What NASA Has to Offer

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When people think of what NASA has to offer science education, one natural starting place is knowledge: NASA scientists have a lot of it, from basic concepts to new results of NASA missions. Another is motivation: the topics and techniques at NASA could fascinate children, spur them to study science, and maybe to consider it as a career. With missions that focus on everything from black holes, the expanding universe, and comets to the possibilities for human space exploration and extra-terrestrial life; with robotic probes to explore Mars and Titan and the outer reaches of the solar system, human space flight, and orbiting telescopes, NASA is simply a wonderland for science education.

But, as the report discusses, there are serious challenges to using NASA resources. First, the most exciting topics are difficult to study in any but a superficial way without background understanding. If the purpose is knowledge, it just doesn't make sense to spend time on black holes before children have basic understanding of mass and gravity. The exciting topics might be motivation to study basic concepts, but children who were drawn in by the idea of black holes may lose interest as they end up spending most of their time in much more mundane, earth-bound activities.

Second, for many children the first blush of excitement about spacecraft or other planets and distant moons fades quickly as the details of information come in. That's why educators working from NASA content often look to old strategies, designing activities around games (from high tech video to bingo and word-searches), stories and songs (now including rap), and the old stand-by—candy. Maybe that's not a good sign: If the purpose is motivation for science, shouldn't the science do the motivating?

More powerful possibilities

Knowledge and motivation may be the first things that come to mind because of how people think about science education: Learning is about acquiring knowledge (or "constructing" it), and that takes engagement and attention. These seem to be obvious truths, but as science has shown again and again, obvious ideas sometimes get in the way. The pilot work in the afterschool programs described in this report point to further and maybe more powerful ways to think of connections between NASA and science education.

Let's start with what children said they enjoyed: "I liked talking," "I liked saying my opinion," and "You got to say some things that you really wanted to say for a long time," were typical comments made by participants describing this activity. This fits with what we and others have seen working with children (and what parents already know): They like talking. It doesn't take games or candy. Children are motivated by opportunities to express themselves, and all the more so when they expect someone is genuinely paying attention to and appreciating what they have to say.

More than that, they like talking about many of the same questions near and dear to NASA scientists. But—is this what most people would expect?—they aren't always so interested in finding out the answers scientists have decided are right. They often, as they do in the vignettes, would prefer to think through the questions and talk and argue among themselves.

But what does all that talking do for them? Most of what they're saying is wrong! And if they're not interested in what experts have to say on the matter, what do they need NASA for? We want to offer some answers to those questions, but first it will help us to answer the analogous questions for a more familiar afterschool activity: basketball. For the moment, consider this: if you wander through the labs at Goddard or Ames or Langley and peek in on scientists as they work, you won't find them playing videogames or singing songs (at least not as part of their work!). But you will often find them thinking and talking and arguing.

Basketball

We're stopping to talk about basketball because in some respects "afterschool basketball education" already has what we'll suggest afterschool science education needs. Basketball is another area where children are mainly motivated to do. If you gave small children a basketball, even if they'd never heard of the game they'd probably start bouncing it and throwing it and chasing it around the room. It would make sense to let them do that for a while. Nothing replaces getting a ball in hand, getting onto a court and just playing around. That's how they learn to handle the ball, how they develop the dexterities that will be so important when they learn the game.

Naturally, they'll also be kicking the ball, holding it and running, and other things that won't end up part of basketball (they'll be parts of other games). At some point they'll need to learn what things are allowed and what aren't, and to work on basic skills: how to dribble, how to pass, how to shoot, the basic rules. These things they can learn from their parents or physical education teachers or other children.

So far, it's all just like science, and we'll get back to that in a moment. But here's the big difference: by the time they're learning not to dribble with two hands, most children are already starting to get a sense of the game as a whole. Unlike science, in basketball children have ready access to observe and think about play at more advanced levels. They can watch NCAA and professional games; they can watch older children and young adults at the gym or in the neighborhood. What does it do for them?

It helps with those basics, for one. Children who've seen proficient players dribbling have an image they can try to emulate. They've seen how the action moves up and down the court, and that helps them make sense of the rules they've heard. It's one thing to hear a list of the rules; it's another thing to see how it all fits together in play. They still need to play around, and it's ok for them to do that without worrying about form, or setting up plays, or even dividing into teams, but as they develop a sense of the real game their playing around can start to take on more of its forms.

But there's much more than that. They can see how often professional players miss their shots and then just keep playing, which might help them learn that missing isn't so terrible a thing. On the other hand, when it is time to practice free throw shots, every child can imagine the tied game when they're at the free throw line with time running out—practicing becomes purposeful. Picturing what a real game looks like, they may learn to space themselves out around the court rather than all cluster around the ball, for example, as children starting out tend to do. It may help them learn to pass the ball around the court to their teammates, rather than holding on to it or shooting it whenever it comes into their hands.

As they learn, they notice and understand more of what they see in proficient players. Having played, that is, can make them more sophisticated spectators; that in turn can help them draw lessons at more sophisticated levels. They see a player pull off a fading jump shot, see how useful it is, and maybe they go try it themselves. They see players bending or breaking the rules during a game, and get a more nuanced sense of how that's part of the game too. It's illegal to carry the ball, for example, but the line between dribbling and carrying can get awfully blurry—at what point does the ref call a penalty? When does a player commit a foul on purpose?

Back to science

The vignettes illustrate what children can and will do with questions, if they're given a chance. Like children first learning to handle a ball, these children are playing around with ideas. They're asking questions, talking about causes and effects, reasons to believe and not to believe one thing or another, using what they've seen in the world and what they think makes sense to them. They're doing things that are as much part of the game of science as bouncing and throwing are part of the game of basketball.

For the same reasons that it's good to let children play around with a basketball, it's good to let children play around like this with ideas. Afterschool programs are terrific for that, not having the constraints of coverage and correctness that more and more govern school. Talking with each other is how children learn to be articulate, to form and respond to arguments, things most scientists will tell you they experienced at home and with their friends growing up.

Maybe that's why these aren't the first things that come to mind, for scientists thinking about education, because they learned them in the background and may take them for granted. But not all children have those sorts of experiences at home. Think of teaching basketball to a 10 year old who has never developed the dexterities of holding, throwing, and catching a ball. Remember how the ball would hit you in the chest, before you learned the timing of when to move your hands together to catch it? For children who aren't accustomed to it, hearing a reasoned argument, much less responding to one, might be just as awkward. So they need to have time to play around. Naturally, they'll also be telling make-believe stories, inventing experiences they never had, and other things that won't end up part of science (they'll be parts of other activities). At some point they'll need to learn what things are allowed and what aren't in science.

Some of that they can learn in school, but the political and structural constraints keep the emphasis on the basics—foundational facts and concepts, how to take measurements and record data. These are certainly important. What's missing there is a sense of the game as a whole. Here is where NASA and other scientific institutions could contribute—not to help with the basic ideas, directly, which schools already address, but to give children what they have so easily in basketball: Access to the real thing, science as practiced by scientists.

This access could help children learn many things that are hard to get from school, especially if they can have that access through the less-constrained, less formal contexts of afterschool programs. We'll talk in a moment about what NASA might do to help; let's first talk quickly about the sorts of things students could learn about the nature and practice of science.

> **1) Science is driven by questions***.* The first lesson learned in this report is to shift the focus of attention from knowledge, the information NASA missions use and produce, to questions. That's something children and scientists share, a common starting point. Like NASA scientists, the report tells us, children are captivated by questions about "the origin and nature of the planet, the solar system, and the universe." Of course, for scientists the posing of questions is a refined art, but that refinement starts from what children can do.
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> So, children can learn, scientists devote their careers to big interesting questions, —"how did life start on earth?" and "how old is the universe?" This is something children do, and it's naturally motivating for them. They should understand and see for themselves that it's what scientists do too. As they gain in sophistication, they can learn how talking and thinking and arguing about these questions leads scientists to other questions, more narrow but testable, such as whether light from an explosion on the surface of a comet shows particular spectral lines, or whether radiation from empty space varies from one part of the sky to another. In the afterschool, children can have the freedom to talk, think, and argue about the interesting questions, and to let the possibility of testable implications emerge or not. In schools, the main agenda is to teach how to pose testable questions; what's missing is a sense of where these questions come from or why they're important.

2) Science progresses through argumentation. This is something else children share with scientists: They want to think things through for themselves, to express their ideas, and to argue for their views. That's what we could see the children doing in the vignettes, the 9- and 10-year olds providing arguments about whether objects were living or not— "a book is not dead because it was never alive anyways." If they could get a glimpse into what scientists do, they'd see how much it is about making arguments from evidence and logic, for or against one thing or another, how scientists are constantly in controversies and disagreements. For some children, arguments may feel like a bad thing, like fights, things to try to avoid. They need to learn the difference between fighting and intellectual discourse. Of course, scientists are more sophisticated in the ways they defend their views, but again it's a refinement of what children can do.

So children can learn what sorts of arguments scientists make, how they use evidence from what they've seen, how they may question it when it conflicts with other things they know or figure out. As they gain sophistication, children can learn how the need to answer other points of view leads scientists to use evidence to tie together a logical explanation, to use their intuition but also question it, to become systematic in trying to rule out one explanation in favor of another. For example, scientists control variables in experiments because they want to be able to answer what someone might argue. In the afterschool arena, children can have the freedom to arrive at these aspects of practice in responding to each other. There's less time for that in schools, where the purpose is to teach controlling variables as a component skill.

3) Mistakes are part of the game*.* That's so easy for them to learn about basketball, when they watch expert players shoot and miss. If they could watch scientists, they could see how often scientists find out they're wrong about a prediction or a conjecture, or even about something they weren't even trying to find out but just assumed to be true. They could see how mistakes have different significance at different points of a mission; how at early stages it's important to take risks and try things, not to worry too much about being wrong; how as the project progresses, much of the game is to discover the mistakes and correct them. Only at the end of the process, as they get ready for launch or publication, do scientists expect to have the right answers.

Here again, schools aren't set up to help children see science and learning in this way. State and national assessments won't value mistakes, and schools are concerned about scores. Students become afraid to be wrong, as crippling in science as a fear of missing is in basketball; they can learn to hide their misunderstandings. The afterschool space is free from traditional evaluation, and children can take risks in ways that bring them closer to authentic science as it happens in NASA missions, at early phases and late.

How can NASA contribute?

The second recommendation in the report is to "Extract and concentrate on the NASA content that is most appropriate for afterschool science." What is most appropriate? We've talked about what it might mean to "focus on building understanding of the nature and practice of science" as objectives; we now turn to how NASA might help.

1) Start with what they can do. Rather than focus on what children do not know and cannot do that scientists could teach them, focus on what they do know and can do that could be the beginnings of science. They're interested and able to ask questions, to talk about their ideas, and of course to try things, so let these be starting places.

It's important to realize that it's essential for children to have these opportunities. At the outset, one of the most valuable things they can get from scientists is respect and encouragement for what they're doing. When children are trying to express their reasoning, to think about connections among ideas, to give arguments and counter-arguments, they are doing things that are part of science. Who better to help them appreciate that than scientists? And when they veer into make-believe or silliness, scientists can laugh along but help them see that these things aren't really part of the game in the same way.

2) Focus on questions. To start from what children can do, this has to mean different things at different levels. At the outset, children are motivated by some of the same questions that drive NASA missions, but they don't yet have the background knowledge to understand what NASA is doing. We think that's ok, when they're just getting started; as we said, it's like children first putting their hands on a basketball. For them, it might be enough to know what sorts of questions would interest scientists, and what sorts do not. Looking through the list in Table 3, "Is there life on every planet?" and "What are stars made of?" are perfectly reasonable scientific questions; but "Why was the moon made?" is not. An early goal in science education is to help children learn the difference—how better to learn that than from scientists?

As children become more sophisticated, the focus on questions can shift to be more specifically about what questions NASA scientists are asking and how they are pursuing them. Schools already focus on traditional content; what NASA can provide that schools can't is a sense of the live questions driving science today. Where did these questions come from? Why and how did they become significant? How do questions of interest turn into questions for study?

This will be a challenge, to identify when children are ready for more background and details. At what point will children be ready to understand how the question "How old is the universe" leads to the question "What color light comes from distant stars?" We don't have any simple answers for that. The main point is to keep questions the central objective, the questions that drive passions and careers, and these can be understood at many levels of sophistication.

3) Highlight controversies and confusions. Thinking about what's of educational value from a mission, the first things that come to mind might be the results so far. But for children to learn how science progresses through argumentation, they need to be able to see some. At one level, they need to see, simply, that disagreements are not only inevitable, but productive; scientists like to find things to argue about, because arguments are opportunities for learning.

So it is helpful to display the controversies in NASA missions. Again, this can happen at different levels, depending on the students. Early, it may be enough for them to see that scientists argue in these ways; later, they can start to understand the specifics of a debate. Then the objective can be for them to see the logic and evidence on either side, even if—especially if!—the controversy is not yet resolved. If the main objective were students' acquiring knowledge, this might be counter-productive, because they'd hear conflicting ideas. But we second the reports' view that this shouldn't be the main objective; that's already the focus in schools. Instead, NASA can help afterschool provide something that doesn't happen in class, opportunities for students to see and experience how the game is played.

For the same reasons, it is helpful to display mistakes and confusions that happen in authentic science. Students need to see that scientists shoot and miss, as they do in basketball. It's not the same as having a teacher tell them it's okay that scientists make lots of mistakes; they'd get much more out of having access to particular examples and the people involved.

Closing thoughts

Certainly foundational ideas are important, but they're already in the state and national frameworks, and they're already at the center of the agenda for school science. Some people may argue that it isn't working in school. But maybe this is why: Children need a sense of the game as a whole. Without that, learning component facts and skills may not make much sense.

Children are already motivated to talk, ask questions, express and argue about their ideas. Starting from there gives us a different way to think about the objectives of science education and about what NASA has to offer, centered on activities for which children have interests and abilities and that are continuous with professional practices of science.