J’s Epistemological Stance and Strategies

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Introduction

Theoretical Framework

The focus of this chapter might be described as “intuitive epistemology,” what people know about knowledge, knowing, and learning, as acquired from their experiences in everyday life and in school. The study of students’ epistemological ideas has become increasingly active in recent years; see Hofer and Pintrich’s (1997) review article. In general, this research has validated the principle that students have ideas about knowledge that affect their learning in significant ways. What we say here continues in that direction.

Our approach to intuitive epistemology, however, differs substantially from most prior studies. In particular, most prior research has taken what we describe as a categorical approach. A prototypical categorical strategy is to attribute particular beliefs to students. “A student believes that knowledge is simple and unproblematic.” (Schommer, Crouse, & Rhodes, 1992) Or, “knowledge is always subject to questioning and change.” (Linn & Songer, 1993) We describe these attributions of belief as categorical because they presume a consistent attribution to the student without attention to context, for example, that elements of the belief exist as coherent categories within the student’s conceptual repertoire, and that the student behaves consistently with respect to the stated belief. Researchers usually recognize that there are often exceptional circumstances and difficulties in data. However, unless researchers explicitly take on the issue of context dependence, we describe the approach as categorical.

A categorical approach typically divides students into classes (e.g., those that have, vs. those that do not have some belief); students within the class are assumed to behave similarly to one another, and the research program does not explicitly include the reasons for variation of behavior across people and across circumstances. More subtle and complex approaches may still be aptly described as categorical. For example, stage theories (Perry, 1970; Kitchener and King, 1994) are likely to be categorical at each point in time. Multidimensional frameworks (Schommer, 1990; Hofer and Pintrich, 1997) still may presume coherent belief-like attributions (most obviously at poles of the continua) and may not explicitly describe context dependence of the positioning of a subject between the poles.

In this chapter we examine categorical approaches to intuitive epistemology critically. In part, we are motivated by prior work on “intuitive physics,” students’ unschooled ideas about the physical world. diSessa (1993) argues that intuitive physics is best understood as made up of hundreds or thousands of fine-grained, context-sensitive knowledge elements. Views of intuitive physics that attribute to students a smaller

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1 Hammer and Elby (in press) use the term “unitary” instead of “categorical.” The intended meaning is similar.
number of more coherent structures—naive theories, beliefs, or misconceptions—greatly underestimate the richness and generativity of students’ reasoning about physical phenomena. Moreover, such views assume too much systematicity in intuitive thought. If many context-sensitive elements are at issue, then any description in localized form (e.g., as the possession of a theory or misconceived belief) almost certainly overestimates either the power of a single element to control thinking or the organization of multiple cognitive elements into a coherent whole. This is not to say that students’ reasoning about physical phenomena always lacks coherence and systematicity. What we question are theoretical frameworks and attendant methodologies that presume such coherence and systematicity (or choose not to examine them explicitly), and as a result may overlook evidence in students’ behavior of the context-sensitive activation of finer-grained knowledge elements.

We expect a similar state of affairs in the study of intuitive epistemology, that categorical approaches (a) underestimate richness and generativity and (b) presume too much systematicity. Our main purpose in this chapter is to probe the validity of categorical approaches in these respects against a case study of an individual student.

It may be helpful to lay out a rough model for scientific description of individual cognition (or, perhaps, of any focus of scientific inquiry). In general, we expect to find a level of description we could call “causal.” A successful account at the causal level would explicate the details of action in context to explain a person’s behavior in any instance. We might, for example, have a computer model that shows exactly which knowledge elements are activated and how they combine to produce the behavior observed. diSessa’s (1993) account of phenomenological primitives is an example of a framework for formulating causal level descriptions of intuitive physics.

Causal level descriptions are very difficult to achieve, however, and we do not attempt one here.2 At the opposite end of the spectrum from causal level descriptions, common sense tempts us to make phenomenological attributions, such as “he believes people are stupid” when someone seems systematically to disregard others’ ideas. Between causal and phenomenological levels we should expect levels that have the advantage of simplicity compared to causal descriptions, while still demanding more accountability to detailed specification and consistency than commonsense phenomenological descriptions. We make generalizations about individuals and groups based on critical analysis of their cogency and based on hypothesis checking across multiple circumstance; we expect these generalizations to be insightful for their relative breadth even if they do not hold in every instance. Categorical accounts lie in these intermediate levels of description. Our work here is, in part, to make exceptions to the application of categorical descriptions evident in order to assess more precisely what these accounts have traded off, mainly in terms of adequate specification of context dependency, for their relative simplicity.

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2 We have discussed the needs and begun to explore possibilities for such an account of intuitive epistemologies elsewhere (diSessa, 1985; Hammer and Elby, in press).
To study the reasoning of an individual in detail is to work outside mainstream categorical methodology. Categorical work usually seeks correlations across large numbers of subjects rather than attempting analysis of specific cases of epistemologies in action. This lack of attention to detailed analysis is a critical omission, in our view, because theories of intuitive epistemology need—eventually—to provide accounts at the causal level. We need to assess how much we are missing at various higher, coarser-grained levels of analysis and to get a sense of the context-sensitive behavioral dynamics that causal-level models will need to encompass.

Setting in This Book

This section briefly positions the present chapter with respect to the main interests of the book, intentionality and conceptual change.

Conceptual change is, in our view, best defined phenomenologically. In wide-spread instruction, students demonstrably have great difficulty with a few particular topics. Force and motion is one such topic, which we pursue here. Others include evolution, the nature of matter, and the distinction between heat and temperature. The fundamental questions are (a) what accounts for observed difficulties, and (b) how may they be overcome? We subscribe to the term “conceptual change” to indicate that we presume difficult topics are difficult because of a substantial change in existing knowledge that must take place. We do not, however, believe that “concepts” necessarily describes what changes, nor even that “what changes” necessarily characterizes the learning process. More directly, we believe that some conceptual accomplishment is difficult because of the huge amount of reorganization that must take place, and frequently because unusual kinds of systematicity are required of expert thought. (See diSessa, 1993; diSessa, 1996; and diSessa & Sherin, 1999.)

Since intentional learning means different things to different people, we describe our orientation here along several dimensions. These dimensions are drawn from the introductory chapter by Sinatra and Pintrich. First, intuitive epistemology may be classified as metacognitive in two senses: (a) It is knowledge about cognition, broadly speaking, and is likely to have arisen from the subjects’ experiences of their own reasoning; and (b) it is likely to be involved in executive or control functions in thinking. For example, a student may judge that her knowledge is sufficient, and therefore cease studying. That judgment involves her sense of what constitutes sufficiency. Another person might have “higher standards,” and continue working to try to understand better. In the study that follows, epistemological ideas exert obvious controlling influences.

The “intentional learner” in the sense of Bereiter and Scardamalia (1989) is not the same thing as the “epistemologically wise” learner. The intentional learner orients specifically toward learning goals; an epistemologically wise student knows what to do if she chooses learning goals. Epistemological knowledge may be more instrumental than directive. It is an open question which is more influential in learning: deliberately setting learning goals or easily being able to attain learning goals that arise spontaneously. If it turns out that one always learns best by focusing directly on
learning, then a good intuitive epistemology might, in fact, involve being an intentional learner. But a categorical adherence to learning goals may, for example, limit experience and rely too heavily on limited knowledge subsystems (e.g., the ability to judge what one must do to learn). Being intentional may simply be impossible in certain circumstances in overcoming epistemological problems. We’ll return to this issue in later analysis.

Perhaps most central to intentionality as discussed by Sinatra and Pintrich are two foci: goal formation and consciousness. As mentioned above, intuitive epistemology seems to play an important role in goal formation in learning and problem-solving tasks. Students “reflect on” their current knowledge state, make judgments, and take actions they feel are necessary. This notion of reflection may be misleading. At least some of this “reflective” knowledge is implicit and reactive (Schoenfeld, 1992) and so would not meet the high standards of conscious goal formation. To be sure, as our study affirms, some parts of epistemological thought appear in conscious and deliberate form, satisfying the strongest standards for intentionality. We caution, however, that even in these cases there is almost certainly a strong undercurrent of implicit knowledge involved in the process of “noticing,” “judging,” and a strategy’s “coming to mind” that would not pass the consciousness test. We feel this is neither a limitation of intuitive epistemology nor evidence that intuitive epistemology is not related to intentionality. Instead, we believe it is a fact of life that the most conscious thoughts and actions rely on a critical and frequently invisible substrate of unconscious thought. That is, there is no account of “conscious goal setting” that does not depend critically on an unconscious and inarticulate substrate (see also diSessa, 1994).

In this chapter we deal with intentionality from the bottom up. That is, we look at an individual and occasions where she appears to involve her intuitive epistemology. Then we will try to characterize the relation between the student’s behaviors and intentionality, including consciousness and goal formation. In particular, we will try to assess the plausibility that a “belief” (conscious or unconscious) could account for her behaviors. Although the bottom up approach certainly has limits and disadvantages, it meshes nicely with the more-detailed-than-usual way in which we propose to explore the nature of intuitive epistemology.

**Nature of the Study and Its Conclusions**

This chapter presents a case study of one individual. As such, it has obvious weaknesses, but also some important strengths. Most obviously, we cannot conclude that all people are like the subject, nor even that anyone else in the world has a similar epistemological orientation. Beyond that, the study is exploratory and will result in hypotheses (a) about this student, (b) about what epistemological knowledge people have and don’t have, (c) about the form of epistemological knowledge (e.g., whether it is belief-like), and (d) about how epistemological knowledge works in learning and problem solving. None of the hypotheses will be definitively established, although we

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3 In fact, the subject was selected precisely because, as we will discuss, she provided an especially clear case of the difficulties inherent in categorical attributions.
feel many competing hypotheses can be ruled out by the facts of this case. Specifically, we believe we can rule out many categorical descriptions of the subject’s epistemology as consisting of global beliefs and/or personal traits.

The strengths of case study methodology are several. Most strongly, we should see context-dependent richness in the details of a subject’s actual reasoning, if such richness exists. Although individuals may behave quite differently from each other at this detailed level, still the degree of context dependence should be indicative. Observations of context dependency can challenge specific categorical characterizations and also the cogency of particular levels and types of description. Even more, we believe it is appropriate to look to the phenomenology of reasoning in order to generate hypotheses about the nature of epistemological thinking. Too much prior work on epistemology involves speculation about what might or should count as epistemological knowledge, without the hard test of looking at process data. A case study can show how epistemological knowledge actually affects the students’ learning and reasoning; by contrast, categorical studies typically provide general evidence of the influence of epistemology on behavior in correlations across many subjects. Our strongest results will be precisely here: Struggling with actual student reasoning, we will develop an unusual set of hypotheses about the specific nature and dynamics of an individual’s epistemological knowledge and how it affects learning.

The Case of J
The subject of this case study, whom we call J, was a female freshman taking introductory university physics. She was interviewed in a series of seven roughly one-hour one-on-one clinical sessions with the first author. The interviews spanned the second half of her first semester of physics and carried into the second semester. J had done well in high school physics and did not seem to be having particular difficulties in freshman physics. All of the interviews were videotaped and transcribed. The analyses that follow are based on repeated viewing of the video tapes and review of annotated transcriptions. Roughly speaking, we reviewed the data, looking for hypotheses about J’s epistemological knowledge. Then we collected data, positive and negative, relevant to each hypothesis. Finally, we rejected hypotheses that were sufficiently undermined and refined those that passed the preliminary data test.

The interviews were not originally intended to probe epistemology; they were intended to study the local dynamics of conceptual change. In J’s case, however, epistemology appeared to play a substantial role in those dynamics, and the interviews raised provocative questions with respect to the nature of her epistemology. For example, although J was unusually creative and prolific at formulating interpretations of physical phenomena, she appeared to reject the obligation to justify some of her interpretations. Despite a demonstrated ability to identify and think through contradictions (on occasion), she often did not seem to feel that what appeared to us as contradictory interpretations needed reconciling. Thus we initiated study of J’s epistemological ideas precisely because some of her tendencies seemed more pronounced than what we’ve seen in other students. She seemed to be quite aware of epistemological issues, but took
actions at odds with our instincts as physicists, and frequently at odds with what we thought a sophisticated physics learner would do.

Some simple hypotheses about J’s epistemological orientation were fairly easy to rule out. J was clearly bright, reflective, articulate and at least as engaged as most students whom we have interviewed. She was articulately cognizant of the fact that learning requires changing prior ideas. While early on we might have described her as careless or disengaged, a large amount of data convinced us that these are insufficient to characterize her on any global level. J often appeared to be seriously engaged in thinking about the problems posed and took extended self-directed paths to consider and check possibilities. Although her physics seemed rich in intuitive ideas, this, by itself, did not separate her from typical freshmen. In the end, we took on the task of characterizing those aspects of J’s thinking that appeared epistemological, and to try to fit them into an overall pattern.

Our analysis comes in three parts. First, we describe some of the interesting patterns of behavior we found repeatedly in the interviews, together with examples and evidence. Examples will mainly take the form of fairly direct descriptions of what happened in the interviews, protocol citations, or both. We describe these as “behavioral phenomena,” and we intend them to be more data driven than theory driven. However, in clumping data into categories, naturally some interpretation is necessary. Second, we return for a more synthetic and interpretive look at the systematicities in J’s epistemological behavior. This amounts to a second, coarser level of description. Finally, we argue that the evidence of richness and context-sensitivity undermines characterization of J’s epistemological behavior in terms of global traits or systematic beliefs. In other words, we use J to argue that a categorical approach ignores details essential to a causal understanding of intuitive epistemology.

**Behavioral Phenomenology**

Before entering into detailed analysis, we preview the epistemologically loaded behaviors that we noticed in J.

1. Shifting Interpretations: J gives contradictory accounts of the same situation on different occasions.
2. Splitting Concepts: Technical terms, most notably “force,” are used in multiple situations in ways that imply different core meanings. It is as if J thinks there is a range of fundamentally different kinds of forces.
3. Migrating Language: J uses alternative technical terms (force, momentum) in the same contexts as if the terms were interchangeable.
4. Weak Commitment to Principles: J denies or demotes known-to-be-sanctioned physical principles because she feels her context-specific understanding is adequate.
5. Discounting Details in Explanations: J does not appear to feel she is bound to justify the existence of elements in her explanations.
6. Hedging: J frequently and explicitly shows limited commitment to what she is saying, or she provides explicit notification of vague meaning.
7. Strong Commitment to a View: J is, on occasion, capable of careful, conscious consideration leading to strong personal commitment to particular ideas.
8. Reflective about Learning: J thinks about learning and has drawn many sensible lessons from her experience.

Although items 1 through 6 may suggest that J has a weak or maladapted intuitive epistemology, items 7 and 8 are particularly important in qualifying that view. In particular, 7 and 8 define occasions when J violates many generalizations one might make about her with regard to the systematicity and weakness of her epistemological knowledge.

1. Shifting Interpretations
J sometimes provided multiple interpretations of the same events. This is not in itself surprising in students. J’s shifting interpretations, however, especially in one instance, had several striking properties. First, J shifted her interpretations frequently. Sometimes she would reverse several times in a single session, and in a matter of seconds from one to another. Second, she sometimes did not converge on one interpretation, even after extended work on a problem. With more typical students, one or another interpretation generally becomes “standardized.” Finally, J seemed not to notice or care about multiple interpretations that, to us, were blatantly contradictory. In the principal example that follows, concerning a ball tossed straight up into the air (after it leaves the thrower’s hand), she first claimed there was only one force (gravity) acting on the ball, and then, seconds later, she claimed there were two interacting forces. (To a physicist, there is only one force on the ball, the force of gravity. Gravity at first slows the ball in its upward motion, then accelerates it downward. There is nothing particularly distinguished about the peak of the toss. Gravity doesn’t change size or direction, no new force enters or leaves the situation, nor does gravity enter into some special relationship (such as balance) at the peak.)

The interviewer introduced the ball toss in J’s third session. The following quotations are sequential, and nothing is left out between the introduction of the task, her first interpretation, and her revised interpretation. (In transcriptions, we denote breaks, abrupt halts, or interruptions by the second speaker by “//”. Brackets enclose explanatory notes or parallel comments by the second speaker. Ellipses denote speech omitted from the transcript. Before each extended quotation we denote its position in the corpus as [<interview number> <hour>:<minutes>:<seconds>].)

[3 0:2:23]
A: I want to ask you about tosses. So um. Alright so, I’ve got this thing and I just throw it up in the air [tossing a ball and catching it], and // would you describe for me in a physics kind of way what’s happening when you do this?
J: In terms of forces, or energies, or both or whatever?
A: Forces.

In J’s subsequent description, she twice proclaimed that, after the hand released the ball, there would only be one force on the ball. She produced a description of the toss that
was, for all practical purposes, correct. Emphasis is added below to bring out her contrasting interpretations.

[3 0:2:30]
J: Not including your hand, like if you just let it go up and come down, *then the only force on that is gravity*. And so it starts off with the most speed when it leaves your hand, and the higher it goes, it slows down to the point where it stops. And then comes back down. And so, but the whole time, *the only force on that is the force of gravity*, except the force of your hand when you catch it. And, when it starts off, um, it has its highest speed, which is all kinetic energy, and when it stops, it has all potential energy—no kinetic energy. And then it comes back down, and it speeds up again.

A: Sounds like a textbook problem.
J: It’s more just like the first thing you learn.
A: Do you remember how you thought gravity worked before you took physics?
J: Well I think on a ball it’s pretty obvious how gravity works, but I don’t remember how first I learned gravity works.

The interviewer then asked about the peak:

A: Could you describe what happens at the peak of the toss?
J: Um, well air resistance, when you’re throwing it, when you throw the ball up, the air, it’s going // I mean, it’s not against air because air is going every way, but the air force gets stronger and stronger to the point where it stops. The gravity *pulling down and the force pulling up are equal*, so it’s in like equilibrium for a second, so it’s not going anywhere. And then, um, gravity pulls it back down. Like *when you throw it, you’re giving it a force upward, but the force can only last so long against air and against gravity*—actually probably more against gravity than against air. But, um, *so you give this initial force, and it’s going up just fine, slower and slower because gravity is pulling on it and pulling on it*. Um, then it gets to the point, to the top. And then, um, *it’s not getting any more energy to go up. You’re not giving any more forces, so the only force it has on it is gravity and it comes right back down.*

… [One of J’s turns is omitted during which she explains that you are not giving the ball any more force at the top.]
A: So is it like balanced at the top?
J: Yeah. For a second.
A: What’s balancing?
J: It’s I mean // I guess you could say that it’s balancing because *I guess the force of gravity is equal to [brief pause] I guess you’d say whatever is left of the force you gave it at the beginning* so that neither one is larger than the other for it to go anywhere. But that’s only for like a second. But you can say it’s in balance for a second.

diSessa(1996) provided an account of the intuitive physics underlying J’s reasoning, focusing on what provoked J to add a second force to her description and on some of the details of the transition. The relevant point with respect to J’s intuitive epistemology, is not that she so easily changed her account but that she made no remark about it. It is hard to imagine she did not notice having changed, within seconds, from saying there is one force to saying there are two. More likely, she did not consider it worth noting, partly because she doesn’t see the two interpretations as being different (see snippet [7 1:17:50] below). This suggests an epistemological judgment that a change in description (e.g., from a one-force explanation to a two-force explanation) does not actually represent a change in interpretation.
J continued to tell some version of this two-force story until some minutes later when the interviewer prompted her to think about acceleration. J then entered into a fairly extended reasoning chain, supported by occasional interviewer prompts. The final part of this exchange brought her to the “school” interpretation that gravity is the only force, and gravity accounts for the acceleration that reduces velocity.

[3 0:22:30]
J: If you took the ball and pushed it up, pushed it up, pushed it up // kept giving it these new forces, new forces, then it wouldn’t be constantly accelerating because acceleration would be changing. You’d be going fast and then slow, fast and slow. But when you just throw it up and let it come back down, then the only force on it is gravity so the velocity is changing, but the acceleration is constant. And so I think that this [drawing of constant acceleration] is better because the acceleration is constant, but it’s negative and the acceleration is still constant, which is [unintelligible] [nods head]
A: Now what you have is the force of gravity, and that’s always the same amount.
J: Right.

J could not hold this interpretation stable. The interviewer pointed to a previous diagram where she had both gravity and the imparted force of the hand displayed, and, although apparently a bit surprised, she resumed the double force story.

[3 0:23:30]
A: So gravity’s always pushing that way. Gravity’s a constant. So if you have // okay, and you said that, going down, this upward force [pointing to the diagram] is all gone, is that right?
J: Right.
A: OK. So it [the second, upward force] just starts at some maximum and goes down to zero and just stays at zero. Is that what it does?
J: Oh, the force? Yeah. It like dissipates. It has a certain amount of energy at the beginning, and it slowly dies out, and it’s gone.

The saga of the toss and its two interpretations is a truly extended one. In the next to last interview, J was given a computer-based instructional sequence designed to teach the one-force model of the toss. With barely a lapse, J progressed through the instructional sequence without invoking the upward force. The tutorial culminated in J providing a perfect and detailed single-force accounting of what happens during a toss.

As the final probe of the whole interview series, the interviewer switched off the computer that had apparently scaffolded a local stability for J’s one-force conceptualization. He asked her again to describe what happens in a toss. At first, she gave the one-force story (mixed a bit with a correct account of energy changes in the toss), even emphasizing that there is only one force (italics below). Prompted simply to remove the energy part of the story, J revised, and, without comment, resumed the two-force story.

[7 0:59:00]
A: Describe one more time what happens.
Okay. You start off and you give the ball an initial velocity, and that comes from the force from your hand. And then, it travels with that momentum. And, once you let it go, it has no outside forces. The only force it has on it is one force downward, which is equal to mg, the mass of the ball times gravity. And, so, it goes up and as it goes up, its kinetic energy decreases because it’s not getting any energy from any outside forces, until it gets to the point where velocity is zero for a split second. And that’s where it has all potential energy and no kinetic energy ‘cause it’s not doesn’t have any more. And then comes back down. And then comes off slow and then picks up speed because of the force downward. And then you catch it again and stop it.

A: Okay. So, um, could you describe that just in terms of forces?

J: Okay, starting from when it leaves your hand. [Sure.] Okay, initially, it has force up and a force down. And the force up is the force that you gave it. And the force down is mg. And the force down stays the same all the whole time. [omitted details] The force up is what changes. Because, it starts off big and as it goes up it gets smaller and smaller and smaller. So, it’s just like the forces are adding just like vectors. And, so, at the top, when it has no velocity, is the point where the vectors are the same for a second. And then, this force stays zero, and this force [gravity] overcomes it and then goes back down.

A: What vectors are the same at the top?

J: [coyly] The up one and the down one.

A: The down one is what?

J: Mg. [OK.] And the up one is the external force that you gave it with your hand.

In Appendix A, we document another case of Shifting Interpretations having to do with what is happening in the case of constant speed motion. In this case, J shifted in and out of claiming an unbalanced force is required for motion. In order to keep the size of the chapter manageable, we leave details out of the main text.

Commentary: It should be expected that students will change interpretations of a problematic situation. J, however, seemed indifferent to two apparently radical changes: the number of forces acting on a tossed body, and whether unbalanced forces are needed for constant motion. She did not note or worry about these shifts, even over an extended set of encounters that, for example, included instruction on a one-force model of the toss. When asked point blank about her two different interpretations of the toss at the very end of the last interview, J replied that she didn’t really feel there was a difference between the two interpretations. It seemed a matter of language to her, and she had merely learned to “use the right words” in the one-force explanation.

According to physicist standards, J is making inappropriate judgments about the compatibility of different descriptions, which we interpret as an epistemological issue.
Notably, J acknowledged that “somebody watching” would think that she had changed her story; she accepted the fact that she had nominally changed her account. She thinks, however, that there was no change in her understanding, only in the language. We could not determine, based on this data alone, to what extent she was correct in this. However, two points are more definite. First, by the standards of physics, one cannot sustain both one- and two-force interpretations. They are different claims about a situation. Second, diSessa (1996) provides an interpretation of J’s two descriptions that implicates specific conceptual changes, in particular, a shift in activation of specific p-prims. In net, we believe the most plausible interpretation is that she is genuinely thinking differently in the one-force and two-force cases, and that it is unusual that she doesn’t feel any contradiction.

Our purpose here is to understand J’s epistemological stance and strategies in these interviews.4 How can we make sense of the ease with which she was willing to shift interpretations? One approach is to identify contexts in which her actions would not seem out of place. Everyday experience often involves feelings, thoughts, and ideas that are “hard to put into words” and that admit multiple, seemingly contradictory accounts, each trying to point toward the intangible from a different direction. J may have been applying such an epistemological stance to her reasoning about the toss, producing behavior that, to physicists, seems very strange. J’s behavior, however, is not bizarre; it is just contextually inappropriate by the standards of physics.5 Below, we will have more to say about her stance toward language.

On a higher plane, the strategy of analysis we just used with J—noting a context in which the epistemological strategies she employs may be appropriate—goes to the heart of the difference between categorical approaches to intuitive epistemology and the contextual approach we advance here. Again, J is not doing something that is absolutely wrong. Instead, it is a contextual issue, her use of an otherwise productive strategy in an inappropriate context, that defines her epistemological orientation toward learning physics. As a bonus, understanding the contexts in which counterproductive physics-learning strategies correspond to sensible epistemological stances can help teachers map instructional pathways; teachers can help students adapt (and in some cases contextually limit) their naïve epistemological knowledge to construct a more sophisticated stance toward physics knowledge and learning.

**Intentionality:** What do we make of these situations and this pattern of behavior from the point of view of intentionality? First, it is difficult to see how J could even potentially formulate a goal that will help her directly in this context. Rather, (at least in the case of the toss) she apparently doesn’t perceive sufficient difference between her

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4 We are not suggesting that J’s behavior is entirely a matter of epistemology. Clearly J’s intuitive physics plays a role here. So may her feelings in this moment about admitting having been wrong: J may be trying to cover herself. Still, her epistemology is implicated in that she considers saying that her accounts differed only in language a plausible way to defend her earlier arguments.

5 Reasoning in physics does often involve multiple accounts of the same phenomena. For instance, one may describe a toss in terms of forces or in terms of energy. However, these multiple accounts are expected to be rigorously and explicitly consistent with each other. One force cannot turn into two.
interpretations to warrant any concern that would motivate a relevant action. Furthermore, the most obvious beliefs one could formulate to explain her behavior, say, “you don’t have to be careful of description,” or “any two descriptions are the same,” simply don’t make sense categorically. J knows that sometimes you need to be careful (as we show later), and sometimes different words make a difference. Instead, following the arguments above, we propose that J’s epistemological orientation is embedded in a judgment in context, which responds to the particulars of this situation (in what turns out to be an epistemologically unproductive way). In this case she judges that her different descriptions are not sufficiently different to worry about.  

2. Splitting Concepts

J acted as if she believed that the designation “force” could apply to different kinds of entities, without being constrained by common properties. By contrast, to a physicist, all exemplars of technical categories share a core set of properties. For example, all forces have a magnitude and a direction, and they all relate to motion in exactly the same way (as described by $F = ma$). As far as we could see, J neither expected nor searched for core common properties among different kinds of forces. Instead, she acted as if different forces merely had a family resemblance to one another, like the multiple senses of everyday words.

We give several examples. First, J essentially claimed that the force of air pressure can never enter into the physics of a situation (except as air resistance to motion). She said that pressure acts in all directions at once, and hence cancels out: (Again, emphasis is added, below, to highlight focal statements.)

[2 0:43:30]

J: It’s [air pressure is] just everywhere, you know. It’s not moving in one way to make the book move, because the book’s not going anywhere. You could say there’s air pressure on every point, but there’s air pressure going the exact opposite way on every point too. So it all completely counteracts. And it doesn’t play a part.

Even when prompted by the interviewer’s calculation of the amount of force on one surface of a book (14 lbs. per square inch times about 30 square inches of book surface area = about 450 lbs. of force, “So, there’s quite a lot of pressure on this book.”), J replied, “Not enough to make it move,” as if 450 lbs. were a small force. She later explained, “But air pressure is every which way…. I can’t think of air pressure as being this way [gestures pressing on a book].”

J also explained that friction is a special kind of force that could never actually move things. “The friction is just sitting there; it’s just there and it’s something that just resists, you know, it doesn’t actually like physically push.” According to physicists, while friction forces come and go in unusual ways, when they act, they have identical core properties

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6 To be a bit more precise, we would see J’s epistemology acting in two stages. At first, she either doesn’t notice these different interpretations of the same situations, or she may, implicitly or explicitly, regard them as unproblematic variations. At the next stage, e.g., when the issue is raised explicitly with her, she is aware of and directly reports a judgment in context: “these differences don’t matter.”
to other forces. They have direction and magnitude and can initiate motion as well as stop it (e.g., when a stationary box is dropped on a moving conveyor belt).

On other occasions, J treated gravity as having different possibilities with respect to motion compared to other forces, and she did the same for the “normal force” a table exerts to support a book lying on it.

Commentary: Some conceptual aspects of J’s thinking are not unusual. Students often think of friction as acting only to resist motion, and they often believe some forces (e.g., normal forces) are special in some ways. However, our attention here is on extreme behaviors that we can interpret as expressions of J’s epistemology. J seemed extreme in her willingness to split concepts, which is a counterproductive attitude toward physical concepts. Our judgments that J is extreme in particular ways (this one included), of course, relies on experience that is not documented here and is subject to further empirical scrutiny.

Shifting Interpretations is in a sense opposite to Splitting Concepts. In one case, J allows two descriptions of the same situation (e.g., two forces are involved, or only one), and in the other, she feels the same word (“force”) may apply, yet the situations are different in important ways (air forces and friction forces don’t actually push like other forces). In the case of Shifting Interpretations, she felt intuitively that each (different) description was appropriate, despite strong cues of contrast (e.g., asserting the existence of two forces in one case and one in the other). In the case of Splitting Concepts, she feels intuitively that descriptions need to be differentiated, despite cues of similarity (e.g., the use of the same technical term, force; only one version of \( F = ma \) for all forces; and the fact that, presumably, her physics instructors and text never distinguished types of forces in their core, causal properties).

At the general level, J is not reading certain classes of cues about similarity and difference (i.e., similarity among exemplars and what constitutes a significant difference in description). In particular, it seems J does not draw a meta-conceptual (possibly meta-linguistic) distinction between everyday terms, exemplars of which may share only family resemblance, and technical terms, which require a core similarity between exemplars. J’s behavior is sensible when applied to everyday terms such as “food.” In various contexts of everyday use, it is often appropriate to split the general idea of food into a variety of related ideas that do not necessarily share common properties, or a common definition. It is, for example, a simple matter to find exceptions in everyday use to definitions such as “something you eat” or to “something that provides nutrition.” Depending on context it may or may not be appropriate to consider “salt,” “water,” “vitamins,” or “candy” as food. The philosophically classic example of an everyday category whose members share no definitive properties is “game.”

Intentionality: As with Shifting Interpretations, it is implausible that J could, on her own, formulate any obvious goal to help her out precisely here. Given her reading of situations and of her own descriptions of them, it would not be sensible to “try to unify
these (‘obviously’ different) kinds of forces.” In this case, we don’t have data on whether J could respond more appropriately if the issue were raised explicitly, as it was in the case of dual models of the toss.

Just as with Shifting Interpretations, it seems difficult to formulate a relevant categorical belief that might be driving J. Perhaps it is that “words have variable meanings”? Certainly J would believe this (or at least act consistently with this belief) in some contexts. The difficulty with the categorical attribution, however, is that she also believes the opposite (or acts consistently with the opposite belief) in other contexts, that “words have specific meanings.” For example, she does decide that one shouldn’t use the term “force” for things more aptly described as “momentum” (see the immediately following section). Furthermore, J simply can’t believe that using particular words doesn’t imply any constraints. What’s at issue is when the constraints are loose, when they are tight, and in what way are they tight. Once again, describing her epistemological knowledge as carrying out judgments in context (how different might things be and still be called by the same name?) seems more appropriate.

3. Migrating Language

J would often switch among terms like force, momentum and velocity as if they were interchangeable. On one occasion, J was asked to graph acceleration, and she graphed velocity (although she acknowledged this when queried). On another occasion, J glossed \( F = ma \) as implicating a proportionality between force and acceleration. However, she illustrated this by showing a proportionality between force and velocity, saying “the more force you give, the faster it’s gonna go.”

Once again, J is not so unusual in this regard. Confusions between velocity and acceleration, and between speed and position, have been widely documented. However, J seemed persistent in Migrating Language, and surprisingly unconcerned when she, herself, uncovered an inconsistency. These, we hypothesize, are epistemological orientations, and they are especially prominent with J.

Recall that J frequently described a moving object as “having a force.” At one point in discussing a puck moving on ice, J seemed spontaneously to notice that that is a different situation than when the puck is constantly being pushed by a force. The interviewer gently suggested that, perhaps, J’s “force” in the moving-without-pushing situation should be described as momentum. J seems to pick this up quickly and firmly.

[5 – 0:9:55]

A: Okay. What if I suggested that, um, that maybe you should describe that [an object just moving along, not being pushed] as momentum rather than force.

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7 This is an example of the limits we hypothesized for “intentional learners”—in this case, J is not in a position to recognize what she should learn (which we called “dependence on limited knowledge subsystems”).

8 If J held “words have variable meanings” as an categorical belief, she would have difficulty understanding questions such as whether a tomato is a “fruit,” whether Baltimore is the “capital” of Maryland, or whether an older sister can be a “legal guardian.”
J: Oh. I’d agree with you.
[brief clarification]
J: Yeah. Definitely. Because I actually shouldn’t have been calling it force the whole time, because momentum takes into consideration the velocity that it’s moving and how much mass it has. Whereas, when you give something a force, I mean, if you give something a force, then it has momentum. It doesn’t have a force [“on it,” a physicist would add] the whole time. So I was using them, not interchangeably, but I was using it to mean [inaudible]. Momentum does describe it a lot better.

Yet, J continued in other circumstances to describe momentum as “force,” as in “the force given to it by the hand.” See the earlier quoted segment in session 7, where she reverts to talking about “the force that you gave it.” J’s own discovery of a case of Migrating Language didn’t “take” as a warning to be careful.

Commentary: We can rehearse the same objections to categorical constructions of J’s behaviors here as in previous cases. A proponent of categorical descriptions might say J’s behavior in this section stems from a tendency “not to be careful with language” or from the belief that “words have many meanings.” But these attributions cannot account for her willingness to distinguish, on occasion, between force and momentum. At minimum, we must admit a context-specific dependence to Migrating Language.

To emphasize the contextuality of Migrating Language, we can imagine a context in which it is sensible for language to migrate. In high school English class, many students learn the distinction between a simile and a metaphor. When preparing for a test, students can generally learn the difference and use the words correctly, just as J, sometimes, distinguished force from momentum. But later that night, when discussing a flowery anonymous love note, the same students might use “simile” and “metaphor” interchangeably because the technical distinction does no work for them in the context of trying to explicate the meaning of the note. J may have been similarly contextual in her judgments about force and momentum. She may see the difference when prompted, and view the distinction as relevant in some contexts, but in other contexts feel the distinction is artificial and unnecessary to her goal of getting her meaning across.

It is worthwhile emphasizing the epistemological nature of J’s behaviors, beyond, say, specific conceptual confusions. First, we claim that J is not sufficiently attuned to the nature of scientific, technical concepts in general. Of course, we could be wrong about this. However, if we are correct, this is an epistemological issue, not just a (specific) conceptual one. Secondly, the irregularity of J’s behavior supports an epistemological interpretation. Mixing force with momentum may be conceptual, but failing to be careful about the distinction after articulately noting it, constitutes a failure to deal with a knowledge-related issue effectively.

Evidently there is some relation between Migrating Language and Shifting Interpretations. However, they are not the same. J did not merely substitute “force” for “momentum” in describing the two-force toss. She implicated an entirely different causal mechanism, involving the dying out of one force and a shifting balance of strength (contrasting with one constant force acting to change velocity). On the other
hand, it is entirely possible these two behaviors come back to the same epistemological orientation, one that does not recognize patterns of language use or concept types in learning physics that differ from those appropriate to more everyday contexts.

*Intentionality:* The patterns in Migrating Language seem similar to the previous two behavioral phenomena. J simply does not notice some differences and similarities in description or fact. Or, if she notices them, they are judged unimportant. One novel feature in the case of migrating terms is that J, at least sometimes, recognized a “slip” she previously gave no signs of recognizing (that one should call the motion of an object “momentum,” not “force”) when it came up explicitly. In this case, it seems J could have formulated an appropriate goal—to stabilize the differences she “discovered.” But she apparently had no inclination to do this. At least, she did not give any evidence of taking on this goal, and, indeed, her language continued to migrate. So, with respect to Migrating Language, but not with respect to Shifting Interpretations or Splitting Concepts, J might have been in a position where intentional learning could have helped her.

4. *Weak Commitment to Principles*
J showed only a weak, context-sensitive commitment to general principles, often treating them as “rules of thumb,” heuristics rather than laws. She often self-consciously (unlike Shifting Interpretations) changed her way of thinking about a situation, abandoning a physical principle she professed to believe, because it seemed right to do so in the particular context.

Several examples of Weak Commitment to Principles occurred while examining the case of a book pushed at constant speed across a table. The interviewer introduced some new forces into the picture, in addition to the force of the hand on the book and the force of friction pushing backward on the book. These additional forces were “reaction” forces to the forces that J initially saw in the situation. He introduced the force of the book pushing back on the hand (reaction force to the force of the hand on the book). J initially accepted that force, and even declared it equal to the force of the hand on the book. This is correct physics according to Newton’s third law, also known as the principle of “action and reaction.” (To every action, there is an equal and opposite reaction.) However, J soon retracted the “equal” assertion because, if the force of the book on the hand were equal to the force of the hand on the book, it would cancel out (in her mind), and leave motion unexplained.9

What are the epistemological implications of this move? Here, J found a conflict between her understanding of Newton’s third law and her intuition that motion requires an unbalanced force. Rather than try to reconcile this inconsistency, which could have led her to revise her misunderstandings, she chose to abandon the third law.

9 As do many physics students, J was misunderstanding two points. First, the force by the hand on the book could not cancel the force by the book on the hand because these two forces act on different objects: One acts on the hand; the other acts on the book. Second, the condition of balanced forces acting on the book would be consistent with constant velocity: An unbalanced force would be needed to cause a change in velocity.
deciding that it must not apply in this situation. This abandonment would not implicate epistemology if J never really “believed in” Newton’s third law as a general principle. But in discussing the necessity of revising one’s intuitive ideas when learning physics, J specifically cites the third law as a principle she believes, even in cases where it initially seems intuitively problematic:

[2 0:46:0]
J: …I mean, it’s hard to convince someone that right now the chair is pushing on me as hard as I’m pushing down—130 pounds…I think that’s something that once you’ve taken physics, that’s totally normal. But if you said it to someone off the street, I think they’d say, “What are you talking about? No it’s not. You know, obviously it’s not pushing; there’s nothing to push it up.” But it is. [emphasis added.]

We now return to the pushed book example. After J retracted her claim that the forces exerted by the hand and book upon each other are equal and opposite, the interviewer suggested considering the horizontal force by the book on the table (the “reaction” force to the force of friction impeding the book’s motion). J immediately rejected this second force. The interviewer persisted by showing her that the book would drag along a piece of paper placed under it; he claimed that that showed the book was pushing on the paper.

[4 0:21:50]
J: I think it’s just sliding, and I think it’s [the book is] just bringing the paper with it. I mean, it’s a really simple situation. I think you could start saying there’s all these millions and trillions of forces…. Um, I think you just have to make it real simple and say these are the major forces. I mean, yeah, we’re talking air and there’s air on top of this, but if you said that the force of air is gonna play a part, and you start getting this book that’s just sitting there and millions of forces, then you start setting up more complicated situations, like flying on a plane or something like that, and there’s just zillions of forces on this object. So I would just say that it’s sliding against the table and bringing the paper with it.

J seems to be saying two things. First, she says that you should not consider such forces, because, if you did, that would create a confusing world of “millions of forces.” In this moment, J’s epistemological orientation is toward simplicity of description, which she prioritizes here over consistency with principles. She justifies omitting these other forces by describing the forces she allows as “major,” perhaps thinking of the strategies she has seen in class of neglecting small forces. Note, however, that the action and reaction principle she used at some times, but not at other times, guarantees that the force she dismisses, the force of the book on the table, is as large as one she included, friction.

Note that we quote two instances in other places (among several in the corpus of data) where J affirms “action and reaction”—that if object \( a \) is pushing on object \( b \), then \( b \) pushes on \( a \) with the same magnitude of force. Here, she denies that principle by acknowledging the table’s frictional push backward on the book while denying the book’s push forward on the table. J’s version of “action and reaction” is quite contextually sensitive.
Second, in this passage J just asserts, with no explicit justification at all, that the paper’s motion requires no force. Forceless motion is an everyday experience, but if J were holding at this moment to her view that motion needs unbalanced forces, this would not be an adequate explanation for her. Apparently, she sees the book as “bringing the paper with it,” and her epistemological judgment in this context has her complacent with respect to the principle she used a moment earlier, that motion needs unbalanced forces.\(^1\) (A moment later, as we discuss below, she returns to that principle, explicitly choosing it over \(F = ma\).)

**Commentary:** J’s commitment to principles is weak and contextual. She sets them aside in particular situations when they make things confusing, or when she feels she has another sensible way to treat the situation. This epistemological stance is appropriate to decision-making in everyday situations, when sensitivity to immediate circumstances often appropriately supercedes general principles. Individuals who would never tell a white lie to spare a friend embarrassment may sensibly be considered somewhat fanatical. Abandoning principles easily is not, however, a productive stance to take with respect to learning physics, when students should be working toward principled coherence in their understanding. In contrast to J’s behavior, students who are committed to principled coherence treat moments of confusion as opportunities to identify and reconcile inconsistencies between general principles and specific intuitions, pushing through their confusion to construct new understanding (Hammer, 1994).

**Intentionality:** J’s deliberation concerning the applicability of Newton’s laws provides another indictment of the formulation of epistemological knowledge as beliefs, and further support for the viability of “judgment in context” as an alternative formulation. At first glance, J’s behavior might appear to follow from a general belief such as “for every rule, there’s an exception.” However, as part of J’s reflection on denying the relevance of \(F = ma\) to pushing a book across a table (see Appendix A and the end of the section of protocol \[4 0:38:20\], below), J asserts that she initially believed \(F = ma\) to be always true; but since she judged it could not apply to pushing a book, she was forced to revise her beliefs. Thus, a consciously avowed epistemological belief (“\(F = ma\) is always true”) not only fails to govern her behavior in the situation, but also gets modified because of a judgment specific to this situation. Of course, as in all other cases, we cannot guarantee that there is no reformulated view of what she does that doesn’t follow from some as-yet unknown belief. However, it seems difficult to formulate such a belief, and even more difficult to remove some implicit contextual judgment balancing her avowed belief that \(F = ma\) was general vs. whatever countervailing belief J might have had that caused her to abandon her prior belief.

\(^1\) Why did J deny the reaction force of the book on the table, while only “demoting” the reaction force of the hand on the book to a small, ignorable force? While it is not important for the analysis of this chapter, we note the following contextual issues: (a) J could not feel the second force, as she could the force of the book on her hand. (b) Friction is a special force (split concept), so it might not need to behave like other forces. (c) J had specific intuitive excuses, “sliding,” “sticking,” or “carrying along,” that explain the motion of the paper on which the book rested without the need of a force. See, for example, diSessa & Sherin (1998).
5. Discounting Details in Explanations

J went beyond not pursuing details. She sometimes (implicitly) denied that they were relevant to the task of judging the adequacy of an explanation. In particular, when faced with difficulties working out the details of an explanation, J often settled for an incomplete explanation instead of exploring the possibility that her difficulties stemmed from flaws in her understanding of the underlying principles.

To explicate this claim, and to explore how this behavior does and does not differ from that of physicists, we distinguish between two kinds of accountability to details in physics explanations. The first, we believe, is a commonsense accountability, that if you impute particular entities acting (such as a force), you should be able to justify the existence of those entities (say, as forces of known kinds, such as gravity, that occur in known circumstances). A second level of accountability may be more specific and learned in school. In physics, you must hold yourself accountable for what happens at each instant. At an instant, a force either exists, or it does not.

In contrast, J seemed to see it as acceptable to make claims without being able to justify the elements in those claims. For example, to J, it was acceptable to say that there is balancing without being able to say what balances (see the second quotation below). Similarly, J found it acceptable for a force to have two different magnitudes at the same instant in time.

In the toss situation, J said at one point that the upward force given to the ball by the hand balances gravity at its peak and then that the hand’s force was zero at the peak. The following quotation is J’s response to the interviewer’s questioning her with respect to these conflicting claims. Note that half way through, J acknowledges the logic underlying the contradiction: If a decreasing upward force balances a downward force at a given moment, the upward force can’t vanish until some time later. But instead of taking this contradiction as cause to question her explanation, she grasps for a way to keep her two ideas intact, eventually using the fact that “it’s such a short amount of time” to excuse the need for a detailed reconciliation. This is an example of evading the more subtle “moment-by-moment” accountability.

[3 0:24:20]

A: If it’s gone though, how can it balance?

J: Well, at that second that it balances, which isn’t very long, is when it’s like it’s on its last // You know, it’s slowly, slowly dying out, and that one second is the one time when it’s equal. So it’s not gone at that second it’s, obviously. Or else, if it would be, if it was gone that second, then it would have been falling earlier, and it would have been gone a little bit lower. But at that one, when it’s at its peak, it’s right before it’s going to be gone.

A: OK. That’s right before, so it’s gone some time after it starts the downward //

J: Well, when it stopped is when they’re equal. But obviously it dies at that exact point for the gravity to pull it back down. So I guess you can say that at that point it goes away. But when it was completely stationery, it was still there enough to have it not fall. But, it’s such a short amount of time, you know, it’s not like it goes up and hangs out there for a while and then, oh, it dies out and comes back down. It goes up and it comes right back down. So it’s like a really short amount of time. Just dies out.
Much later, in the last interview, J again asserts both that the upward force cancels gravity and that the “force of the hand” is zero. Indeed, at very nearly the end of the interview, when she has once again been brought to the point of recognizing both that she has all along claimed (from time to time) that the force of the hand is zero at the top and that (from time to time) she has said there is only one force, gravity, during the entire toss, she still maintains that there is a balancing, even though she is unable to identify the canceling force. J does not explore the possibility that her interpretation is in error, but holds fast to her belief that there is balancing, even if she can’t identify the balancing force. This appears to be an example of the more blatant accountability for named entities in an explanation.

[7 1:01:30]
J: At the top, the force is equal to zero because it’s stopped. But // I guess you can’t say they’re equal to each other. I guess you have to say that they cancel each other out.
A: Which two forces cancel each other?
J: I’m obviously wrong [laughs] about something. [Interpretation: The persistence of the interviewer suggests to J that she must be doing something wrong.]
A: I’m just trying to get all the details.
J: … When it’s at the top, it only has one force on it. Downward. And //
A: So, what’s canceling out?
J: Well, I guess nothing’s canceling out. I guess it’s just, uh [long pause] I still think forces are canceling out, but I don’t know which one’s they are. [Laughs]

Commentary: Can we account for J’s behavior in this subsection by ascribing to her a belief such as “details don’t matter” or a trait such as sloppiness of thought? The evidence suggests not. For instance, in section 1 above, J justifies her omission of air pressure by referring to the details of how it acts. Air pushes in all directions at once, which makes the air pressure force cancel out. Similarly, section 7 below provides an extended episode of J’s using careful, details-oriented reasoning to explore an apparent contradiction. So, once again, J’s behavior is best described as arising from a judgment in context: If J is using conceptual resources that seem very sensible to her at a given moment (e.g., the “balancing” schematization), and she faces difficulty working out the explanatory details, then she is likely to settle for an explanation that violates the accountability conditions listed above rather than to question her conceptualizations.

When faced with anomalous data, physicists often decide that their inability to account for details does not threaten the core principles underlying their reasoning. So, even in the context of academic science, J’s behavior is not completely inappropriate. From a physicist’s perspective, however, J stops pursuing the details too quickly in favor of just feeling things must work out somehow.

Typical of case studies, we cannot be sure how common J’s refusal of accountability to details is. We do not know whether students come regularly into physics class accepting

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12 From a physicist’s perspective, a version of this argument correctly explains why air-pressure forces do not appear in most force descriptions in introductory physics.
both of these types of accountability (to justify the existence of entities used in explanation, and to account for such analyses at each instant of time), one of them, or neither. Based on data and argument we do not present here, it is our expectation that moment-by-moment accountability regularly requires physics-specific epistemological sophistication. In any case, both kinds of accountability constitute likely epistemological difficulties, and targets for instruction, for at least some students.

**Intentionality:** J didn’t spontaneously note her own lack of accountability to details. Probably, her judgment in context is that she is being sufficiently accountable. Even bringing the issue to conscious consideration doesn’t provide enough impetus to consider that there might be a problem in her thinking that needs consideration. As with prior cases (with the exception of Migrating Language), J does not seem to be in a position where conscious reflection or intentional learning could be productive.

### 6. Hedging

J frequently hedged with linguistic tags of limited commitment. Hedging is an explicit linguistic strategy for softening a claim, which we distinguish from Weak Commitment to Principles, the inconsistent adherence to or abandonment of principles.

In addition to explicit forms such as “kind of like” or “sort of,” J allowed multiple views (which appeared contradictory to us) with noncommittal statements like, “You could think of it that way.” Sometimes J made weak statements without explicit hedges when much stronger statements might be made. One such move that struck us as particularly interesting occurred when she was in her bind concerning unbalanced force, constant-speed motion and \( F = ma \) (reviewed in detail in the next subsection). In examining the case of a falling body, she said, “Well, I guess if you applied a constant force, you could have constant acceleration,” ([4 0:29:00], emphasis added). She did not suggest that the lesson was the obvious one from \( F = ma \): You must get constant acceleration with a constant force.

**Commentary:** Hedging is sensible when one has a developing knowledge system. Appropriately tagging both lack of commitment and also rough descriptions can be quite useful. But Hedging also serves as a buffer when sharper descriptions can be made, when more commitment is implied in the rest of one’s analysis, or when one knows that one needs to strive for better, less-qualified descriptions. The choice of when to hedge and when not to is an epistemological judgment on the amount of commitment and accountability one should have toward some statement. It is important to make such choices well to leverage reconsideration of weak, possibly context specific ideas based on stronger ones. Students who perceive their own knowledge landscape as flat (no part of it more generally secure than any other part) will have difficulty bootstrapping toward a well-organized, consistent knowledge base.\(^{13}\)

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\(^{13}\) Of course, students may also guess wrong about what parts of their knowledge are reliable, to be built upon.
A proponent of categorical descriptions might hypothesize that J could never take a strong position on anything. One might also believe she is unreflective, did not monitor her statements and did not think much about what learning physics was about. In what follows below, we show that these generalizations do not hold. J ended up taking a very strong position with respect to the unbalanced forces $F = ma$ dilemma. Moreover, she several times remarked how frequently in the interviews she had to change her mind upon reflection. J could engage in relatively elaborate argumentation around a single point (see directly below). Finally, she did reflect on physics learning, and knew, for example, that it frequently forces one to change one’s intuitive schematizations of the world (again, see later examples).

Thus, these final two behaviors, in sections 7 and 8, play a different role in our analysis. They directly show contextual difficulties in categorical descriptions of J’s epistemology. Based on sections 1-6, it would be easy to caricature J with categorical (negative) descriptions of her epistemology. As now argued, however, she often showed sophistication and behavior at odds with the patterns we have described to this point.

7. Strong Commitment to a View

In the episode previewed above, J claimed that unbalanced forces are necessary for any motion. With some prompting, J saw that this conflicted with $F = ma$. In particular, objects that move at constant speed need unbalanced forces on them (according to J’s intuitions), but $F = ma$ then would require acceleration. In this situation J: (a) questioned her own analysis; (b) carefully reviewed the logic of her arguments, for example, checking that the meaning of acceleration would really imply one should be able to see an object speeding up; (c) summarized her own reasoning and the broad implications of it concerning general properties of physics knowledge; (d) used reasoning about different exemplar situations (one she introduced and another that was introduced by the interviewer) to elaborate her understanding.

Here are some quotations from critical portions of this 25 minute-long segment:

After J identifies the two primary forces on the book (the hand pushing it and the friction resisting its motion) the interviewer asks:

[4:0:17:10]
A: So could you relate the amount of force that I’m applying to the friction?
[Clarification omitted]
J: Well, if it’s moving, then yours is going to be bigger than the frictional force. And that’s why, when it’s not moving, the frictional force is greater than your force.

At this point, the interviewer deliberately introduces some reaction forces, as described above. J clearly monitored the implications of her “equal and opposite” description of

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14 This claim contradicts several other things that J appeared to believe at other times. For example, it is in contradiction with the one-force model of the toss she occasionally espoused. It is in contradiction because if gravity is the only force, then it is in the wrong direction to explain the upward part of the toss.
the force of the book on the hand pushing it. She sees that it is in conflict with her principle that unbalanced forces are required for motion. Further, she checks her belief that there is such a reaction force in the first place and concludes: “You know it is because you can feel it.”

At this point, the interviewer introduced the second reaction force, which initiated the segment where J denied that a force was needed to move a piece of paper, described under Weak Commitment to Principles, above.

Following on, J proceeds on a fairly systematic pursuit (supported by the interviewer) of what might be wrong with her analysis. For example, she checks at least twice that she is justified in assuming acceleration is zero when velocity is constant. She seems careful and reflective about what it would take to convince her that there is acceleration in this situation.

A bit later:

J: See, I would think that when you’re pushing it, it was a constant velocity, not a constant acceleration. I can’t imagine someone telling me something that would convince me otherwise. Because // It’s like you see accelerations, you feel acceleration. It’s not like this book is really accelerating, and we just don’t see it.

A: I see. It’s something in physics you can see.
J: Yeah.

After checking alternatives, checking that she really believes you need unbalanced forces to move, checking that acceleration really must be visible if it is happening, J is committed to a paradox. You need unbalanced forces, but \( F = ma \) says unbalanced forces require acceleration, which, however, she knows is not present. The interviewer tries to offer an opening.

[4 0:32:00]
A: So you said, the hard question is why is it moving if the forces are canceling. Suppose I said that well, things don’t need a reason to move, they just move.
J: That wouldn’t fly well.

Note that if J systematically had very limited commitment to ideas, she could have solved her problem, “taken the easiest path,” by just accepting this (ironically, correct) offering from the interviewer. Instead, she is true to her beliefs, and remains troubled.

J summarizes her perplexity:

[4 0:36:50]
J: No, I’m just thinking about if that’s true, let’s say that every time there’s a force something’s moving, then it’s going to be accelerating, because anytime something moves the forces aren’t equal. And to me it’s going to be very mind boggling to think that every time something’s moving, it’s accelerating.
A: That just does not sound possible.
J: That just is not slightly possible.

J is not hedging here. In the final segment, below, J shows she believed \( F = ma \) was a universal idea. But she has come to an impasse. Rather than abandon her unbalanced force idea, she demotes \( F = ma \) to “one of those darn equations” that is not always true. She shows that she has reflected on her own prior conceptual change, but she does not take this as an occasion where her conceptions need to change. This is a judgment in context.

[4 0:38:20]
J: I want it to be true, but there’s just no way it is, you know. Like to me you look at \( F = ma \), and there’s a force and that has to mean acceleration [no hedging here]. But then it’s easy to say “that’s true,” but I mean there’s no way it is. I guess you can just say that, you know, those darn equations aren’t applicable to every single thing. They’re not always true. You can’t live by them. But, I just want // I was just trying to think of an explanation of why. I mean, it makes sense. You can see it happening. You know that’s what’s happening. I don’t know why I just started doubting myself because that stupid force formula.
A: Yeah, you said before that you “wanted it to be true.” … I didn’t know what you meant by “it”. Do you remember?
J: No. I’m sure it was just // I mean I want what seems logical to me to make sense with what I’ve learned and what you can, like, you know, like when we were talking about the formulas. I mean you learn these formulas and you apply them to all these problems. But when something that you know is true—I mean to me it makes so much sense that it’s crazy to even debate it, that if
you’re pushing this with a constant force, and you see it moving, that it’s not accelerating. But then, to think about something that you’ve learned and you’ve been applying for so long and have it not make sense. Then you start doubting what // I started doubting what makes complete sense to me.

A: Does that happen a lot in physics or classes generally?

J: Well, I mean it’s really neat when you learn something that isn’t what you would intuitively have thought, but it makes sense, you go, “God, I totally understand that. It’s not what the everyday person on the street would know, but I understand.” Rather than this when I’m saying, “OK, that’s something that I’ve learned, but it doesn’t seem like that could //” I mean I know that can’t be right. And do I just discard it and say // Because, I mean, you learn these formulas in school and you can’t // You know half the time they only apply to certain perfect models, especially like in chemistry, you know, certain situations. And you can’t apply them to absolutely everything. You think, oh, plug it into the formula. But when you’re in real life, I mean, so many things have so many different things going on that you can’t always say // I just thought that \[ F = ma \] was one of those that was universal, you know, it wasn’t like specific.

Commentary: In this long sequence, J shows she is not in any sense categorically careless or uninvolved. J is not docile in her learning. “I want what seems logical to me to make sense with what I’ve learned.” She shows she sometimes takes strong stands, unlike what Hedging and Weak Commitment to Principles suggest. Once again, contextuality is clear. She is making a judgment in this particular context that her intuitive understanding is the way to view this situation. Here, she is making an unusually bold move in demoting \[ F = ma \], about which she had correctly gotten the impression that it was a very general principle, to “just one of those darn equations” that applies to “certain perfect models.” She is reflective about the nature of the knowledge that has been provided to her (\[ F = ma \] is general; equations frequently apply only in particular situations).

From a physicist’s standpoint, J made the wrong choice of commitment, to her principle of unbalanced forces rather than to \[ F = ma \]. What is relevant to this section’s analysis, however, is that she made a commitment, holding to her idea and explicitly accommodating \[ F = ma \] as only applying to certain, “perfect” situations.15 Whereas Hedging and other patterns we discussed above might lead one to believe J was not capable of or generally inclined to commitment—we describe this below as a tendency toward accepting fragmented knowledge—this episode showed her invoking epistemological resources for such commitment. Instructionally, we would like to help students like J make commitments to general principles more systematically, and, of course, we need to provide help in understanding how to judge which commitments are best to make. While it is inappropriate to go into details here, we believe there are many strategies and considerations to discuss with students to help them make productive choices.

Intentionality: In a sense, J was intentional here in “learning” that unbalanced forces are necessary for motion: She explicitly considers and then responds to a challenge to the

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15 In keeping with Discounting Details, J does not seem to consider it important to pursue this reconciliation in detail—what specifically determines whether a situation is “perfect” such that \[ F = ma \] would apply? Why might it be that pushing a book across a table is not “perfect”?
idea, and, in the end, reaffirms her commitment to it. Of course, as we have noted, she was intentional in the wrong direction, and this raises again the question of the relationship between intentionality and epistemology. Here as previously, intentional learning seems dependent on epistemological judgments in context.

8. Reflecting about Learning and the Revision of Intuitive Ideas

The segment quoted directly above shows the result of prior reflections on her own learning and of reflections on the nature of the knowledge she is being taught. In addition, the segment is, itself, an instance where she is forming her epistemological ideas. It certainly doesn’t look like it involves “a belief in the immutability of scientific ideas,” or the formation of an “authoritarian” or “anti-authoritarian” stance. It looks like she is generatively bending and shifting the contextuality of her prior ideas specifically about $F = ma$ (“certain perfect situations” becomes a more relevant description of context) and, possibly, about the nature of equations as knowledge.

J gave many other indications that she reflected on her learning experiences, and, in particular, on her learning experiences in physics. She seemed quite conscious of the fact that physics changes the way one thinks about familiar events. In one episode, she recounted how difficult it would be for a person unschooled in physics to believe action and reaction. Note the subtlety in her thinking: People would know what is happening, but not how it works.

[2 0:46:0]
A: And you say you know the desk is pushing up because if it weren’t, the book would just come down.
J: Right. And it’s the same as like equal and opposite forces. I mean, this chair right now is pushing up on me and the chair is pushing up on you. And the ground is pushing up on your feet. And that’s something that’s hard to think about. [You’re tempted to say:] “No it’s not; I don’t feel it; I’m not moving anywhere.” But it is [pushing up].

A short time later:

J: I think it’s hard to think in your mind, “Oh, this table’s pushed up.” It’s easy to say the table’s counteracting, the table’s supporting. I think that’s something anybody would know…. [But] I mean, it’s hard to convince someone that right now the chair is pushing on me as hard as I’m pushing down—130 pounds. This chair’s pushing up on me. I think that’s something that once you’ve taken physics, that’s totally normal. But if you said it to someone off the street, I think they’d say, “What are you talking about? No it’s not. You know, obviously it’s not pushing; there’s nothing to push it up.” But it is. So maybe it’s like what is going on is common knowledge, but how it actually works maybe I learned.

Commentary: J is not unreflective. She is learning at the epistemological level while she is learning physics, and she has a lot of important epistemological ideas right, from a physicist’s perspective. Learning physics sometimes requires changing ideas to the point where ideas previously judged to be absurd come to seem natural. A physicist might find many faults in J’s epistemological stance and strategies. But these are not
categorical gaps, and they do not necessarily stem from beliefs that are wrong so much as contextually inappropriate judgments and actions.

*Intentionality:* These latter episodes appear the most like conscious reflection and belief formation of any in the corpus. Yet, still, judgments in context seem implicated in the very possibility of sensibly initiating reflection, and in the judgments that select which new beliefs will result.

**Synthetic Interpretation**

In what follows, we seek a simplified, coarser-grained view of J’s intuitive epistemology that loses as little as possible of the detail and contextuality displayed above. We make no claim to having found the best compromise of succinctness and coverage, although we have tried to enfold as many of the behavioral phenomena as possible.

Two central tendencies stand out in J:

1. A systematic bias toward accepting fragmented knowledge.
2. A tendency to view learning physics as sense-making (as opposed to, say, memorizing information).

We now discuss these two tendencies in more detail.

**Bias Toward Fragmented Knowledge**

J was not exceptional in the nature of her intuitive ideas; naive physics, we claim (e.g., diSessa, 1993; Smith, et al., 1993), is inherently fragmented. She was unusual, however, in her stance toward that fragmentation. Compared to most students we have encountered, J seemed more at ease in offering multiple interpretations that fail to converge and in using multiple explanatory frameworks that we would see in tension with each other—including frameworks that contradict explicit instructed principles. One manifestation of her acceptance of fragmentation is that she does not feel compelled to believe physical categories share core properties (Splitting Concepts). A common meaning to “force” for example involves, to her, an implausible commonalty across diverse-feeling situations. Furthermore, no way of thinking about things seems privileged over other ways. Instead, she relies on her intuitive feelings of understanding in particular cases. When she feels confidence in an interpretation, she judges it to be valid even if it appears to contradict another analysis she has given (Shifting Interpretations). The fact that physics frequently ignores some things (like small forces) is just one more example to her that you just have to go with what seems right. For J, the world is complex and diverse, and she is comfortable providing different analyses at each turn.

Because of her unusual dependence on intuitive judgments (and hence, on piecemeal, largely inarticulate knowledge), articulation *per se* is often infeasible. She refuses certain kinds of accountability about the details of her pronouncements. She acts as if she
doesn’t think\textsuperscript{16} that exercising linguistic precision and making strong predictions are necessarily good or even workable strategies for promoting her own conceptual development (Migrating Language, Hedging). Words may shift their meaning as she shifts her attention, but this is not something she systematically attends to or worries about.

J has enough confidence in her own intuitive schematizations of how the world works that she often chooses them over some of the most prominent principles of a physicist’s world view—namely, her unbalanced forces schematization vs. $F = ma$, and her analysis of a pushed book (and slipping paper) vs. “action and reaction.” In the same vein, if she feels that a line of reasoning is correct, she does not feel that she needs good, articulable reasons for abandoning a stated principle (Weak Commitment to Principles).

J does not have confidence that some of the standard modeling procedures of physics need to apply and should be expected to be decisive. For example, physics demands moment-by-moment accountability in its analyses. At every instant, one is accountable for identifying and justifying the existence of each component of the analysis—for example, which forces are present. J doesn’t see this universal systematicity as a good idea, or even workable. For example, J refuses to drop “balancing” just because she can’t find forces to balance.

Plenty of evidence suggests, however, that J’s attitude toward learning is not entirely naïve from a physicist’s perspective. She is not unreflective. She monitors her thinking and corrects some of her own mistakes. She knows to review her own arguments carefully, especially when they draw problematic conclusions. She knows that physics requires revised conceptualization. From a physicist’s standpoint, her problem is not a lack of commitment to reconceptualization, but rather, a lack of commitment to the right kind of reconceptualization, for example, that physics technical terms require a core commonality among exemplars. J explicitly states, for instance, that she would like to think laws such as $F = ma$ are universal; but she is unable to make that work because intuitive schematizations have such a high a priority in her thinking. Despite the fact that she does not seem to have a view of physical knowledge that captures some of its core and unusual properties, a physicist would in some ways appreciate J’s strong commitment to sense making, which we now discuss.

\textbf{Commitment to Sense Making}

To J, learning physics entails making sense of the material in her own terms, as opposed to simply accepting the physics as presented in her class. For example, since passive forces such as friction seem intuitively different from forces that “actually like physically push,” J views friction as a special kind of force with different properties (Splitting Concepts).\textsuperscript{17} In general, she does whatever it takes—abandoning Newton’s

\textsuperscript{16} J does not seem to be conscious of these particular issues, nor articulate about them.

\textsuperscript{17} A physicist, devoted to global coherence as well as to sense making, might try to understand in what sense friction and the normal force can be understood as “pushes.” But J’s systematic bias toward fragmented knowledge makes this move unlikely.
third law of action and reaction, for instance—to reconcile the physics under discussion with her intuitive sense of mechanism (Weak Commitment to Principles). Sometimes, when a bit of physics such as $F = ma$ conflicts with her sense of mechanism, she is willing to commit strongly to her intuitive view, for example, by concluding that $F = ma$ is “one of those darn equations” that does not always apply. Along these same lines, when considering the ball at its peak, J switches from one story (no upward force) to another story (balancing forces) precisely when her intuitive sense of “balancing” kicks in (see diSessa, 1993; 1996); without realizing her shifting conceptualizations, she adds an upward force in order to express her intuitive sense of what is happening. To a physicist, providing two contradictory explanations seem inconsistent with sense-making. But to J, accepting as she does the fragmentation of knowledge, the “competing” explanations each seem sensible enough, so they are judged compatible. Since she has made sense of the material at a level of precision and consistency that she accepts, she ends up considering herself to understand the ball toss (with a one-force model), and also to have understood it before (with a two-force model).

[7 1:17:50]
J: It’s funny though because I think that it would be easy for somebody watching that [the tape from her prior interview] to think that I didn’t understand what was going on. And it’s funny because I don’t think that now [the one force model] I understand what’s going on any better than I did then. But I can explain it to you in the right way.
A: In the physics way, probably.
J: Which is, kind of, not frustrating, but it’s weird…. I can say, OK, I correctly said what was going on, but I don’t think I understand any differently. Like maybe I’m getting words confused, but I don’t think that I have this revelation “that’s how it works.” Because I still think I understood how it worked.

J is articulately aware of her bias toward sense making: “I want what seems logical to me to make sense with what I’ve learned.” When reflecting upon her learning, she explicitly focuses on the need to reconceptualize her own intuitive ideas rather than just to absorb new information. On the other hand, just because she has some articulate awareness of her orientation toward sense making doesn’t mean she is constantly aware of this, or even that, in a particular instance, sense making behavior is driven by any conscious awareness. For example, it is likely, if not certain, that on many occasions she will persist in thinking about something (a good sense making strategy) just because she perceives she hasn’t achieved a feeling of understanding.

In summary, ascribing to J a systematic bias toward fragmented knowledge and a tendency to view learning as sense making summarizes the eight patterns of behavioral phenomenology described earlier. On the other hand, this higher level and more compact description cannot be understood in a categorical sense as global beliefs or traits. First, in the previous section, we made clear there were many contextualities even at the finer grain of more specific behaviors (e.g., when to hedge, and when not to), and we argued that most of these behaviors could not be viewed as corresponding to or stemming from generalized beliefs or traits. This contexuality is still unexplained at the higher level; since the individual behaviors cannot be understood categorically, neither can a generalization derived from those behaviors. Second, we have evidently lost some
specificity. Our two general characteristics don’t literally imply all of the eight behavioral phenomena. For example, as far as we know, we might be wrong in attributing an unusual degree of hedging to J, even if she is unusual with respect to Shifting Interpretations. The overall patterns (bias toward fragmented knowledge and tendency to view learning as sense-making) are “soft” enough to allow this. Furthermore, other students who warrant the same high-level description might, nonetheless, show the behavioral patterns in different degrees from J, and might show other patterns J did not display. Instructionally, different students might warrant different emphases.

We make the argument against categorical interpretation more fully and carefully in the next section.

**The Case against a Categorical Interpretation**

Our analysis of J’s reasoning, focusing on her strategies and decision-making, finds systematic epistemological tendencies. In this respect, we replicate a substantial body of earlier work (Perry, 1970; Hammer, 1994; see Hofer & Pintrich, 1997, for review). The central issue we review here is whether intuitive epistemologies are appropriately described categorically in terms of coherent knowledge (beliefs or theories) and/or global traits (e.g. cognitive styles or stages of development).

**Context Dependency and Coherence**

Systematic answers or other behavior can arise in a variety of ways; they do not always reflect systematicity or even coherence in the underlying cognitive structures. For instance, consider a pattern identified in diSessa’s (1993) study of intuitive physics, which is directly relevant to J’s toss analyses. Asked to identify the forces acting on a ball at the peak of a vertical toss, students systematically described a balance between an upward force, in the direction the ball had been moving, and a downward force of gravity. However, when students were asked to identify the forces acting on the ball on its way down, or on a ball dropped from rest, neither balancing nor even a force competing with gravity were likely to appear in subjects’ accounts. Subjects do not describe the descent of the ball in the toss in terms of the downward gravitational force overcoming a lingering upward force. (The force must linger, since it is still present at the top of the toss—a fact that most students, other than J, readily acknowledge.) So, subjects are systematic in attributing balancing forces to the ball at its peak. However, subjects don’t typically notice the apparent contradiction in their reasoning (a force gradually dying away and strong enough to balance gravity, but which instantly disappears from the analysis past the peak) unless the interviewer brings it up. These repeated inconsistencies in students’ answers indicate that their reasoning isn’t driven by coherent and consistently used beliefs or theories. So, this example shows that

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18 Galileo, pursuing the same two-force “theory” of a toss as naïve subjects, in fact, tried to incorporate a continuing-to-fade force in his analysis past the peak. He also sought to involve a competing force even in the simple situation where an object is dropped from rest, where forces other than gravity are essentially never introduced by novices. (See sections 201 and 202 in Galileo, 1954.) Scientists pursue systematicity and coherence well beyond what naïve or novice subjects do.
systematicities in students’ behavior (e.g., their answers to questions about a toss) can arise even when the underlying knowledge structures are not belief-like or theory-like.

Despite the above example and others like it, we, as analysts, are prone to put ideas together because they seem logically to belong with one another. Yet, we need empirical warrants to impute such connections to subjects. For example, at one time the common “balancing and overcoming” explanation of the toss was believed to illustrate an intuitive theory of physics (McCloskey, 1981). Later analysis suggested that a number of independent knowledge elements—which, in fact, are rarely activated together—account for the “intuitive theory” (diSessa, 1996).

These and other arguments and data suggest that systematicities in students’ reasoning about physics often result from regular responses to particular contexts, not from broadly used individual mental constructs or integrated patterns that one might call “theories” or systematic “beliefs.”

In general, there is no reason to believe that intuitive epistemological ideas behave differently from intuitive physical ideas. J’s data, in particular, does not support claims of either pervasive beliefs or global traits. Indeed, we have taken pains to show data that contradict many obvious categorical claims one might make about J’s epistemology. Of course, it its difficult to rule out the possibility that some small coherent set of beliefs or “theory” can account for all the contextual dependencies we see in J’s data. But the mere documentation of the complexity of J’s reactions makes this implausible. Furthermore, in the following subsections we will explicitly take up the challenge of showing that prior categorical views of epistemology fail to account for J’s patterns of behavior.

Instead of categorical epistemological knowledge, we see in J characteristic tendencies that “go together.” However, these tendencies not only show significant context dependency, but also seem, on the face of it, to involve a multiplicity of dispositions and strategies. We continue to make these arguments below, augmenting consideration to include the extent of articulate awareness.

**Articulateness and Consistency**

Researchers working within a categorical framework typically assume that students’ epistemologies are (a) coherent, and therefore applied with a fairly high degree of consistency; and (b) accessible to conscious reflection and report, with the right kinds of probes. However, J’s tendency toward fragmented knowledge was neither consistent nor articulate. Although J explicitly states her devotion toward sense making, she never in seven hours of interviews articulates her acceptance of fragmented knowledge, and she seems unaware of the influence that this acceptance exerts on her reasoning. For instance, she views her decision to reject Newton’s second law in favor of her unbalanced force schema not as a choice stemming from her beliefs about knowledge, but as something that any rational sense-making person would do:

[4 0:38:20]
J: I want it to be true, but there’s just no way it is, you know… I don’t know why I just started doubting myself because that stupid force formula.

A: Yeah, you said before that you “wanted it to be true.” … I didn’t know what you meant by “it”. Do you remember?

J: No. I’m sure it was just // I mean I want what seems logical to me to make sense with what I’ve learned and what you can, like, you know, like when we were talking about the formulas. I mean you learn these formulas and you apply them to all these problems. But when something that you know is true—I mean to me it makes so much sense that it’s crazy to even debate it, that if you’re pushing this with a constant force, and you see it moving, that it’s not accelerating. But then, to think about something that you’ve learned and you’ve been applying for so long and have it not make sense. Then you start doubting what // I started doubting what makes complete sense to me. [emphases added]

Again, J is consciously aware that sense-making is her primary concern. She is upset at herself for letting a “stupid force formula” make her doubt her intuitions. She entertained those doubts, she says, because she was so used to applying \( F = ma \) to many different problems. She shows no sign, however, of being aware that her bias toward fragmented knowledge affects her epistemological behavior.

Moreover, J’s bias toward fragmented knowledge was only that, a bias, not a consistent stance she took within these interviews. For instance, only after extensive thought and double-checking of her reasoning does J reluctantly decide to consider \( F = ma \) a case-specific formula. Reflecting on her reasoning, she explains that she (mistakenly) “just thought that \( F = ma \) was one of those that was universal.” If J possessed the categorical belief that physics knowledge is fragmented, then she would have no reason to expect \( F = ma \) to apply universally. In brief, J’s tendency toward fragmented knowledge reaches neither the degree of articulation nor the degree of consistency generally associated with beliefs.\(^{19}\)

Importantly, we do not claim that J is completely inconsistent in her reasoning, nor that she lacks articulate beliefs about knowledge and knowing. The former would belie our claim that we have found systematicities in J’s epistemological stance, her orientation toward sense-making and toward fragmented knowledge. The latter is contradicted by our noting her explicit beliefs about the nature of conceptual change, for example how ideas that would seem implausible to a “person on the street” can come to make perfect sense. Our claim is simply that tendencies and articulable knowledge constitute only a partial description of J’s epistemological stance and strategies.

**J defies Categorization within Existing Systems**

So far in this section, to support our claim that categorical approaches to intuitive epistemology are limited, we first offered general arguments (e.g., analogy to research in intuitive conceptions of physics) and then offered arguments based on particular data presented here (concerning the articulateness and consistency of J’s epistemology). Here, we add a third line of argument. We show that some of the most successful

\(^{19}\) Of course, it is possible to assume beliefs are things that come and go, without taking on accountability for explaining when they come and when they go. Such a concept of belief is nearly worthless as a scientific construct.
categorical approaches of which we are aware fail when confronted with the details of J’s case. As we pointed out before, one cannot rule out that some unknown categorical scheme might account for all the patterns of behavior and context dependencies we see in J’s case. But we can make it more and more implausible by demonstrating complexity and contexuality and by the consistent failure of proposed categorical views.

In Schommer’s analysis of epistemological beliefs, the most predictively-useful factor (Schommer et al. 1992) is Simple Knowledge, a dimension bounded on one extreme by the tendency to view knowledge as simple and unambiguous and on the other extreme by the tendency to view knowledge as complex. The four major characteristics of people on the naïve end of this spectrum, as revealed by the subset dimensions that load most strongly onto this factor, are the tendencies to (a) avoid ambiguity, (b) seek single answers, (c) avoid integration, and (d) depend on authority. J’s tendency toward fragmented knowledge certainly entails the avoidance of integration. But emphatically she does not depend on authority, preferring her own ideas (e.g., unbalanced forces schematization) to the principles sanctioned by physics (e.g., \( F = ma \)). Nor does she seek single answers; she often offers multiple explanations of a given phenomenon, such as the ball tossed straight up, which was the backbone of our data concerning her bias toward fragmentation. So, with respect to Schommer’s Simple Knowledge dimension, J’s behavior is in some ways naïve and in some ways sophisticated. Categorizing J as either naïve or sophisticated with respect to Simple Knowledge does not adequately capture her behavior.\(^{20}\)

Perhaps a more science-specific categorization scheme would work better. One of us (Hammer, 1994) developed a framework made up of several dimensions that succeeded in characterizing six different students’ epistemologies within the context of an introductory physics course. Unlike J’s interviews, Hammer designed his interviews to remain close to the physics course context, asking questions about the course and his subjects’ work in it. His subjects were taking an earlier version of the same course that J was taking.

Like our work in the Synthetic Interpretation section, Hammer worked at an intermediate level of description, analyzing individual subjects’ protocols for systematicities that could serve as evidence for the existence and relevance of intuitive epistemology. He developed a framework for coding indications, made up of categories of belief along three dimensions: Formulas…Concepts, Pieces…Coherence, and Authority…Independence. Coded by these categories, each subject’s protocol showed clear systematicities. As with J, each subject showed inconsistencies from the central tendencies. Still, the framework allowed general characterization of each subject’s epistemology in the context of the introductory physics course.

\(^{20}\) Schommer’s (1990) Epistemological Questionnaire might classify J as nearly midway between naïve and sophisticated with respect to Simple Knowledge. But this doesn’t capture the richness of her behavior, such as the fact that she actively tries to construct her own understanding while (implicitly) rejecting global coherence as a goal.
We now argue that the same framework would not be useful in characterizing J’s epistemology in these interviews. No position on the Formulas...Concepts dimension describes J’s behavior, even roughly. It is clear that J usually relies on intuitive, qualitative reasoning, which would rule out Formulas and may suggest Concepts. But J did not behave in a manner consistent with Concepts, either: She switched points of view frequently without noticing, and she did not, in general, treat formulas as expressions of conceptual substance.

We might try to classify her as Apparent Concepts, Hammer’s middle ground in the Formulas...Concepts spectrum. Like J, an Apparent Concepts person relies on superficial conceptual reasoning. But unlike J, an Apparent Concepts person thinks that these conceptual tidbits serve primarily as mnemonics for the formulas, with no general expectation that physics can be understood conceptually. By contrast, in these interviews J tries to understand almost everything conceptually, though not in terms of what physicists would call “concepts.” So, neither Formulas, Apparent Concepts, nor Concepts adequately captures J’s behavior.

Similarly, J doesn’t fit anywhere on the Pieces...Coherence dimension. The central tendency we have identified, J’s acceptance of fragmented knowledge, clearly rules out a characterization of Coherence. But Pieces also fails, for two related reasons. A Pieces person thinks that physics consists of separate pieces that don’t necessarily fit into any kind of coherent whole. As Hammer (1994) writes, for a Pieces person, “to know something is to remember it; one either knows a piece or does not.” But J views knowing as a matter of constructing an explanation that makes sense to her, not of remembering her teacher’s—or even her own—ideas. For J, it is possible to fill in a gap in her knowledge by inventing a new conceptualization (such as balancing forces in a toss), not just by remembering or absorbing a new piece of knowledge. Second, the shifting conceptualizations out of which she constructs her understanding are too ephemeral and too changeable to function as pieces of knowledge that can be remembered and applied to various scenarios. J doesn’t view physics knowledge as being made of well-defined pieces.

The central point is that categories like Schommer’s Simple Knowledge assume that a unified characteristic is displayed in several ways (e.g., the four subtendencies of Simple Knowledge). Cases like J can and do show some of those presenting forms, but not others, undermining claims of coherent categorical attributes. In a similar way, neither the polar categories, nor “compromise” in-between positions of Hammer’s scheme can effectively summarize J’s behavior.

**On the Nature of Context and Contextuality**

We have argued that it is important to test categorical attributions against the details of individuals. Hammer’s (1994) did just that, for six students in an introductory physics course, and found patterns in their epistemologies along categories in a framework. Why don’t those categories capture J?
Our view of the contextual sensitivity of intuitive epistemologies provides a plausible answer. As we noted, Hammer designed his interviews to remain close to the context of the course his subjects’ were taking, a very different approach from that of diSessa in his interviews of J. For example, the physics questions that arose in Hammer’s interviews originated almost exclusively from the homework assignments, textbooks passages, and lectures in the course, which was a traditional, highly formal presentation. Hammer’s dimension, *Formulas...Concepts*, arose from these conditions: What were the students’ epistemological stances toward the formalism?

diSessa’s questions to J, in contrast, were unlike those posed in her physics course, and the context of these interviews was quite different from the context of that course. Although we can only speculate what would have happened if J had participated in Hammer’s study, it is plausible that Hammer’s categories would have applied. Just as students systematically describe a balance when asked about forces at the peak of a toss, but behave differently in other contexts, we expect the systematics in students’ epistemologies will depend on the nature of the questions they are considering. Thus J’s epistemological behavior in her introductory physics class might have differed substantially from her epistemological behavior in clinical interviews centered upon qualitative physics questions. There is some evidence of this difference, as we discuss in Appendix B.

A fundamental issue in this chapter is how much one must say in order to successfully characterize an individual. At one extreme, one may believe that students can be characterized by a few beliefs or even a briefly stateable theory. At the other extreme, one may insist that a good characterization should consist of a detailed model at the causal level that predicts what the subject does in almost all situations. Such an ultimate model, undoubtedly, would include a huge list of knowledge elements and situational dependencies. Our position is two-fold. First, traditional categorical descriptions of epistemologies entail unrecognized assumptions about consistency\(^{21}\) that are bound to fail. Short of producing a detailed causal model, which we emphatically are not presenting here, we feel a great deal of advantage is available by pushing toward “finer-grained” characterizations, such as our list of behavioral phenomena. Of course, there will be limits and contextual dependencies to these as well. We believe our characterizations of J’s epistemology are insightful, but would expect exceptions and cases of epistemological behavior that we could not explain. Future, improved characterizations at this same level may limit exceptions and cover more behaviors. Moving away from more global, simple characterizations will provide significant increase in explanatory power for tolerable extra cost in saying more about any individual.

Our second, higher level of description of J exemplifies what one gives up by providing simpler descriptions. First, the higher-level descriptions do not unify and make redundant the more specific behavior phenomena. We don’t yet know exactly what

\(^{21}\) It may be more accurate, in some instances, to say that inconsistency may be recognized by researchers offering categorical description, but it is not analyzed or accounted for.
these behaviors have in common and how much an individual who displays one will
display another. In fact, our presumption is that these behaviors are independent or
mildly correlated, not strongly correlated or tightly related analytically. In addition, in
looking forward to causal-level descriptions, each behavior provides a locus of analysis
and clues to the yet more detailed descriptions that should explain specific context
dependencies that we pointed out, but did not presume to explain.

Are our two high-level characterizations of J (as biased toward fragmentation and
toward sense making) substitutes for other global schemes? The answer is that we
believe these are relatively good characterizations of J’s behavior in these clinical
interviews, respecting their high level of abstractness. However, we do not advance
them (or their negatives) necessarily as good global descriptions of other students, or
even of J in other macro-contexts. We consider it likely that other students would have
some helpful and similarly high-level characterizations. But we may have to turn to very
different descriptive language to capture what is essential about other students. We are
making no claims to have identified the range of such characterizations that may be
profitable in summarizing the behaviors of other individuals.

We believe that the simple, insightful characterizations that are possible of individuals
may vary from context to context. In this case, “context” does not refer to micro-
contexts where a student might either split concepts or not. Instead, it refers to the
macro-conditions of thinking. The clinical interviewing atmosphere in which we see J
express the characteristics we attribute to her undermines reliance on authority,
encourages thoughtful considerations, and (arguably, because of the nature of questions
asked) undermines reliance on equations. This differs strikingly from the conditions of
most college instruction, including the course J was taking. As argued in Appendix B, J
might display a different epistemology in her class behaviors. A question in the same
category is how would we characterize J’s epistemology outside of physics? Would J’s
dispositions as we have described them from these interviews be at all similar, for
example, in a literature class or in an everyday conversation? We make no pretensions
whatsoever with respect to these contexts.

These considerations reflect on the judgments we make about Hammer’s or
Schommer’s epistemological characterizations. They can provide insight into students’
epistemologies in particular (macro) contexts. However, we suggest that we have shown
in this study a degree of complexity and context sensitivity that deserves respect and
investigation. In general, we advocate that categorical claims about student
epistemologies be put to the test provided by individual process data.

In this section, we refined our arguments that categorical frameworks for characterizing
epistemologies do not adequately capture J’s behavior. One, we argued in general terms
that systematicities in behavior do not necessarily stem from belief-like or theory-like
coherence in the underlying knowledge structures. Second, using specific data, we
showed that J’s epistemology lacked the articulateness and consistency characteristic of
beliefs or general traits. Third, we argued that two carefully-developed categorical
frameworks (in the form of systems of dimensions)—a general one used by Schommer
and a physics-class-specific one used by Hammer, both fail to capture J’s behavior. Our bottom line is that students’ epistemological orientations should be expected to be highly complex and sensitive to contextual details. High-level generalizations may be insightful, but they can be expected to be limited in precision, and, indeed, they may vary from (macro) context to context.

Conclusion
Many researchers of student epistemologies assume a categorical framework, according to which epistemologies consist of a small number of beliefs or can be specified by positions along a small number of linear dimensions. In questioning the validity of categorical frameworks, we don’t deny that students display epistemological systematicities. Indeed, our own work in this chapter and elsewhere (Hammer, 1994) finds a fair degree of epistemological consistency in our subjects. A categorical framework may be problematic, however, if it (a) presumes too much systematicity, and (b) assumes that the systematicities reflect belief-like or trait-like coherence in the underlying epistemological knowledge structures. By contrast, in our contextual framework we assume that intuitive epistemologies are very complex at the causal level. Higher levels of more compact description are possible and insightful. Yet, they will undoubtedly miss details of micro-contextuality, reflected in the micro-contextual exceptions in J’s protocol to the systematicities we identified, and similarly in micro-contextual exceptions Hammer noted in his subjects. It is also possible we will have to change description to afford good coverage in different macro-contexts, say, in moving from the course-centered interviews in Hammer’s study to the more conceptually centered clinical interviews here. Categorical frameworks have no analytical place in studying micro-contextuality. Partly because of usually hidden assumptions about macro- and micro-contextual dependence, or lack of analysis respecting them, researchers working within a categorical framework tend to develop and validate their categorizations by gathering data from large numbers of students, ignoring the possible effects of context on subjects’ responses.

This chapter, by contrast, presented a detailed case study of one student. For the most part, our analysis of J’s epistemological stance focused not on her explicit statements about epistemology, but on her behavior, her epistemology-in-action as she tried to understand physics. We described eight patterns of behavior observed repeatedly during the interviews. These constitute a finer-than-usual look at the cause and effect of epistemological ideas.

1. Shifting Interpretations: J gives causally different accounts of the same situation on different occasions. This characteristic is unusual (compared to other students) to the extent that it is more frequent, does not converge, ignores elements of contradiction that are normally easily read, and sometimes rejects contradictions as an issue when raised by the interviewer.
2. Splitting Concepts: Technical terms are used in multiple situations, but in ways that imply different core meanings.
3. Migrating Language: J uses alternative technical terms in the same (or similar) context, as if they were interchangeable.
4. Weak Commitment to Principles: J denies or demotes physical principles because she feels her context-specific understanding is adequate.

5. Discounting Details in Explanations: J does not appear to feel she is bound to articulately justify the existence of elements in her explanations.

6. Hedging: J frequently and explicitly shows limited commitment to what she is saying, or provides explicit notifications of vague meaning.

7. Strong Commitment to a View: J is, on occasion, capable of careful, conscious consideration leading to strong personal commitment to particular ideas.

8. Reflective about Learning: J thinks about learning and has drawn many sensible lessons from her experience.

The status of these behavioral patterns is important to review. First, they are only hypotheses about what epistemological stances and strategies might look like. We have no calibration from similarly detailed studies of other individuals. For example, most students may hedge as much as J, and we are not in a position to evaluate the extent to which Hedging contributes to J’s unique profile. Follow-up studies using multiple methodologies should help settle such issues.

On the other hand, our behavioral phenomenology results from fine-grained, bottom-up, and data-based analysis. This means of generating hypotheses should provide important complementarity to more a priori methods of guessing what constitutes intuitive epistemologies, or to methods that impressionistically synthesize a wide range of data.

We went on to synthesize those patterns into two broad epistemological orientations that J exhibits: (a) a bias toward fragmented knowledge, and (b) a tendency to view learning physics as sense making. This synthesis serves two rhetorical functions. First, we used it to demonstrate what is given up at higher (coarser-grained) levels of description, compared to lower (finer-grained) ones. One gives up even more ability to deal with variation across contexts, and one gives up more specific and detailed focus to continue investigation in the hope of moving toward the causal level. Second, we used the higher-level patterns to introduce the possibility of macro-contextual dependencies, in addition to micro-contextual ones. We argued that our own high-level description of J, although useful for understanding her behavior in the context of her clinical interview, should not be ascribed to J as globally-held beliefs or traits. She might well behave differently in different contexts, such as “school as usual.” In other words, not only do we reject categorical characterizations as representing the specifics of knowledge-in-action, but we are wary that different macro-contexts may evoke different systematicities.

The contrast of high-level characterizations to our lower-level phenomena might have important instructional implications. Helping students, for example, not to split concepts might be much more effective because of its specificity than just urging less acceptance of fragmentation. Students who don’t treat learning physics as sense making could learn a lot from J’s many different ways of making sense.
Part of our argument against categorical approaches to epistemological knowledge involved showing that J did not fit into two previously validated and seemingly-appropriate dimensional schemes. Overall, from multiple perspectives and employing a range of arguments and analytic strategies, we conclude that analyzing J’s behavior within a contextual rather than a categorical framework provides a richer understanding of her epistemological stance while, at the same time, providing an analysis that is fairer to macro- and micro-contextual issues that we don’t yet understand.

With respect to intentional conceptual change, our study has somewhat complicated conclusions. We frequently found that “beliefs” (explicit or implicit) seemed unable to carry the burden of explaining J’s behaviors. Instead, we offered the idea of “judgment in context,” which provides a first-pass at a replacement for the idea of “exercising beliefs” with respect to what is happening on occasions when epistemological knowledge becomes active. Judgment in context serves to label why J might make one epistemological move in one context (say, split a concept), and another move in another context (say, remain accountable to a core meaning across different exemplars of a concept).

We argued that, on many occasions, J’s actions were evidently implicit and unconscious. Indeed, even when difficulties were raised explicitly, J often did not see problems in the way she treated physics knowledge. Thus, part of the time, she appears not to have enough conceptual or epistemological resources that intentionally bootstrapping her own learning is at all plausible. If one just doesn’t see any difference between two analyses, why should one pose any task relevant to learning to discriminate them? Of course, J might intentionally formulate other learning goals on other occasions that would address the same issues. We did not see any examples of this, and consider it too speculative to pursue.

On the other hand, J sometimes expressed articulate beliefs about physics knowledge. She knew it involved conceptual change and concomitant revisions of “what seems sensible.” She even “knew” that $F = ma$ was supposed to be very general, before a judgment in context made her change her mind. J’s original belief in the generality of $F = ma$ caused her to devote a great deal of effort in trying to find out what might be wrong with her own view of the situation. And yet, in the end, her belief in the generality of the principle was unstable, yielding to her judgment in context concerning how to think about an object pushed at constant speed.

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References


Appendix A: Shifting Interpretations in the Case of Constant Motion

J exhibited two contradictory models of what is happening when an object is moving at constant speed. The first model entails the claim, discussed in the main text, that any motion requires unbalanced forces. In interview 4 (see Weak Commitment to Principles for details), J considers the case of a book moving at constant speed in being pushed across a table. She initially asserts that any motion implies unbalanced forces. But this brings her into conflict with $F = ma$, which says that if forces are unbalanced, there must be an acceleration, not constant speed. J’s conclusion, after extended consideration, is that $F = ma$ can’t apply to this situation. In that exchange, her principle that motion requires unbalanced forces trumped $F = ma$.

In contrast, in the context of the computer-supported tutorial, J seemed completely comfortable with the idea that an object can move at constant speed with no forces. For example, at one point during a simulation of a toss, the interviewer intervened by turning off gravity. At that point in the simulation, the ball had passed from the hand, and the simulation showed that there was no force from the hand, either.

[6 0:56:30]
A: Now what's going to happen if I continue to let it run?
J: Well, it's going to keep going and it's never going to stop and come back down.

After showing that the simulation confirmed J’s prediction, the interviewer continues:

A: So velocity just //
J: stays the same.
A: It stays the same. I turned off gravity.
J: All the forces. Right.
A: So does that make sense to you?
J: Yes. As long as you don’t have air resistance.

Of course, J might well have learned during the tutorial. Still, it is striking that she did not comment that this interpretation of constant motion was counter to a principle she had considered so carefully and eventually endorsed as “obvious,” that things need an unbalanced force to move. Again, see Weak Commitment to Principles for details on her prior consideration and personal commitment to this principle.
Appendix B: J’s Epistemology Depends Richly on Context

Much of this case study displayed micro-context sensitivities within the clinical macro-context. Here, we consider the possibility—indeed, we believe the plausibility—that the relatively simple characterizations of J’s epistemology that we produced apply only in a macro-context that supports sense making. In particular, we believe J’s predilection toward sense making might not appear as strongly in other macro-contexts.

Specifically, we argue that J’s epistemological behavior in her introductory physics class might have differed substantially from her epistemological behavior in clinical interviews centered upon qualitative physics questions. Unlike Hammer (1994), J’s interviews neither centered on her physics course nor mimicked the tenor of that context. Although we have only limited data about J in the “physics class” context, we put together what we know about J and about that other context to argue that J might well appear epistemologically quite different in that context. In addition, we also have case studies of students who tried, successfully and unsuccessfully, to learn introductory physics by reconciling physical laws with their own intuition and experiences (e.g., Hammer, 1989; 1994). Triangulating among these different data sources allows us to sketch the following plausibility argument.

To begin, there is direct evidence that J found the clinical context unusual and different from her experience in physics class. She complained, at the beginning, when the interviewer did not offer evaluations of her answers, and, instead, insisted that she evaluate them, herself.

[1:0:17:0]
J: But, but see, I can’t give you an answer to the question we want to answer unless I know I’m on the right track. Because if I’m totally wrong, everything I say is wrong.

She also specifically remarked that problems posed were unusual, not like “pulleys and masses.” A bit later, J troubled to characterize how she felt about the interviewing process, and she implicated sense making as unusual, but something she found enjoyable.

[1:55]
J: I like it [talking about physics in this way] because it’s problem solving. In a way, it’s weird to feel like I have to give an answer right away, so I’m saying some things that later I am realizing didn’t really make that much sense, you know? Because, for me, I can think through things when I bounce things off each other instead of like thinking through the whole thing and saying, “okay here’s the answer.” I have to say this happens and this happens and maybe this will happen. So it makes me think, and here I am trying to figure something out, and I realize it is wrong, so I try to figure something else out and I think about it. I like that.

J goes on to assert that school makes you feel like you have to give correct answers immediately. “I just have to get over, personally, thinking that if I say all these wrong things this person’s looking at me thinking I’m a total idiot... That’s something school does to you.”
At the time J took introductory physics at Berkeley, those courses proceeded at a very fast pace and emphasized quantitative problem solving.\(^\text{22}\) In this environment, a student can learn what she needs to learn by trying to make sense of the material, reconciling physics concepts with her intuitions and experiences—but only if she is adept at doing so. Otherwise, doing well on tests requires the student to accept a fair amount of material, and to learn certain problem-solving techniques, without making sense of it all.\(^\text{23}\) J, we know from her interviews, is not efficient at reconciling her intuitive sense of mechanism with canonical physics. Still, she earned a B in the course. To do so, she must have learned certain concepts and problem-solving techniques without making sense of it all. As compared to her sense-making during the clinical interviews, J’s sense-making in her physics class must have been less pervasive and different in character. Specifically, in her physics class, J likely did not systematically trust her intuitive schematizations over the sanctioned laws of physics, treat friction as fundamentally different from other forces (Splitting Concepts), or resist thinking in physics-sanctioned ways. Had she done so, it is unlikely, we assert, she could have earned a high grade.

A critic could accept our conclusion about J’s behavior in physics class while denying that it reflects a context-sensitive shift in her epistemology. Perhaps J, like Ellen from Hammer (1989), retained her epistemological bias toward sense making while consciously making concessions in order to survive. Elby (1999) shows that this kind of behavior is common. We lack direct evidence to the contrary. Again, however, we can offer a plausibility argument: J gives us reason to believe that she did not perceive herself as compromising her epistemological values in her physics class. For instance, she speaks often enough of liking her physics course and of feeling that she gets conceptual satisfaction out of it. Consider her comment on the realization that her chair pushes up on her as hard as she pushes down on it:

\begin{quote}
J: This chair’s pushing up on me. I think that’s something that once you’ve taken physics, that’s totally normal. But if you said it to someone off the street, I think they’d say, “What are you talking about? No it’s not. You know, obviously it’s not pushing; there’s nothing to push it up.” But it is. So maybe it’s like what is going on is common knowledge, but how it actually works maybe I learned. [emphasis added]
\end{quote}

She perceives revising her intuitive ideas in pursuit of sense making as an enjoyable part of physics class:

\(^{22}\) When J took first-semester introductory physics in the early 1990s, the course covered kinematics, forces, energy, momentum, angular motion (including angular momentum), statics, gravitation, oscillations, waves, and fluid dynamics.

\(^{23}\) From Hammer (1994) and Hammer (1989), compare Tony, whose sophisticated epistemological stance helped him pursue an integrated understanding of physics and who earned an A, with Ellen, who started off the semester trying to reconcile the physics with her ideas and experiences, but who quickly became overwhelmed by the pace of the course and reverted to rote learning in order to get through the assignments and exams.
J: Well, I mean it’s really neat when you learn something that isn’t what you would intuitively have thought, but it makes sense, you go, “God, I totally understand that. It’s not what the everyday person on the street would know, but I understand.” [emphasis added]

These reflections about physics class do not sound as if they come from someone who has consciously—and presumably, unhappily—renounced her favored learning strategy. Nowhere in seven hours of interviews does J hint that she knowingly made epistemological concessions. Instead, J sounds as if she perceives sense making to have been part of her experience in the class.

We are arguing that J did not—could not—do nearly as much sense making in her class as she did in the clinical context, and yet she did not notice this fact. How could this be? Since some of J’s epistemological knowledge is tacit, as argued earlier, J could have slipped into a different epistemological mode without being aware of it, just as she slipped into different interpretations of a situation without noticing (or without considering the changes to be significant). Our point is that a real shift in J’s epistemology-in-action, not just a conscious adoption of epistemologically-unfavored survival strategies, could well account for differences in J’s epistemologically-driven behavior in the two different contexts.

In summary, a plausibility argument suggests that J’s epistemological behavior in her introductory physics class might well have differed from her epistemological behavior during the clinical interviews. This is not really so difficult to imagine. During the interviews, the interviewer’s interest in J’s thinking and the nature of the questions he asked, combined with the on-line pedagogical materials, probably created an environment friendly toward sense making. By contrast, as Ellen (Hammer, 1989) discovered, the introductory physics courses at Berkeley were not a friendly environment for sense-making, except for students particularly adept at doing so.

The important general point of this argument is that we believe high-level characterizations of students’ epistemologies are subject to macro-contextual effects. One of the consequences is that students, despite years of tuning their epistemologies toward contexts unfriendly to sense-making, may have the epistemological resources needed to function well in more friendly sense-making environments.