from personification to category-based reasoning (Hatano & Inagaki, 1999).

Let us now consider this research on intuitive biology through the lens of the framework we presented in Figure 2, particularly focusing on the research tasks employed in probing student intuitive knowledge and their relationship to the formal domain (R1). As we suggested above, some research on intuitive biology has featured an emphasis on issues of categorization. The framework guides us to ask "How sensible is that focus?" It differs sharply, for example, from the types of tasks that are typically employed in research on intuitive physics where the tasks usually involve prediction and explanation as well as attention to mechanism. Is this difference in the type of tasks employed reflective of real differences between these two fields, or is it just an accident of the particular manner in which the research endeavors have played out? If it is the former, then we can be more comfortable in use of these very different tasks for probing student knowledge. If it is the latter, then we might need to be more careful in drawing conclusions about the nature of intuitive knowledge in biology based on these tasks.

It does not seem entirely unreasonable to conclude that biology, in comparison to physics, is in some ways more concerned with issues of categorization. Biology *is* concerned with cataloguing the variety of kinds of organisms that exist and documenting the distinct sub-structures and behaviors possessed by these organisms. There is not an obvious a parallel focus on categorization in physics. However, it is manifestly not the case that biology is all about categorization (R1). For example, it equally involves attempts to understand mechanism. Why, then, do researchers believe that these types of tasks are so central for understanding intuitive biology when they are clearly not entirely, or even largely, representative of the formal domain?

Let us turn our attention to R2, the relationship between tasks and intuitive biology, as it is often understood in research on intuitive biology. For researchers such as Carey and Hatano, although the classification-focused tasks are not seen as providing an exhaustive map of intuitive biology, they are understood as providing *indicators* of the broad character of developmental changes in intuitive biology knowledge. This viewpoint makes sense particularly if one adopts a view (as many of these researchers do) that cognition is modular and domain-specific, and that one module may be associated with intuitive biology. However, for education researchers, this privileged role given to categorization-focused tasks needs some additional consideration. Whether or not we believe that individuals possess an intuitive biology module as part of their knowledge, it seems certain that the reasoning tasks associated with formal biology are going to draw on repurposed knowledge. For example, if we were to teach students some of the basics of biochemistry, it is likely that we are going to draw on intuitive knowledge that is more generally associated with physical mechanism. Thus, if we care about the learning of classroom biology and facilitating conceptual change in that domain, we need to know more about this wider range of knowledge; we need to consider a range of reasoning tasks that are more broadly characteristic of the domain (R1).

5 Discussion

Education research has rightly devoted significant effort to understanding the intuitive knowledge that students bring to bear in reasoning about formal science. Developing effective instruction that supports conceptual change relies, at least in part, on having accurate and detailed descriptions of that knowledge. Work has been done in a variety of domains, and there is a fair amount of disagreement both within and across domains over the characterizations of knowledge that have emerged. Implicit in these disagreements is the assumption that there is a single kind of thing called "intuitive science knowledge" that spans all domains and can, in principle, be singularly characterized. Here, we questioned this assumption of the domain uniformity of intuitive knowledge. We problematized the construct of "domain" and exposed issues with both the variability and repurposing of intuitive knowledge. We then offered a "meta-framework" that addresses these concerns and provides a way to more carefully frame our research on intuitive science knowledge. We briefly illustrated its application to student data and then demonstrated how it can be used to bring additional clarity to current discussions in the research literature. We hope to have encouraged reflection on the assumptions underlying research on intuitive knowledge, and offered a framework to guide our thinking such that those assumptions will not inappropriately influence our characterizations of intuitive knowledge.

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