BECOMING A RESPONSIVE SCIENCE TEACHER

Focusing on Student Thinking in Secondary Science

Daniel Levin, David Hammer,
Andrew Elby, Janet Coffey

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National Science Teachers Association

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Acknowledgments

This book of case studies came from the final year of a three-year research collaboration among a team of teachers and project staff entitled *What Influences Teachers' Modifications of Curriculum*? (National Science Foundation ESI 0455711). As a regular part of the project, research team members visited teachers' classes to video record, observe, and talk. In the third year of the project, the teachers recorded classes themselves (or had an assistant or student do the recording) and wrote case studies. It wasn't our original plan to develop these materials; that idea came from a conversation with David Campbell, our wonderful program officer at NSF, and Miriam Sherin, a member of our advisory board. They helped us see an opportunity in these cases for professional development materials.

We selected from those case studies to present a broad spectrum of topics and to highlight opportunities for attending to students' thinking. We're very grateful to the project teachers who contributed the case studies included in this book: Sarah Henson, Janet "Izzy" Kovach, Jenny Tanner, Matt Reese and David Hovan, as well as to Terry Grant, whose class we describe in Chapter 1.

The comments presented in the facilitators' notes come from preservice teachers in the Masters' Certification (MCERT) program at the University of Maryland, College Park, Maryland, and from inservice teachers participating in seminars. There are too many of these people to name. Jennifer Richards helped with recording and transcribing the discussions in the MCERT classes.

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CHAPTER 5

The Owls and the Snakes (2)

Janet "Izzy" Kovach was the author of the owls-and-snakes question Sarah used in her teaching (discussed in Chapter 4), and this is a case study of student thinking in one of Izzy's own classes. Izzy, we should say, was a "ringer," a highly experienced teacher with an unusual set of qualifications—including certification in special education, social studies, *and* science, and experience working in an alternative program for students with substance abuse problems. So she's a little different from the teachers in other cases in this book. We include this case to have an example of work in special education: Izzy's was a "self-contained" class for students with a wide range of diagnosed special needs.

As Izzy describes in her case study, she had used this owls and snakes story many times before. This year she planned to take it further, bringing in data from the research article itself to see if the students could use the evidence to draw conclusions about the various relationships that they had proposed.

The main data for this case study are the transcript, the data Izzy shared with the students, and the video. Izzy's case study begins after "Suggestions for Reading and Viewing." The video and the transcript are available at *www.nsta.org/publications/press/extras/responsive.aspx*.

Suggestions for Reading and Viewing

Be sure to make copies of the transcript. Even if you're watching the video, the transcript is useful for following along, for jotting notes, and for referring back to particular snippets during conversations about this class. Additionally, the transcript makes clear what data Izzy was referring to during the conversation.

When we use this case study in courses or workshops, we usually describe the curious owl-snake relationship and pose the question for participants to discuss it themselves, before we present the conversation that took place in Izzy's class (unless of course they've seen Sarah's case in Chapter 4). We have participants read the first part of Izzy's case study, stopping before the section "Students' Use of the Evidence." We then present the conversation, stopping at several spots in order to encourage participants' close, careful examination of student thinking:

The Owls and the Snakes (2)

1. *Line 54, approximately 8 minutes in, when Max and Cameron respond affirmatively to Izzy's question, "And are blind snakes capable of burrowing?"* We've found this is a good stopping point to ask participants: How do you think it's going? What do you notice in students' ideas and reasoning? Does their thinking seem scientific?

2. *Line 191, about 21 minutes in, when Kevin says, "True."* Again, we check in: What do you notice in the students' thinking? Do you see anything new in this segment, compared to the first?

3. We've rarely gotten further than line 191, but there are still things to talk about if you run the video to the end, as we discuss in this chapter. Regardless of where we stop, we ask participants to consider the "menu of possibilities" of how Izzy might respond. What ideas might be worth further attention? How might Izzy structure the next part of the conversation, or the next activity, based on the ideas she has heard?

The Case Study: Using "The Owls and the Snakes" to Teach the "Well-Designed Investigation"

By Janet "Izzy" Kovach

Introduction

A dozen years ago I stumbled across an interesting story about screech owls bringing a specific species of snakes, which are naturally blind, to their nests and allowing the snakes to live with them unharmed, for some unknown reason. It was in a "nature puzzlers" book, which a colleague had donated to me when he was cleaning his closet. At the time, I was looking for an engaging first-day-of-class activity, and I incorporated the case into a list of "unanswered questions" faced by biologists. I then filed the book away in my closet, perhaps to pick up again whenever I decided to retire.

I forgot about the story after that, always on a quest for a better season opener, until about three years ago when I made a move to a new high school. As I unearthed and repacked the book, I wondered if naturalists had ever come up with a reason for the owls' unusual behavior. But I never gave thought to using it until it was time to introduce the concept of symbiosis to my new self-contained biology class of 10th graders in special education[1]. The students had been struggling with the surfeit of vocabulary in the biology curriculum's introductory ecology unit while I had been struggling to find a way to encourage them to take ownership of all these new terms instead of simply trying to memorize a glossary list.

Aha! Why not give them an intriguing nonpredatory relationship between two species that are usually considered mutual enemies and ask them to figure out what might be going on? Better yet, why not use a case where a "correct" answer has not been established, so students need not be intimidated by being wrong? It was time to dust off "The Owls and Snakes" once again.

Each time I used the case, I was gratified by the students' engagement and their willingness to hypothesize all kinds of likely interactions. Classes generally agreed, in the end, that each species probably benefited from the nesting arrangement (e.g., owls may provide a safe haven for the blind snakes in return

1. There were 12 students in the class. The IEP primary code breakdown was as follows: Six students were diagnosed with "specific learning disability," three with autism, one with speak/language disability, one with "other health impairment" (Attention Deficit Disorder), and one with severe emotional disability.

for protection of the owls' eggs from intruders). Even better, when the specific vocabulary for symbiotic relationships was introduced, they seemed to have an easy time transferring the terms to match the interactions they had suggested as plausible, and they used the terminology freely and appropriately.

In fact, the lesson always worked so well and was so engaging that it struck me that it could be extended for another purpose. Here was a question asked by real scientists who were doing real science to find reasoned explanations. And my students were genuinely interested in finding an answer, as well. What a great way to introduce the concept of the "Well-Designed Investigation"[2] without starting with the off-putting vocabulary of *variables* and *controls* and the artificiality of creating an experimental design around some meaningless question about pill bugs and temperature or daphnia and caffeine.

The Lesson

I introduced the lesson as in years past. Following a lengthy and lively discussion of what students already knew about snakes and owls, I gave them a very short synopsis of the case and posed the question, "What is the relationship between the screech owls and the blind snakes?" After establishing a list on the board of "what we know for sure" from the synopsis, students worked in pairs to come up with hypotheses to explain the relationship. They seemed very comfortable with the term "hypothesis," knowing the usual definition of "an educated guess." Additionally, in order to get them thinking about the design of an investigation and useful data, I asked them to list other pieces of evidence that would help them solve the puzzle, explain how that information would help them evaluate what was happening, and devise a way to prove that their hypothesis was correct. Some student written responses fell back on the need to consult experts:

> "I would like to know more about why blind snakes live with owls."
>
> "I would read about how the owls live with blind snakes online or in a book."

Most students, though, generated their own approaches to gathering useful evidence for evaluating their hypotheses. I had given a handout in class, asking students for their hypotheses, and what evidence they would need to support their hypotheses. Here are two of what I consider to be the better responses (from handouts completed in class):

---

2. The "Well-Designed Investigation" is the language used in my school district for what is generally thought of as experimental scientific method. Teachers are required by the state to teach this vocabulary and it is assessed on the statewide biology test, which students must pass in order to graduate.

- *Hypothesis:* "The owl is keeping them for its baby food that when the owlet's hatch they will eat the blind snakes as a first meal."
- *How would you prove that your hypothesis is correct?* "I would need to see the owlets' hatch, and see how they interact with the blind snakes. The owlets would be feeding on the snakes. The number of snakes would begin to disappear."

- *Hypothesis:* "The owl is either using the snake for protection of the eggs or stored food for the eggs when they hatch."
- *What else would you like to know?* "To know if the snakes are protecting the nest, the biologist can put mice or rats in the nest so the biologist can see what would happen to the mice or rats."

So right from the first day, students were developing ideas for experimental designs that would result in measurable outcomes to verify their predictions. We spent the following class refining the hypotheses and compiling a class list of possible explanations for the strange animal behavior. Anything that fit the initial data was accepted. Here are the hypotheses we had in the list:

- The snakes are going to be baby food (for owlets).
- The owls are giving snakes a place to live ("compassion").
- The snakes are protecting the eggs, nest, or owls from enemies.
- The snakes and owls are protecting each other.

We spent the next period with a traditional curricular presentation of symbiosis versus predator/prey relationships and the standard definitions for mutualism, commensalism, and parasitism. Students spontaneously began applying the terms to their understanding of the snake/owl association, (along the line of "So that's what the owls were up to!") and we were able to formally attach a label to each of our hypotheses. I thought the students' spontaneous connection of the vocabulary to the case of the owls and snakes was wonderful, because students were taking ownership of the vocabulary, and using it to make their arguments. One student (Kevin) was adamant that the relationship was *initially* commensalistic (because the blind snake was provided a safe place to live), but would be transformed to predator/prey once the owl eggs hatched. Another student wondered, then, would that mean it really was a mutualistic relationship since both sides benefited at least some of the time?

It would have been difficult to move the lesson beyond this point if I had not been able to locate a published field study of the snake/owl relationship that provided real data for the class to analyze. Now the class had the opportunity to evaluate their hypotheses on the basis of evidence—the heart of real science. Without revealing the authors' conclusions, I inserted summaries of their observations and experimental data, one snippet at a time, into the next day's lesson. After each piece of new information, I asked the students how it impacted their understanding of the relationship. While some of the language and statistical evidence was well outside their comfort zone, the students were invested in discovering what was going on and willing to work at understanding the information in order to assess its relevance. Through the course of the discussion, the students displayed some sophisticated scientific thinking, as well as falling into some common intellectual traps.*

***This is a good point to stop reading, watch the video, and talk about student thinking.**

Students' Use of the Evidence

To start the class, I showed the students their hypotheses from the day before and then started showing them the data so we could talk about it, one piece at a time:

- *Evidence #1: The blind snakes are normally fossorial, but they have been observed climbing trees to reach nests of ants.*

Initially, after I put up this slide, we spent a little time talking about the meaning of the word *fossorial*, and the students were

able to read its meaning from the context. Josh had a question about whether a *nest* was the appropriate term for where ants live. His question was a little off track from the discussion, but I really wanted to encourage students to talk, so I was trying not to "stamp out" any ideas, even if they seemed tangential.

I turned the conversation around to whether or not this evidence was useful for evaluating our hypotheses. Adrian said it was, because it showed that the owls could enter the nest on their own, but I wasn't clear about why he thought that was important. He said, "If the owls and snakes ever turn against each other, they could use that as an advantage for like, uhhh, battle and stuff." It seems like he was thinking that the snakes' mobility gave them another way, "an advantage" in dealing with the owls, but I'm not sure if he was thinking about how that could be used to evaluate the hypotheses.

Maybe he thought that the snakes' added mobility would make them difficult prey for the owls to catch.

Josh had an idea about how the evidence could be used to support a hypothesis.

> Josh: Don't snakes eat ants, and ants might like to, like when a baby gets born, when it hatches, ants will probably swarm around it and eat it, so same thing; it'll eat ants and other pests would [cut off].
>
> Izzy: Oh. Ok, so if ants are living in the owl's nest, maybe the snake is eating those ants and that helps the eggs. Interesting. So which of these ideas would that support Josh?
>
> Josh: They're protecting the nest from ants.

I put up the second piece of evidence, and asked if it gave us any information that would help us to support one of the ideas or get rid of one.

- *Evidence #2: 89% of the blind snakes in the nests are still alive when the fledglings leave the nest; the remaining 11% were found dead—of these, only one was partially eaten.*

Max immediately recognized what this meant.

> Max: Get rid of the predator-prey relationship.
>
> Izzy: Because?
>
> Max: Because only 11% of them are found half eaten. But only one was eaten.
>
> Izzy: Ok, and it-ok only one was eaten out of all the snakes that they found and most of them were alive.
>
> Max: Uh huh.
>
> Izzy: Alright, so that certainly doesn't sound like they're being saved for food. Because, what would you expect if they were-how many would you expect to find alive after the owls left the nest?
>
> Max: None.

In general, I thought the students were doing a pretty good job of reasoning with the evidence. Like I said, though, I noticed some pitfalls in their arguing, such as cases in which they were selectively ignoring some evidence—trying to justify a hypothesis with supporting evidence while ignoring nonsupporting evidence. I saw an example of this with the third piece of evidence I put up.

- *Evidence #3: Young nesting owls will eat both dead and live snakes put into their nest by researchers. However, live snakes that can quickly burrow into nest debris are not eaten.*

  Cameron: So my hypothesis was true.

  Izzy: Which hypothesis?

  Cameron: The snakes-the little owlettes hatch, they eat the snakes.

  Izzy: Ok, so that supports the predator-prey idea, but we have that other piece of evidence that they're still alive. So what must those snakes be doing? Those little-those live blind snakes that-that are put into the nest.

  Alex: Practicing for hunting?

  Izzy: Well, but, if they're-if they're practicing for hunting are they very successful?

  Kevin: Not really.

  Izzy: Not really. So, what are those snakes doing to stay alive, according to this?

  Josh: Burrowing.

  Izzy: Burrowing. And are blind snakes capable of burrowing?

  Max: Uh-huh.

  Cameron: Yes.

Here, Cameron picked up on the evidence that blind snakes put in nests by researchers will be eaten, which he took as evidence that his hypothesis was supported—that the snakes were being saved as food for the baby owls when they hatched. I challenged him a little to remind him of the previous evidence (that most snakes are still alive when the baby owls leave the nest)

and asked what he thought the blind snakes were doing. Alex said that they were "practicing for hunting." I didn't really understand what he meant at the time. Possibly he was mixing up "owls" and "snakes" (like all of us, myself included, did throughout the discussion) and he was saying that the snakes were used as hunting practice for the baby owls (even though they generally didn't catch them). Josh pointed out that the snakes were probably burrowing to stay alive, and Cameron agreed, although I'm not sure if he really understood the implications of the data—that owls will eat the snakes, but the snakes usually burrow into the nest too quickly to be eaten, which essentially argues against a simple predator-prey model.

The next piece of evidence was about what the blind snakes eat, and I expected that it would solidify an argument in favor of the hypothesis that the snakes protected the nests from insects that could harm the eggs somehow.

- *Evidence #4: Blind snakes normally eat the soft-bodied larvae of insects they find in underground ant or termite nests.*

Kevin surprised me, however, by constructing an argument that did not support any particular hypothesis, but instead synthesized a new hypothesis using some of the evidence.

> Kevin: I think it's a little bit of both of commensalism and predator and prey.
>
> Izzy: So you're jumping right-this-is this giving you information to make that decision.
>
> Kevin: Yeah.
>
> Izzy: Why do you say commensalism, predator and prey?
>
> Kevin: Um, because well commensalism because, uh, the owl knows that the, um, that it would clean up the, the nest. Like from getting damaged or something, like, and if it was to get damaged then the, uh, there won't be any eggs to-to be, like, hatching from the nest.
>
> Izzy: So what would be damaging the eggs?
>
> Kevin: The insects.
>
> Izzy: Ok, so if there are insects in the nest it would damage the eggs-
>
> Kevin: Or-or at least do some, like, like termites they eat-they eat wood.

Izzy: Mmmhmmm…

Kevin: So-

Izzy: That's a good point.

Kevin: They could break off the branch or whatever.

Izzy: Oh! Think about that. The nest would fall to the ground.

Kevin: And then like predator-prey because it's like if the blind snake wasn't able to somehow get through underneath the mess, then they'll be eaten.

Rather than assuming that there was only one kind of relationship, Kevin was drawing on the evidence that (1) the snakes will occasionally get eaten, (2) they eat insects that could hurt the eggs (or cause the nest to fall to the ground), and (3) the snakes could "get underneath the mess," so they would be eaten. Based on this evidence, Kevin argued that it was "a little bit of both of commensalism and predator and prey."

With the next piece of evidence, Kevin saw corroborating support for the hypothesis that the snakes protect the eggs.

- *Evidence #5: Table of arthropods found in the debris of owl nests (species known to be eaten by blind snakes are marked by asterisks.)*

Izzy: So what does this, what does this tell me?

Kevin: Normally different animals live in the nest that the blind snakes eat.

Izzy: Ok, so this confirms your idea, right?

Kevin: Yup.

Other students also suggested that the evidence supported another of their hypotheses: that the owls provide the snakes a safe place to live.

Izzy: Yeah, so there're insects there that they will eat. So which hypothesis does that support, Jeff?

Jeff: Both?

Aryton: No, the second one does.

Izzy: (reading hypothesis two from whiteboard): The owls are providing the snakes a safe place to live. Is it a safe place? Or a place with food?

Jeff: Place with food.

Izzy: I guess that makes it safe, right? So, are the snakes getting something out of this relationship too?

Alex: Yeah, food.

Despite Aryton's odd way of phrasing it, "the second one does," I took him to mean that the evidence supported the hypothesis that the owls are providing the snakes a safe place to live.

As Kevin did with the previous piece of evidence, Josh used the next piece of evidence to support the argument that the snakes were helping the owls in some way.

- *Evidence #6: Table of nestling growth rate and fledging weight in nests with snakes present and nests with snakes absent.*

Josh: It looks like the snakes do more helping. They're not as fat when they need to fly and then they—they grow really fast.

Izzy: They grow really fast and they can fly away at an earlier-at an earlier size. At a quick-so they're-they're leaving the nest more quickly. Good point. Not only are they growing faster but they're leaving the nest sooner. So they must-that's a good sign that they're healthy. So, Max, is that support for this?

Max: Yeah.

Izzy: That the snakes are protecting the eggs.

I thought this was one of the more difficult pieces of data to understand, but Josh interpreted it pretty quickly, pointing out that when the snakes are present, the baby owls grow faster and are able to fly at a lower weight. I think his use of the term *fat* is meant to suggest that because they are not as fat when they fly, they can fly better.

By the end of the discussion, the students were nearly evenly split between supporting the relationship as mutualism or commensalism (with the owl as the beneficiary). Of course, they were also curious to know what conclusion the biologists had reached, so I gave them the full copy of the

journal article. Half of the class felt vindicated by the authors' defense of commensalism, with the usual bravado of those backed up by authority:

> Kevin: I was right … Yup, I'm right …. I'm always right.

But I was pleased to see that the opposition was not ready to just drop its own thinking in the face of expert opinion.

> Josh: Can they prove they're really not helping the snake?
>
> Izzy: Can they prove-well what-how would they have to prove that it's not helping the snake? How would you-how would you go about proving that the snake is-is not being helped?
>
> Josh: Well those snakes are blind. I don't think they can find anything. And up there in that nest, they're safe and get free meals.

Although Josh didn't really answer my question of how he could prove that the snake is not being helped, he continued to develop his argument that the snakes were actually getting a benefit, because it was easier for them to find food in the nest and be safe from predators.

As a final activity to underscore the role scientists play in critically evaluating each other's research and the ongoing nature of the investigation process, I charged the students with devising a way to determine which group of snakes were better off—those on the ground or those in the owl nests. Seven of the 12 students were invested enough in the analysis process to suggest methods for deciding if the relationship was mutualism or commensalism. Some of these were simply a rationale for why snakes would be at an advantage on the ground or in a nest:

- *Snakes are better off on the ground because they can move better.*
- *Snakes are better off on the ground because they feel safe.*
- *The nest because they have protection.*

However, many students recognized the need for quantifiable data collection to support their claims:

- *Check the number of predators in the nest and the number of predators on the ground.*
- *You can see how many foods are on the ground and how many are in the nest.*

- *I would be looking for how much food the snakes would be eating. I would also be looking for how they move. It can sometimes tell how they are feeling.*
- *See if the insects in the nest, if the snakes like them better than the ones on the ground.*
- *The size of the snake.*

Reflection

At the end of this five-day (50-minute periods) lesson sequence, I was satisfied that the time had been well spent. Not only did I hear a classroom full of engaged students, I felt that I had evidence of sophisticated scientific thinking and authentic participation in inquiry. Still the bottom line in today's data-driven classroom is assessment numbers, and all I had generated was taped conversations with students.

Therefore I felt compelled to look at my students' performance on countywide administered semester exams, specifically at items purported to assess scientific thinking. I also compared their scores to those of 21 other students in biology classes in which I had only used the snake/owl relationship as a five-minute warm-up activity to introduce symbiosis.

The data was disheartening. While scores on these items were low (average 59% correct), they were higher than the average for the entire test (47%). However, they were not notably higher than the scores of students who did not participate in this five-day sequence. So did I waste valuable teaching time when I could have been covering more of the information on the test? If so, how do I reconcile that with calls for authentic, inquiry-based education and with my own sense from what students were thinking that this had been a really productive exercise to that end?

Perhaps the real concern should be with the test-driven assessment practices fueled by the expectations of "No Child Left Behind." Special education students in my district score notoriously low on exams—a 47% average is not unusual! The multiple layers of knowledge and reasoning necessary to answer test questions (background information, analysis of data, facility with language) make test-taking a daunting task for students with exceptionalities, akin to the difficulties faced by nonnative English speakers. Maybe the tests are not an adequate measure of students' science learning.

I believe that more meaningful (albeit more difficult to quantify) data on student learning can be derived from tools such as the video/transcript generated by this class. Including students' participation in such discussions as part of a student portfolio, we could more meaningfully assess what our students know and are able to do. In this case, my students demonstrated

the ability to recognize evidence and design controlled investigations. They interpreted complex data sets and used them to refine their ideas. They recognized flaws in their own thinking and made revisions. These are the things I hope to see from my students in science class!

Our district's curriculum claims to put a very high premium on learning that science is a dynamic process of discovery. This does not match up well to a static, standardized testing regime. Analysis and evaluation of evidence are central to participating in science, and are not adequately assessed by the tests. It's time to take a hard look at how we assess students' science learning.

Facilitators' Notes

Please see the general notes for facilitators in Chapter 3. Here we'll provide specific comments and suggestions with respect to discussing the case at the recommended stopping points, the rest of the snippet, and the teacher's case study. Our purpose here isn't to present a thorough analysis of the snippet but to give a sense of possible topics that might arise or that a facilitator might bring up.

What Is the Nature of the Relationship Between the Owls and the Snakes?

Often, especially if we have 90 minutes or more to spend on the case study, we will have participants discuss what they think is the nature of the relationship between the owls and the snakes. In the previous chapter, we discussed how we facilitate this discussion and the kinds of things that come up. One difference between these two cases, however, is that Izzy gave the students the data, whereas Sarah did not. With this case, therefore, we give participants an opportunity to reason with the data themselves, so that they can compare their own thinking to the students' thinking.

One interesting question participants have asked is, "Do the owls bring the snakes to the trees or the snakes crawl up there?" The first piece of evidence says that blind snakes are observed climbing trees, but it's never clear if they do that to reach the nests or if the owls bring them there. People think this is important; the argument is that if the snakes went to the nest on their own, then it might be evidence for mutualism, as they would seem to be going for "choicer" food. On the other hand, if the owls bring the snakes there, it would not necessarily support a mutualism argument because the snakes are not choosing to go to the owls' nests.

The Discussion to Line 54

Opening the Conversation

We usually stop the recording at line 54, approximately eight minutes in, when Max and Cameron respond affirmatively to Izzy's question, "And are blind snakes capable of burrowing?" We ask participants how they think it's going, what they notice in students' ideas and reasoning, and what they see in the students' thinking that seems scientific.

Emphasizing the Substance of Students' Ideas and Reasoning

Often, people first want to talk about what Izzy is doing (or not doing) or the nature of the activity. Here, people usually comment positively on how Izzy has set up the activity, and what a great way it is to get students thinking about using evidence. At this point, we try to steer the conversation away from discussion about Izzy or her methods, trying instead to focus participants on the students' ideas and reasoning. For example, if a participant says, "This is a great way to get students to think about the relationship between evidence and hypotheses," we might say, "What is it that you hear that makes you say the students are thinking about that relationship?"

It also commonly happens early in the conversation that participants comment on students' engagement, especially when we've shown the video. This is particularly problematic in Izzy's case study, which takes place in a self-contained special education classroom where several students appear not to be participating or even following what's going on. Some students have their heads down on the table, and one (Max) is rocking back and forth.

There's no question that it is important for students to be engaged, and we acknowledge that it may be problem. But, we emphasize, we chose this clip for the student ideas it puts on display. So, once the point is made about student engagement, we work to refocus the discussion on student thinking. (Sometimes, if engagement issues continue to dominate the discussion, we have pressed the point that while it is important to help the unengaged students, it is also important to work meaningfully with the students who are engaged. As well, we note, it may be difficult to assess these students' engagement, based on their physical behavior.)

Pressing for Specificity

Another common tendency is for participants to make general statements about how the students are doing, and we try to press them to include examples from the transcript to support what they are saying. For instance, if someone says,

"I like what Josh is doing in line 12," we ask them to interpret specifically what they understand Josh to be saying, and what they like about it.

Interpreting the Substance in the Students' Thinking

We rarely use this case study as our first one, primarily because some of the student ideas are difficult to interpret. This is a special education classroom, and some of the students in the class have disabilities related to language use. Often it seems as though a student *has* an idea, but it can be difficult to understand what it is. By the same token, the students' difficulty in expressing themselves makes it more important to listen carefully in order to interpret what they are trying to say, and participants who have already had some practice may be in a better position to study the transcript for meaning.

For example, Adrian responds very quickly to Izzy's question in line 20 about whether the first piece of data (that the snakes are normally fossorial but can climb trees to reach ant nests) can be used to evaluate the hypotheses. He says that we can "use it to evaluate." Someone usually mentions what Adrian says at the beginning of the discussion, and the general consensus is that he hasn't really constructed an answer to how the data can be used to evaluate a hypothesis; he is treating the question as a "yes or no" question, without realizing that he needs to explain his answer. As one participant put it, Adrian is approaching the question as "low-hanging fruit"—one in which he can give a simple one-word answer without putting too much thought into it.

We've pointed out Adrian's statement in line 21, "The snakes are capable of climbing up trees, and they can get to the nests on their own." What can we say about Adrian's reasoning there? In response to this prompt, people often interpret him to make an important distinction; one teacher remarked that Adrian's comment "suggests something about the relationship, like [that the snakes are] a voluntary participant in whatever is going on."

Pushing even further, we ask participants to think about what Adrian means in line 23 when he says, "And if owls and snakes ever turn against each other, they could use that as an advantage for like, uh, battle and stuff." Again, the perception is generally that Adrian is not thinking about how the data could be used to evaluate the hypotheses, but someone usually interprets him to be continuing to support the idea that the snakes have some agency in the relationship. It seems to some that he might be trying to reject the predator-prey hypothesis; that is, the snakes' ability to climb trees might suggest that they could easily escape from the owls and thus are not easy prey.

Josh's comments in lines 25 and 27 are usually not the first thing mentioned, perhaps because it is very clear from what he says that he is making an argument that the snakes could be protecting the baby owls from ants and other pests that might harm them. If no one mentions Josh's idea, we ask about

it, and the consensus is usually the same as what Izzy mentions in her case study, that Josh is clearly using evidence to support a hypothesis. Interestingly, it has been suggested that Adrian's comment might have prompted Josh's idea. Perhaps Adrian's comment that the snakes are voluntarily going to the nests helped Josh think that there might be something in the nests that benefits the snakes.

Max's statement in lines 29 and 31 is very interesting, and if no one brings it up, we do. He says, "We can get rid of the predator-prey relationship … because there's only 11% of them were found half eaten, but only one was eaten." He has incorrectly summarized the slide, which says, that *11% were found dead* and *1 snake was found half-eaten*. When we ask about his meaning, participants seldom notice that he has incorrectly summarized the slide and instead focus on what appears to be his overall argument—that since most of the snakes were *not* eaten, we can "get rid of the predator-prey relationship." One option here is to draw participants' attention to what Max actually says; does his incorrect summary mean that he has not appropriately interpreted the data? When we have done this, most participants are unconcerned with his summary. They argue that despite his misstatement, he has used his overall interpretation (that most of the snakes are not dead) to support an argument against the predator-prey hypothesis. We also like to draw focus to Max's idea because we believe it suggests that he is demonstrating an important understanding of science—that claims are made on the basis of a preponderance of evidence, although some discrepant or anomalous data may be present.

Participants also often mention Cameron's comment in line 37: "Well, I was gonna say the-because of the dead-uh the dead blind snakes-thinking they were picky about their food, because they'll eat live ones." What does Cameron mean here? Why was he "gonna say the…are picky about their food" and then change his mind? Is he doing some good scientific reasoning? Although what he says is a little confusing, it is generally agreed that he is saying that he thought the *owls* are picky about their food because the previous data suggested to him that the "half eaten" snake was a dead one. He had his hand up as Izzy was introducing the next set of data, so this is likely what he "was gonna say." However, hearing that new data, he decides that "it doesn't seem that way."

If someone doesn't bring this point up, we do, mostly because it suggests beginnings of scientific inquiry that require close listening and interpretation to recognize. Many participants point out that he is not using the evidence to consider the hypotheses available, and so they don't think he is reasoning with the data. However, participants who focus on how Cameron is *trying to make sense* of the data disagree. Even though he is not doing what Izzy wants him to do, he is doing some sensible thinking and being metacognitive about his own ideas. As one participant put it:

> [H]e's shown this marvelous bit of scientific reasoning—[he] has this idea from the beginning of (line 39) that maybe the owls are picky, they'll only eat dead snakes—they won't eat live snakes. Right, because you know I think everybody sort of has some familiarity with this, like some animals will only eat like live food that they catch and they won't eat dead food and some won't eat dead things and only live things. But, then he hears the rest of the data and he like he evaluates his own hypothesis and he compares it to the data and it doesn't fit and so he rejects his own hypothesis.

Another interesting thing happens shortly after that in this discussion. Cameron keys on the piece of evidence that says that the baby owls will eat live blind snakes *if they can catch them* to argue that his hypothesis is true—that the baby owls will eat the snakes if they can catch them. Although he appears to miss the other evidence that (a) most snakes found in the nest are alive, and(b) live blind snakes can burrow into the nest, he seems to understand the nature of the activity, as one participant noted:

> He gets that whole "well-designed investigation concept," that I started off with a hypothesis, now I have evidence, and now the point is to see if the evidence makes my hypothesis true or false, and I found something that sort of agreed, and so now I made a conclusion, my hypothesis was true.

In response to Cameron's idea, Izzy asks him to consider the other evidence, that most of the snakes are still alive, and asks what those snakes must be doing. Alex says "practicing for hunting." We ask about this idea, too, because it seems like an odd response to the question of what the snakes are doing. Reading it carefully in context, participants generally agree that Alex is referring to what *the owls* are doing, and not the snakes, reasoning, "I think he was thinking about the owls, or owlettes, are keeping the snakes for practicing for hunting."

Another participant said, "Maybe he's saying that the snakes are practice for hunting, the snakes are just practice." Some special education teachers who have seen this case have suggested that this might also reflect language difficulties, specifically over syntax and word endings. Alex might have been *trying* to say the snakes are *practice* not *practicing*.

This happens frequently throughout the discussion, that the students (and Izzy also!) often refer to the owls, when they likely mean the snakes, or vice versa. This makes it all the more important that participants try to interpret what the student might be saying in context, because the students often use the wrong word. If Alex does mean the owls, then he's doing something very interesting—he's proposing a new hypothesis, based on his reading of the data. One possibility is to ask participants to consider the alternative here. What if Alex does mean the snakes? Is there some way to understand why he might be saying that? Is he just confused?

Moving From Interpretations to Ideas for Instruction

After we have discussed the student thinking up to line 54, we ask participants to think about ideas for instruction, asking them to ground ideas for instruction in what they've heard so far. As always, we try to forestall criticism or praise of the teacher; we ask participants to think not in terms of what the teacher *should do* or *should have done,* but rather what the teacher *might do* next, or what she *might have done* in response to particular student ideas. What is the "menu of possibilities"? Since we don't generally use this case first, this point does not generally need much discussion.

Most frequently, the first item on the menu is what participants assume Izzy will do, namely to continue on to the next piece of evidence. Another frequent suggestion is that she might halt her established procedure to have a discussion about how data should be used to evaluate a hypotheses, since we have heard students both considering the preponderance of evidence (as Max does in line 31), and keying on the aspects of data that fit with their hypotheses (as Cameron does in lines 39–45). How can Izzy help students to see the distinction in the reasoning here? Working from the same interpretation of student reasoning, some participants have thought she could stop and ask students which hypothesis is supported by the preponderance of data that they have seen so far. Does the evidence so far support one hypothesis over the others?

The Discussion to Line 191

Sometimes someone points out the tangential conversation that starts in line 68 when Josh asks if a caterpillar counts as a larvae. (He did something similar earlier in the discussion when he asked whether the place where ants live should be called a nest). Often people argue that his question isn't related to the overall conversation about whether the evidence can be used to evaluate the hypotheses; others occasionally see something positive in what they think he's doing. As one participant said,

> You know, we often talk about how high schoolers will learn something in class and then they just won't relate it to a different problem. In this case, he's actually seeking out something that he thinks it's related to, it's a living thing—it shows him trying to achieve a particular understanding, and connect the conversation to something he knows about.

Often someone points out that this is one of the few times in the conversation when the students speak to each other directly, without going through Izzy. Max says, "It's a living thing, actually," and Josh responds, "Well, larvae are living."

We give time to this topic if someone raises it: What do people think of Josh's question? What does Max mean with his statement that "it's a living thing," and why does he think it's a response to Josh's question?

Every time we've used this case, someone notices the exchange between Kevin and Izzy in lines 77 to 94. Kevin seems to be doing something that no one else has done up until this point. The usual interpretation is that he's keying on the data showing that most of the snakes are not eaten but some are. One participant surmised,

> [He's saying that] If the blind snakes weren't able to get through then they'll be eaten. Like if that's true, some of them might get eaten but some of them are protecting the nest, then it is like a combination of commensalism and predator-prey.

We think this exchange is worth talking about because Kevin has decided the evidence suggests a combination of two hypotheses, and that seems like a sensible thing to do. Relationships in the natural world are often complex! Think of the way house cats will sometimes toy with a rodent before letting it go. In this case, the relationship could be thought of as commensalistic, because the cat is "practicing for hunting" while the rodent is not necessarily being harmed. Other times, however, the cat will eat the rodent.

One thing that is unclear to many people about Kevin's comment is why he insists that one aspect of the relationship is commensalistic rather than mutualistic. A participant stated, "I'm not entirely convinced why he's saying it's commensalism because he talks about how the owl benefits, but he's not specifically saying the snakes are getting nothing out of it."

Additionally, there's often some disagreement about what Kevin means when he says that the snakes would "clean up" the nest. In the class, Izzy appears to assume that he means that the snakes are cleaning up the nest like a maid would clean a house. However, one participant pointed out that he may be using "cleaning up" in a different way based on what the evidence suggests the snakes are doing:

> I feel like when he uses that phrase "cleaning up" I don't think he means it in the sense that like you know the way he cleans his room I think it's more of like the way cops would clean up a street or something—like in order to improve the security of the nest.

We think this is a very productive place to stop and talk about what a student means. Why is Kevin claiming that it is both commensalism and predator-prey? Why does he think it's commensalism and not mutualism? Is that clear? How is he using the term *cleaning up*? All of these are productive questions we might ask to help focus participants on Kevin's meaning. Here as often, it is hard to be confident about an interpretation; still, we are trying to cultivate practices of close attention to students' meaning. What participants decide in any particular seminar or workshop is not as important as their considering the matter closely.

Another place we like to focus attention is the conversation that follows the sixth piece of data. What do the candidates hear in the students' reasoning with this data? Someone usually points out Josh's comment in line 165:

> So I mean isn't he getting at mutualism because snakes are helping? The owls are having an increased growth rate, and the snakes are surviving also so isn't that kind of what he's thinking over?

While most people agree that Josh is seeing in the data that the faster nestling growth rate, and the lower weight at first flight, means that the snakes are benefiting the owls, there is often disagreement over whether or not he thinks that this supports mutualism as the participant above argued. Josh does not seem to make an argument that the snakes are benefiting, only that they're helping the owls. When the discussion comes up, we like to ask if people think that Josh is supporting a particular kind of relationship. It may be that participants read into his statement that he thinks the snakes are benefiting, so it's worth stopping and giving them an opportunity to check their own assumptions.

Kevin's comments in lines 186 and 188 are a little unexpected, and so it's worth drawing participants' attention to what goes on here. Kevin states that he disagrees that it is an example of mutualism, but reiterates his comment that it's an example of both "predator-prey and commensalism." His comment in response to Izzy's question "you don't think the snakes are really getting anything out of it?" is surprising though, because he says "yeah, but what are the owls getting out of it?" This seems surprising because his explanation before that the snakes were protecting the nests seems clear and sensible. So what is Kevin thinking here? Is he mixing up the owls and snakes (in name only) as others have done? Participants point out that this is unlikely because he appears in line 191 to accept Josh's explanation that the owls "get to be more healthy." So we may have to reconsider what Kevin was thinking, when he says it is commensalism; who does he think is benefiting, and why does he think the other species is not benefiting?

Moving From Interpretations to Ideas for Instruction

Again, after we have discussed the student thinking in this case study, we invite participants to think about a menu of possible ideas for instruction, asking them to ground ideas for instruction in students' ideas and reasoning.

One frequent suggestion is to ask Kevin to explain more about who he thinks is benefiting in the relationship, and who is not, because participants often think he has become less clear as the conversation has gone on. Other possibilities usually come up as well. Given that Izzy has discussed all of the data with the students, asked them to suggest what kind of relationship they think the evidence supports, and heard a variety of ideas, she might ask the students to write down what kind of

relationship they think the data supports, and to explain why they think the data supports this relationship. After all, only a few students (primarily Max, Josh, and Kevin) have made clear explicit arguments. It might be useful to "check in" on everyone else's thinking at this point in the discussion. Another frequently suggested possibility is to tell the students what the researchers concluded, and see what they think of this conclusion. This may be valuable, because it will let the students see how scientists have evaluated the evidence, and show them that their own arguments resemble those constructed by scientists.

We suggest continuing to press for other possibilities until there are no more suggestions. Some people take longer than others to speak up, and we want to capture everyone's ideas. After all, there are other possibilities that most participants don't even consider. For example, Izzy continuously responds to student ideas, such that the discourse pattern usually goes Izzy/student/Izzy/student. She might work to push students to respond to each other's ideas directly. For example, in line 165, Josh has made a fairly sophisticated inference from the data. But do other students understand the inference? Izzy's move here is to repeat Josh's idea and mark it as a "good point," but she might ask if anyone else can explain what Josh said, and explain how the evidence shows that "the snakes do more helping."

The Rest of the Snippet

In most workshops and pedagogy courses, that's as far as we get, partly because we usually spend a lot of time at the beginning of the class talking about the snake/owl question itself, and partly because the first two segments are fairly long. If you do want to go further, the rest of the transcript is provided. Since we don't usually get to this part, participants usually want to know what happens at the end of the class. We usually tell them, especially if we want to ask them to anticipate how the students might respond.

At the end of the class, Izzy gives the students the article and asks them to look through it to find out what the authors conclude about the relationship. If we do get this far, we hope that participants notice the discussion between Josh and Izzy in lines 303 to 308 after it is established that the authors conclude that it is a commensalistic relationship. If they don't, we bring it up because we think Josh is doing some good things—he's questioning the findings of the scientists and suggesting why they might not be correct.

Josh asks if the authors can prove that the owls "are not really helping the snake." When Izzy asks how you would go about proving that the snake is not being helped, Josh says "Well those snakes are blind. I don't think they can find anything, and if they're in the nests they're safe and get free meals." One way to look at his comment here (especially if you're looking for deficits in students' thinking) is to notice that Josh is not really responding to Izzy's question about what evidence would support

the commensalism theory. Another way to look at it, however, is to see the theory that Josh is offering for why the scientists might not be correct. That is, he is suggesting that since the snakes are blind, their presence in the nests makes it easier for them to find food than if they were on the ground. We like this exchange because we think it's important for students to question the authority of scientists, and Josh makes a valid point that could possibly be tested. In fact, it's not at all clear from the article why the authors have rejected mutualism. They appear to assume that the snakes are receiving no benefit—since many snakes of the species never live in owls' nests. They find food on the ground, and they can also find food in the nests.

Discussing Izzy's Case Study

We have always shown and talked about the video, at least through line 54, before people read Izzy's own analysis in her case study. Showing the video first, we think, helps the case seem more real. It also gives workshop participants the chance to form their own ideas about what is happening. Often their ideas align with Izzy's.

One option is to have participants discuss the case study in a subsequent class or seminar. During this conversation, we prompt participants to pay attention to Izzy's interpretations in discussing the case. Rather than focus first on what she does as the teacher, we ask participants to focus on what she sees and hears. What are the interpretations that motivate her to respond? How do her responses fit with her interpretations?

The final section in Izzy's case study, Reflection, can be useful for stimulating a conversation about what we should be thinking about in assessing our students' learning. Izzy expresses some dismay about how her students did on questions related to the Well-Designed Investigation on the exam, and articulates her struggles in reconciling her students' test performance with her experience leading the discussion.

A discussion about Izzy's concerns could be productive. How do other teachers reconcile what they hear from their students with what they see on exams? Do they join Izzy in questioning the role of their own "summative" assessments and the connection of these assessments with what students can be heard and seen doing? We think Izzy's honest expression of ambivalence in this case study can provide an opportunity for other teachers to question the alignment between what they care about students doing in science class, what they hear in their students' ideas and reasoning, and how their students perform on standardized measures of achievement. We encourage participants to bring in examples of video and student work from their own classes, in order to address these questions in their own context. In this way, analysis of what students are learning is focused not only on what they have "mastered" by the time the test comes around, but on how they're engaged in authentic scientific activity.

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BECOMING A RESPONSIVE SCIENCE TEACHER

> "No one would find it strange to see a geologist poring at length over a single rock, or an entomologist over a moth, or a botanist over a leaf. Examining a specimen closely can help scientists develop new understandings. That's just what we hope to achieve in poring over moments of student thinking."
>
> —from *Becoming a Responsive Science Teacher*

When you begin a new unit and discover that some students don't understand an important concept, do you just correct the error and give them the answer? If so, you run the risk that students will memorize what you say without changing their core misconceptions. This thoughtful book explores how to identify such moments through "responsive listening" and turn them into opportunities to build students' science literacy.

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- a philosophical framework for understanding the beginnings of scientific thinking in high school students.
- five real-life case studies, four of which are captured on videos—and accompanying transcripts—available on the NSTA website.
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- advice on next steps, including how to overcome systemic impediments and maintain your focus on student thinking.

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Grades 9–12

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