

# The Beginnings of Energy in Third Graders' Reasoning

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**Abstract.** We present snippets of third-graders discussing ideas about energy as part of their considering and comparing different ways to make a toy car start moving. This case study illustrates a “responsive curriculum” approach to coordinating inquiry- and traditional content-oriented objectives in early science education.

## INTRODUCTION

Over the past 20 years, research on learning in physics and other sciences has been shifting from views of students' prior knowledge as comprised of misconceptions that need to be corrected to views of prior knowledge as rich in productive resources for learning [1]. These include both conceptual resources for understanding causal mechanisms [2], and epistemological resources [3] for understanding kinds of knowledge and knowledge-related activities.

This shift in perspective provides fresh support to old calls for children to participate in scientific investigation [4, 5], but with new onus on instructors to attend and respond to the substance of their inquiries [6]. As part of our project to study learning progressions in inquiry, we are working to develop a model of a “responsive curriculum,” designed to support teachers in attending and responding to the substance of student thinking. This model, we suggest, affords new ways to coordinate the objectives in science education of promoting student inquiry while making progress toward canonical understanding. Rather than guide inquiry to follow a predetermined path, we lead children into situations that are likely to tap into their productive resources for learning. It is the job of the teacher to attend to the students' thinking and support productive beginnings. Much of the challenge is in recognizing those beginnings.

Our purpose here is to illustrate how attention to student ideas can support progress, helping them to enter practices of scientific inquiry as well as to make steps toward understanding canonical ideas.

## THIRD GRADERS DISCUSS MOTION

For 14 days in the fall of 2009, Sharon Fargason's third-grade class considered and compared various ways to get a toy car moving, along with a variety of issues that arose along the way. We cannot hope to

give a thorough presentation of the students' inquiries; we try only to give a sense with some examples.

### “How Can I Get This Toy Car Moving?”

We chose the opening question “What could get a toy car moving” for this module in order to tap into rich stores of students' conceptual resources for constructing the concept of *energy* as well as related mechanical concepts including speed and force. At the same time, we wanted to tap into productive epistemological resources, in particular to help children experience learning as beginning from what they know and can see in the physical world, rather than, e.g., as a matter of following instructions in what and how to speak.

To be clear, however, this will not be an account of third graders' arrival at canonical concepts. Rather, it will be an account of the productive beginnings. In this paper, we briefly describe the opening activity and then focus on the children's thinking relevant for the concept of energy that arose in the final conversation.

After Ms. Fargason posed the opening question, the children worked for 40 minutes in small groups to come up with ideas as she moved among them to listen to and inquire about student ideas. The students then shared ideas in a whole class discussion, using white boards to present. Each group had an opportunity to try one of the methods students suggested to get the car moving (air from a fan, a ramp, rubber bands, etc.). Their exploration led them to ask questions such as, ‘Does the surface material make a difference to the car's speed?’, ‘How does the steepness of a ramp make a difference in the car's speed?’, and ‘Can a car go down a hill and have enough speed to go up another?’

These presented authentic opportunities for further work; Ms. Fargason's role was to recognize and take advantage of some of these opportunities. She facilitated new explorations, including testing which would go farther: a car shot by a rubber band or a car

rolling down a ramp. That experiment, in turn, led to a discussion of whether *farther* means *faster*—a topic that resurfaced throughout their work in the module.

For most of the module, Ms. Fargason helped students discuss ideas in their own terms. Much of what they had to say reflected conceptual resources for understanding a force, or push, or power that objects can be given, have or lose. On the final day, however, she decided to highlight the term *energy*, partly in preparation for the FOSS Energy unit [7] the students would see later. A child's comment provided an opportunity for her to do this in a way that kept the discussion centered around student thinking.

### A “Rubber Band Is Just Like a Steep Hill”

Mike, Ms. Fargason told the class, had written that a stretched-out rubber band would push the car farther and have “more energy” than a loose rubber band, “but he kinda put a question mark [after “energy”] because he wasn't exactly sure what he meant by that... So what do you think that can mean that, that rubber band has more energy? Or why would this rubber band push the car farther? What do we think about that?”

The way Ms. Fargason posed the question likely impacted both the attitudes of the students and substance of the following discussion for a few reasons. First, the fact that she wanted to discuss something from a student's notebook probably helped the students think of the topic as arising from their own knowledge and experience. At the same time, that she highlighted the comparison of a stretched and loose rubber band, and asked why one would push the car farther, she probably helped cue their thinking about physical mechanism, about the pushes and pulls they experience from using rubber bands. Moreover, she positioned herself as learning with the students rather than as the authority who possesses the answer. Jeffrey was the first to respond.

Jeffrey: The rubber band is just like a steep hill.

SF: What do you mean?

Jeffrey: By where the car heads down the ramp but it's getting pushed by a rubber band --- instead of going down a hill.

SF: So you said --- so it's like a steep hill. So this rubber band and a steep hill are kind of similar?

Ms. Fargason drew a picture of a ramp, repeated Jeffrey's idea to the class, and pressed further.

SF: So, okay, thank you. So a ramp like this and a rubber band like this are similar? And did you say why you think they're similar?

Jeffrey: Because they have the same energy.

SF: They have the --- these have --- these two have the same energy? What do you mean by that?

Jeffrey: They go the same speed.

Jeffrey's comparison between the ramp and the rubber band described a sameness to them concerning their respective abilities to get the car moving; he described them to “have the same energy,” and explained that meant the car will “go the same speed” in the two situations. In this moment, he was speaking of energy as a kind of ability to get the car moving, which, he said, the ramp and stretched rubber band both have. Here is an example of a child's thinking that is clearly in the direction of the scientific concept, although, as will be evident below, it was not Jeffrey's only way of thinking about energy.

### Energy Does Not Always Mean Speed

Ms. Fargason picked up on Jeffrey's connection of energy with speed and asked the class if they are the same thing. Zachary answered “sometimes.” She asked him to explain, and he responded, “Sometimes energy means like a car has enough gas. That's energy. And speed is like two people are racing and they're running and they have that much speed.” Zachary then gave an example of two cars racing, one with half a tank of gas and one with a full tank. The car with a full tank of gas would be able to make it to the finish line, but the car with half a tank of gas would not. Here, he related energy to fuel, and the amount of fuel to the amount of distance the car would travel. He also made it clear that this example did not necessarily reveal anything about the speed of the two cars. The car with half a tank of gas *could* go faster than the car with a full tank of gas, but it would still stop short of the finish line.

Then, Zachary gave an example of how energy and speed can be related: If two people are racing, and one person takes a drink of water, the person who drinks will run faster, because the person who did not take a drink will be thirsty and tired. There is a slight shift between this example and the previous example that marks a change in the way that Zachary was viewing energy. When he was thinking about cars and fuel, he was directly connecting the amount of fuel with the distance traveled. When he was thinking about runners and water, however, he seemed more focused on levels of personal energy [8]. Natalie seemed also to think in terms of personal energy when she expressed the idea that “if you go too fast, then your legs will get tired and tired and tired, but if you're jogging, you're still have more energy.” Zachary's running example and Natalie's observation both describe energy as something that can be used and controlled through human effort.

## **“Two Different Energies”**

Conversation about drinking raised a new question for Stephanie: “Is an energy drink the same as energy?” Ms. Fargason reflected it back to the class.

SF: So we've described energy in so many different ways. That there's energy in a ramp, energy in a rubber band, you can drink energy... And Stephanie wants to know if this kind of energy is the same kind of energy that's in an energy drink. Corrin.

Corrin: Um, I could tell the answer to Stephanie because I know that it's not, it's not right because can I tell Stephanie? I know the answer to your, um, uh question. The, the energy is not the same as the energy to the car because the energy that you're talking about is a drink, but the energy that we're talking about is like gasoline. But the one that you're talking about is a drink but ours in like the car like gasoline or oil.

SF: So the drink is different than what goes in the car? And is that different than what's in the rubber band?

Corrin: Yes. Because if you put the the drink, the energy drink um, in the car, your energy will mess up.

Stephanie: I think she's, I think she's right because there's two different energies, one is to drink and one, like, to make that energy right there, just makes it go fast.

Again, Ms. Fargason framed the discussion around a student's specific question while keeping the students focused on the overall concept of energy. Corrin (whose request to speak directly to Stephanie suggests her sense of school norms), pointed out, simply and sensibly, that it would not be a good idea to put an energy drink into a car's gas tank. Stephanie agreed and went on to give her own reasoning for the difference, that “one makes you get hyper...and then the other one like just makes something go fast...” An energy drink makes a person feel more awake and hyper, but not necessarily go faster.

On the other hand, the purpose of putting gasoline in a car and pulling back a rubber band is to give the car movement or speed. This reasoning ties into the earlier discussion about whether speed and energy are the same. Although Stephanie did not completely articulate it, she seemed to recognize that “energy” can refer to different kinds of things, including personal levels of energy as well as an object's speed. Thus she and Corrin were identifying and trying to make sense of an apparent inconsistency (between meanings of the term, or between different “energies”), drawing on their personal experience with energy drinks and cars, and rearranging those pieces of knowledge to form a logical conclusion, important aspects of inquiry.

## **“You're not doing the running.”**

After the class had discussed a range of ideas, Ms. Fargason said that they talked about energy in a lot of different ways, but she still didn't know what energy was. She highlighted the topic Stephanie raised and told the class, “I know that this ramp and this rubber band didn't drink an energy drink.” Here, she alluded to another question: Just as a person's energy comes from an energy drink, energy from a ramp and rubber band must come from somewhere, but where?

As a final task, Ms. Fargason assigned students to “do some writing... What is energy?” She asked them to consider energy “when you're talking about ramps, rubber bands, cars, people running, and energy drinks. Are they “all the same, or are they different?” Students began writing; some broke into groups on their own to talk about the question; some, including Jeffrey, came to speak to Ms. Fargason.

He expressed an idea that echoed Natalie's from earlier, that someone walking slowly is building up energy, because “you'll be able to catch up on your breathing.” Ms. Fargason asked him to talk again about his thinking in terms of ramps or hills.

Jeffrey: When you start to run, when you're, when you're trying to walk down a ramp, you'll start to go to running power, but you're still building up energy because you're not doing the running.

SF: What do you mean, “you're not doing the running?”

Jeffrey: Because the more steeper of the hill that you're walking down, the more faster that you go.

SF: Why?

Jeffrey: If you don't, if you keep getting more energy, because, because, because every time that you do a running step, then you're about to start sweating.

SF: When I run I'm about to start sweating?

Jeffrey: When you're not heading down a hill.

SF: But when I am heading down a hill you said that I'm not doing the running.

Jeffrey: No.

SF: What-who's doing the running for me? If I'm going down a hill?

Jeffrey: The hill is. Because-

SF: It's like the hill is running for me?

Jeffrey: Because the hill, because the weight makes you go faster.

SF: What weight?

Jeffrey: The weight on your body.

Ms. Fargason asked him to go write about his new thinking. A hill gives a person speed, as it does a toy car, so the person does not use as much “personal energy” [8], and this happens because of “the weight on your body.”

## DISCUSSION

Many educators accept that teaching science means teaching inquiry [9]. The challenge has been to coordinate inquiry with the traditional call for students to learn specific canonical ideas. This paper has illustrated the implementation of what we envision as responsive curriculum—responsive to the substance of student thinking—as an approach to managing this coordination.

Ms. Fargason's part in this account illustrates the role of the teacher. She paid close attention to students' thinking and helped them learn to articulate and reflect on their own and each others' ideas, and she was sensitive to the possibilities in what they were saying. She could keep the activity focused on the students' making sense of physical phenomena and mechanisms for themselves, based on their knowledge and experience, while at the same time directing their attention to ideas and questions that could contribute to their constructing the concept of energy. This is the target of a responsive curriculum, to support teachers in managing both inquiry- and traditional content-oriented objectives.

The children's part in this account gave evidence of the productive beginnings both of participation in science as inquiry and of conceptual understanding. There is evidence of their expectations that this is what learning and thinking in science involves: making sense of phenomena and mechanisms; trying to make connections among aspects of their knowledge and experience; working to articulate ideas clearly; identifying and trying to reconcile inconsistencies. There is also evidence of the beginnings of reasoning about energy: as an abstraction that has to do with motion or the ability to cause motion; as taking a variety of forms—a stretched rubber band, height on a hill, fuel, and food; as having quantity—a stretched rubber band or a full gas tank has "more" energy than a loose band or a half full tank. We see children recognizing questions they will eventually need to resolve, including apparent inconsistencies in the use of the term: You can't pour an energy drink into a fuel tank. We see them raising phenomena they will eventually need to reconcile: Resting *can* give someone more energy, a matter they will one day be able to model in terms of different forms of energy differently available to the body.

Our contention that the children were making progress toward understanding energy, along with the coordination we envision of that objective with inquiry, reflects a shift away from the notion that progress is a succession of correctly formed conceptual attainments, as research on learning progressions has generally been formulated [10]. We do not present or expect that third graders will achieve "closure" on the scientifically correct concepts of energy, in our curriculum or any other. To be sure, whatever children

construct in third grade they will need to reconstruct later. Rather, we hope to see students learn to put ideas together and take them apart, and the progress we hope to see is their doing this in ways and with resources that will help them in later, more sophisticated constructions.

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