Phronesis: Children's Local Rural Knowledge of Science and Engineering

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This study analyzes videotaped interviews and 407 photographs taken by 20 grade 5 and 6 students in rural New York State to document their science and engineering learning. Aristotle's concept of phronesis or practical wisdom frames the findings and their implications. Key findings indicate that: 1) All 20 children found examples of science and engineering; 2) The children learned by observing or doing or both; 3) The children learned from family members, particularly parents and grandparents; 4) These 20 children learned numerous science and engineering concepts by participating in activities associated with their daily lives; and 5) Only when directly probed did students make explicit connections between what they learned outside school in their local environments and what they learned in the science classroom. These findings point to the need to anchor the teaching and learning of science and engineering in the students' experiential habitat; thus, bridging the gap between children's local knowledge and global science.

Instances of science and engineering are normal and frequent in rural life. Whether on the farm, working with the hydraulic system of a tractor, or in the backyard tinkering with old car parts, children in rural settings acquire science and engineering skills and knowledge in the context of their daily lives. Arguably, rural settings may offer greater opportunities for experiential learning of science and engineering because of the outdoor and rural nature of the children's habitat and the expectation from their families for their contribution in terms of day-to-day chores. Therefore, this source of learning enables a significant opening for linking the teaching of science and engineering with children's everyday experience. This study explores how the life experiences of these children, primarily outside of school, ultimately contribute to their learning of science and engineering at school. Using interviews with fifth- and sixth-grade students in a high-need rural school in upstate New York and photo documentation by these children, we illustrate their experiences of learning science and engineering. Our findings suggest that within this low-income rural context, children learn science and engineering through engaged observation and doing. Aristotle's concept of *phronesis* frames our findings and points to the need to anchor learning of science and engineering in experiential knowledge.

This study is timely. As pressures mount to increase the number of scientists and engineers cultivated in the United States, the nation is increasing its focus on science, technology, engineering, and mathematics (STEM) education in K-12 school settings. Organizations like the National Research Council (NRC, 2000) and the National Academy of Engineering (NAE, 2008) are calling on colleges and universities and on professional and technical societies to rethink how science and engineering have been portrayed in society and to create new and better methods to teach and learn science—and particularly engineering—in elementary and secondary school classrooms. We see this new focus as a unique opportunity to build on the science and engineering foundations children have developed in their local environments by bridging the gap between what children already know and the required science curricula. However, rather than merely infusing tidbits of children's local knowledge into existing curricula when time permits

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during the school year, we suggest a more robust and nuanced approach that positions rural children's funds of knowledge at the epicenter of their science education.

According to Dr. Christine Cunningham, founder and director of the internationally recognized Engineering is Elementary Curriculum at the Boston Museum of Science (Hu, 2010, p. 1), "[Children] are born engineers — they naturally want to solve problems — and we tend to educate it out of them." The national and New York State science standards for elementary (K-4) and intermediate grades (5-8) are rich with content that lends itself particularly well to the teaching of engineering (Analysis, Inquiry and Engineering Design Standards) and the use of local context for teaching and learning science (Living Environment, Physical Setting Standards) (NRC, 2000). Thus, with the natural enthusiasm and innate skill sets that children possess, the required science content, and the rich rural context, the foundation is in place for meaningful learning to occur.

In addition, there is tremendous opportunity for investigation of science education in rural areas, which have historically been underserved and underrepresented in the teaching of STEM. Although more than 10 million children in the United States grow up in rural areas (compared to approximately 15 million in urban areas), very little research has been done on topics related to their science and engineering knowledge and education. Rural areas have yet to be fully explored as a rich context for learning science. This study explores and documents the scientific and technical knowledge children acquire outside school, which can bridge the gap between their own experience and formal learning.

Theoretical Framework

Because rural science education is a relatively unexplored topic, we draw upon literature bases from other areas to inform our work on children's local rural knowledge. Research on indigenous and local knowledge helps to frame our definition and understanding of the knowledge that rural children have acquired outside of school. Gruenewald's critical pedagogy of place creates awareness of the need to link school with place and local ecology. Lastly, Aristotle's model of phronesis informs our understanding of the explicit ways in which children learn science and engineering concepts in local ecological contexts.

Local Rural Knowledge

Yli-Pelkonen & Kohl (2005) have defined Local Ecological Knowledge (LEK) as a person's general knowledge of nature and a more specific local, lay, or experiential knowledge, which can be a blend of learned scientific concepts and information from personal observations and experiences in the surrounding environment. Olsson and Folke (2001) define LEK in rural conditions as "knowledge held by a specific group of people about their local ecosystem and a meld of scientific and practical knowledge, being site-specific and often involving a belief component" (p. 3). They also argue for the value of local context and local expert knowledge to help students engage in the process of science.

Luis Moll, in his work within Latino families and his documentation of knowledge and skills found within local households, developed the concept of *funds of knowledge*, a term that refers to the "historically accumulated and culturally developed bodies of knowledge and skills essential for household or individual functioning and well-being" (Moll, 1992). According to Romero (2007), Moll's work has "elaborated on the indigenous knowledge base, daily practices, heuristic skills, and learning styles of household members as they pertain to student backgrounds and cognitive development" (p. 17). Moll's approach both recognizes and emphasizes social contexts and the situational nature of learning, as well as the dynamic construction of meaning and cognition associated with contextualized learning.

We extend this "funds of knowledge" concept to include what rural children learn at home, in their community, and in their local ecological environment. Thus, we conceptualize rural children's local knowledge about science and engineering as the information and skills they have acquired in places outside of school. These places include family settings, places of play and work, venues of organizations or sites of community events (such as firehouses, venues of rescue squads, sport or women's clubs), and other local environments (such as streams and farms) where children have gleaned science and engineering knowledge in the context of their rural life (Avery, 2008a, b, c). This knowledge is largely context-specific and often contains a blend of practical or lived experience and applied scientific understanding. It is knowledge that children have acquired through engaged critical observation and performance in play and day-to-day chores in their home environment.

A Critical Pedagogy of Place

Place-based educators recognize and value alternative ways of knowing, such as local or indigenous knowledge, and incorporate them into their teaching. In addition, they advocate embodying place as a context not only for policy making, but also for teaching and learning. In fact, several researchers decry the absence of place in K-12 curricula and teaching (Battiste & Henderson, 2000; Costa, 1995; Gruenewald, 2002; 2003; Schafft, 2010; Semali & Kincheloe, 1999; Tuhiwai-Smith, 1999; Theobald, 1997). According to Gruenewald (2003),

> Currently, educational concern for local space is overshadowed by both the discourse of accountability and by the discourse of economic competitiveness to which it is linked. Place becomes a critical construct not because it is in opposition to economic well-being (it is not), but because it focuses on analyzing how economic and political decisions impact particular places. (p. 3)

Romero (2007) characterizes place-based education as structured learning in issues of local history, culture, language, environment, and economy. He states that teachers can identify local resources and use them to design relevant study programs. By emphasizing learning related to the immediate surroundings, teachers can involve students in applications that are real and meaningful.

Woodhouse and Knapp (2000) and Smith (2002) together list several qualities of place-based education: 1) It emerges from a specific place and includes cultural and nature studies from that place; 2) It is multidisciplinary in nature; 3) It is experiential; 4) It includes internships and entrepreneurial opportunities within local spaces; 5) It connects individuals with the community and involves them in aspects such as decision making and real-world problem solving; and 6) It reflects a much wider-ranging learning paradigm than that of simply learning to take a test.

Building on this work of place-based educators, Gruenewald employs ideas from both critical pedagogy (Barton, 1998; Freire, 1995) and place-based education to create a new pedagogy called a "critical pedagogy of place" (Gruenewald, 2003). According to Gruenewald,

> A critical pedagogy … explicitly makes the limits and simulations of the classroom problematic. It insists that students and teachers actually experience and interrogate the places outside of school—as part of the school curriculum—that are the local context of shared cultural politics … Acknowledging that experience has a geographical context opens the way to admitting critical social and ecological concerns into one's understanding of place, and the role of places in education. (p. 9)

A critical pedagogy of place provides the framework to anchor and empower rural children's local knowledge by moving the discussion from teacher attempts to activate prior knowledge through a cursory introduction to the day's lesson to anchoring the entire curriculum within the children's experience. It gives power as legitimate learning spaces to places outside of school and voice to alternative ways of knowing. Anchoring and valuing these funds of knowledge are two ways to bridge the gaps between what children have learned outside of school and school science and between the local and the global.

Knowing *That* and Knowing *How*: Phronesis

Finally, we situate the concepts of local rural knowledge and critical pedagogy of place within Aristotle's concept of phronesis or "practical wisdom." Aristotle's concept of phronesis recognizes the role of context-dependence in knowledge generation especially within a rural setting. Furthermore, in this idea, there is no mind-body dualism in the process of reflective engagement with one's own sense of place. The validity of the knowledge is determined by an individual's ability to cope in one's environment because this knowledge is concerned with practical consequences.

Gilbert Ryle, in *The Concept of Mind* (1984), discusses the relational nature of knowing through direct experience. Ryle differentiates between "knowing *that*" and "knowing *how.*" Knowing that inquires into whether something is the case. Textbooks, worksheets, and science kits are examples of teaching supplements that lead to knowing that. Students draw on the experiences of their teacher combined with information contained in these resources. The learning in the classroom is abstracted from the context where the knowledge was generated. While this form of knowing is valuable and necessary, it is different from knowing how. Knowing how considers how to achieve something. It is embedded in experience. Learning by doing is an example of generating knowledge through knowing how. In situational learning, experience is the impetus for reflective thinking, which in turn impels inquiry (Lave and Wenger 1999). For instance, the day-to-day chores undertaken by rural children are examples of knowing how.

Knowing how is manifested in the performance of an act. A child who is bodily active is also mentally active; thought is not separated from action. Thus, a performance is not simply habitual practice: it is intelligent practice because each action is modified by its predecessor. It is reflection in action (Schön, 1983). Because learning is involved with each act, activity is tantamount to the movement of the child through the world. In order to achieve knowing how, a particular type of competence is required. Just as the intelligent performer acts critically, the intelligent spectator must follow critically. This is called learning *how*. Learning how is not imparted, like learning *that*; rather, it is achieved through participation and direct experience much like performing chores in rural context.

The dynamic process of learning that, knowing that, learning how and knowing how is best illustrated by Aristotle's concept of phronesis, a notion discussed in greater depth by Kassam (2009). Phronesis is central to effective education because it provides a philosophical and pedagogical foundation for daily living (Kassam, 2009). Phronesis is marked by reflexive analysis in which cultural values are contributing factors. It is knowledge of *how* to secure the ends of human life. It involves daily praxis, pragmatic action, and context-dependent knowing based on variable factors. Phronesis is not a state of knowledge, but a dynamic process within the framework of socio-cultural and ecological relations. Aristotle (2004) maintained that we may grasp the nature of phronesis if we consider those who are adept at it. This dynamic and participatory conception suggests that knowledge is in the relations of people to their environment. Therefore, knowledge lies not in the heads of teachers, but in the world that they point out to students. It is found in the experience of *living through and within*—that is, knowledge is in the salient features of the rural experiential environment of the grade 5 and 6 students (see Figure 1).

Methods

The place-based and experiential framework of active learning described above informed our methods and our approach to student participation. The school we targeted for this study is in upstate New York, in a K-12 district that a recent statewide report classified as "High Need/Resource Capacity - Rural" (NYSED, 2006). Participants were drawn from an upper elementary school classroom (grades 5 and 6).

A tenured elementary school teacher who teaches a combined fifth- and sixth-grade class for the district each year volunteered to participate in the study. (She has a history of participation in teacher professional development with Avery and was interested in participating in this research project.) All of the children in her class were invited to take part in the study, and we obtained permission for students to participate from their parents and from the teacher. Institutional Review Board approval for the project was also granted. All names used in this paper are pseudonyms to maintain confidentiality. Of the total 22 students in two classes over a two-year period, 20 elected to participate.

To ascertain students' local science and engineering knowledge, we gave disposable cameras to the children, along with an instruction sheet that asked them to take pictures of what they perceived to be examples of science and engineering taking place in their home and local environment (see Appendix 1).[1] After the pictures were developed and printed, we discussed them with the children.

[1] While the instruction sheet prompted students with a few examples of possible science and engineering activities, the diversity of 407 photographs in 29 separate categories indicates that these examples did not bias the data.

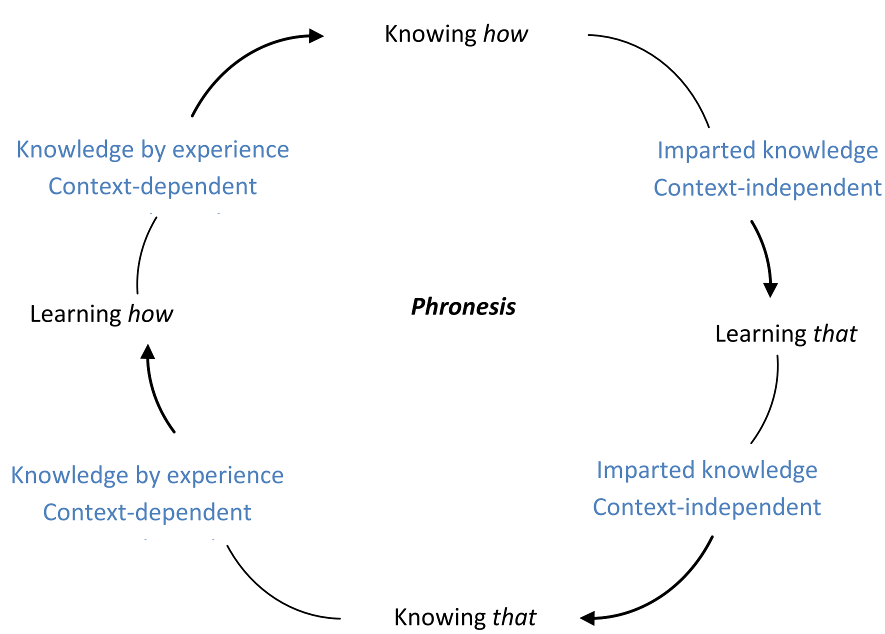

Figure 1. The dynamic process of experiential learning.

Source: Kassam (2010).

Two sets of pictures for every participant were made so that the children were able to keep their own set of pictures that they took and the researchers were also able to keep a copy of the photos taken by the children.

Photographs

The children's photographs (total 407) were analyzed in several steps. In the first step, the two authors viewed the photographs together. The second author organized the photographs into several categories on the basis of what he perceived to be the subject of the pictures. Then, together, we created a list of questions regarding our perceptions of the photographs in preparation for the student interviews. In addition to learning why the students chose to take specific pictures and what they knew about the items in the photos, we wanted to check whether our perceptions of how students understood science and engineering in practice were accurate.

In the second step, we created a database in Excel to organize the photograph information for further analysis. The database included titles for the photographs, our descriptions and perceptions of the photos, students' names (pseudonyms), and the location or context where each photo was taken. The photographs were then further analyzed (Avery & Meyer, 2007) using the Constant Comparative Analysis method (Glaser, 1969) and Content Analysis (Patton, 1990). Twenty-nine categories were generated from the analysis of the 407 photographs. One or more categories were assigned to each photograph. These categories were largely influenced by the words used by the fifth and sixth grade students when they discussed their photographs.

Kassam retained a distance from direct contact with students and teacher in order to double-check biases that we might have built into our interpretation of findings. The combined approach complemented our research, and we believe it contributed to a more robust interpretation of findings without biases. After the interviews, we updated the database. The students confirmed our original categorization of all but four of the 407 images (0.99% error rate). A final review of the data concluded the analysis.

Interviews

Semi-structured interviews with children (Reeve & Bell, 2007; Avery, 2008c) were held to discuss their photo documentation. Open-ended interview questions enabled researchers to elicit student responses to the photographs and probe deeper into some of their comments. The lead author interviewed the children at their school. The interviews, which ranged in length from 30 to 50 minutes, were video- and audio-taped, and notes were also taken. The interviews were transcribed and analyzed (Avery & Meyer, 2007) using methods of Glaser (1969) and Patton (1990) as previously done with the photograph data. As done with the photograph data, all of the transcripts were coded in a searchable master Excel file. This database allowed us to tie each code to all related images and to specific line numbers in the interview transcripts so that all relevant examples of a concept were flagged for easy retrieval and to organize and classify the data in various ways for analysis. Kassam also analyzed the transcripts separately from Avery, applying the lens of phronesis. When the analyses were compared, the inter-rater reliability was 90% or greater.

For guidance in identifying instances and concepts of science and engineering understood and described by children, we used both the national standards (NRC, 2000) and the New York State Elementary and Intermediate Science Standards[2], as well as the internationally recognized "Engineering is Elementary" curriculum.[3]

Findings

Figure 2 represents the matrix we created from the photograph data. The matrix is intended not only for use as an analysis tool, but also to provide a comprehensive snapshot of the set of photographs taken by the 10- and 11-year-old children. Figure 2 illuminates both the similarities and the diversity of the photographs. The 407 images covered a broad range of subjects: family members, farms, gardens, toys, and swing sets; fire stations and rescue sites; and simple machines, tools, and appliances. One or more subject categories were assigned to each photograph. These categories are listed along the horizontal axis of Figure 2, while the number of times each category was assigned is shown on the vertical axis. Maintaining these multiple categories enhances opportunities to connect school science to children's local knowledge.

What did we learn from the children? The discussion of photos during the interviews illuminated the children's knowledge about how and where they learn and the ways in which this knowledge facilitates their learning of science in the classroom.

1. All 20 children found examples of science and engineering taking place in their everyday lives.
2. The children learned by observing (learning how) or by doing (knowing how) or both, engaging in activities such as chores, play, construction, auto repair, and woodworking that take place in their home environments. This illustrates the context-dependent rural basis of experiential knowledge.

[2] See http://www.emsc.nysed.gov/ciai/mst/sci/ls.html.

[3] See http://www.mos.org/eie/.

3. Students learned from family members: parents and grandparents seemed to be the key source of local rural knowledge.
4. Through observing or participating in usual life activities (point 2), often with parents and grandparents (point 3), children gained phronesis.
5. These fifth- and sixth-grade children learned science and engineering concepts by participating in normal or usual activities of their daily lives.

Only when directly probed did 19 of the 20 students make explicit connections between what they learned outside school in their local environments and what they learned in the science classroom.

Instances of Science and Engineering

All children in the study were able to identify instances of science and engineering in their daily lives: more than 30 different examples were depicted in their photos (Figure 2). The top 10 categories were electronics, vehicles, appliances farm-related topics, people, plants, animals, lighting, toys, and carpentry. During the interviews, the children described the pictures they had taken and the ways in which the images depicted examples of science and engineering taking place in their local environments. When we asked them what they knew about the photo subjects, they often told us that they had learned about them by observing or engaging in related activities, although sometimes they had photographed something new they found relevant or interesting. They told us why they thought each image exemplified or related to science or engineering and what they knew about its subject (where they learned it, what happens, how it works). Usually they had learned about these examples from their families. Their descriptions and discussions often demonstrated a dynamic learning process that involved interconnections between "learning how," "knowing how," and "learning that." These instances of learning were frequently embedded within their experiences of interacting with others and with their surrounding ecology (see Appendix 2).

Learning How: The Steps to Practical Wisdom

Experiences of science and engineering outside of school and learning by doing contributed to students' practical wisdom or phronesis. Their learning modalities

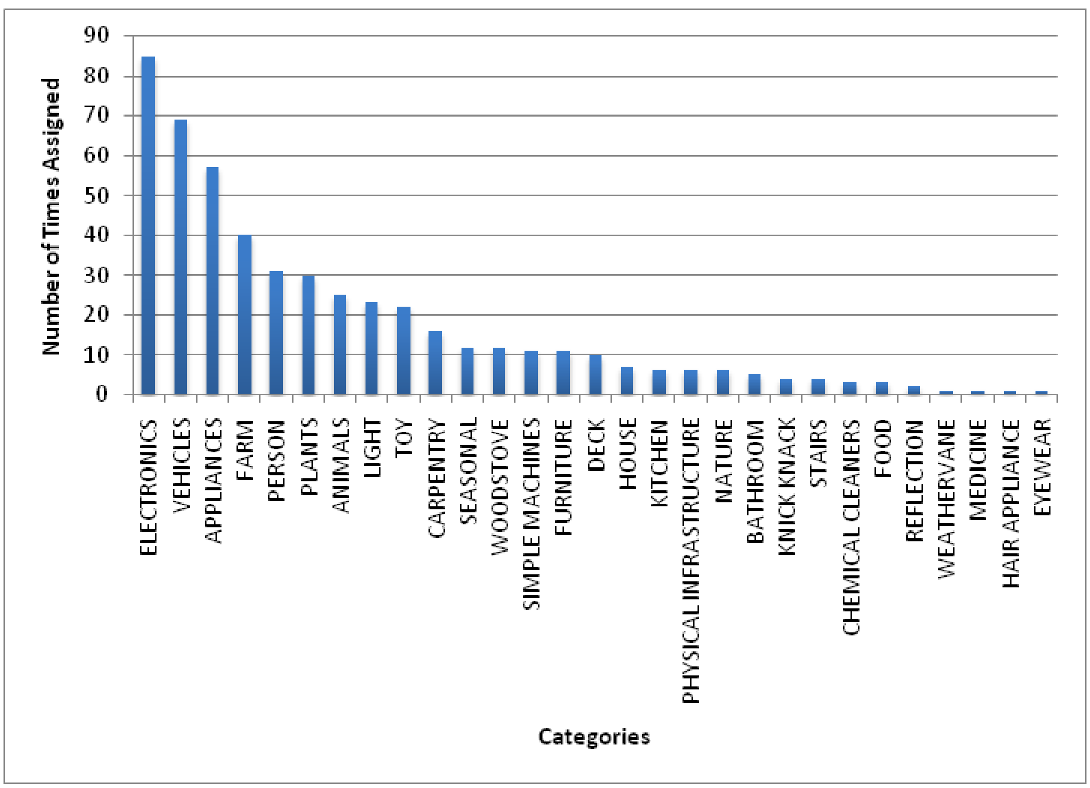

Figure 2. Categories of Engineering and Science information generated from the 407 photographs taken by fifth- and sixth-grade children. One or more categories (horizontal axis) were assigned to each photograph. The number of times each category was assigned is shown on the vertical axis.

included observing someone else doing something (learning how), observing phenomena around them (learning how), doing something themselves, or taking things apart and putting them back together again to see how they work (learning and knowing how).

Purdy, one of the student participants, illustrates the steps in this process from learning how to knowing how. He explained that he learns by observing something being built, or he watches something being taken apart and puts it back together himself. Describing pictures of his deck and stairs being built at home, he explained: "Well most of these pictures are of what I helped put together or I saw getting made." Purdy described a set of stairs being built at his home (see Figure 3):

> I saw stairs being built. I saw them increase every day. Pretty much what they did was they took logs or slabs of wood, and they put them down, and they cut them out so they go like this [he used hand gestures throughout to help describe learning how]. Then they actually put up two pieces of wood that go like this. It does the same thing and so it goes like this and they put the slabs on it and they put them back here.

Purdy's explanation relied heavily on gestures to demonstrate the building of the stairs. He also described taking things apart and putting them back together in order to see *how* they were made (see Figure 4):

> In this picture I was taking pictures of my bikes. The bicycle chain goes around; it turns the bicycle wheels. I would play with the tires and the wheels and take them apart. I used to have a tricycle and.... Well, I launched it down a hill and everything just all fell apart, and I sort of saw *how* everything was hooked up. I like taking things apart. I find things that are old and I try to build something else with them. I like to build my own stuff.

Similarly, another student, Meyer, discussing his picture of the family lawn tractor, described *how* he learns from critically watching his father repair the tractor:

> I helped my Dad fix it. We had to put a belt back on because it fell off. We had to take the blade casing off. We had to take it apart.

For example, Nate described how he learns by doing—learning how—when he helps his mother to fire pottery in her studio:

> My mom, she's a potter, she uses engineering to do this because when she fires, she has to make sure that it's the right heat and stuff so that the pots come out right.

Figure 3. Purdy's picture of the stairs being built in his home.

Figure 4. Purdy's picture of his house with the deck, grill, and bicycle.

Nate went on to describe how he helped to build the brick walls enclosing the kiln (see Figure 5):

> You have to assemble it and take it apart after each firing and stuff. Then you can get the pots out and put pots back in. I helped build up the doors when she fires it. I build up the doors with these bricks so my mom can fire without any heat getting out so that the doors close.

In the example above, we can see Nate's transition from learning how to fire pottery and prepare the brick walls, to a place of knowing how and knowing that about the overall process of pottery making. This instance illuminates the interconnectivity of the inner workings of phronesis and shows how learning takes place in context over multiple experiential iterations.

A female student, Amie, also told us *how* she learns from taking things apart and putting them back together. However, in Amie's case, she is the teacher, and her parents learn *how* from critically observing her. When discussing the pictures she had taken of the family camera and computer, she told us *how* she teaches her parents to use the equipment:

> I help my mom with her camera because she doesn't know much about cameras. I know a lot about cameras and computers. My dad and my mom, they don't really know about computers, and I am on it every day. I'm like the one in the family who knows most about science.

Amie's case illustrates that knowing that and knowing how are not in binary opposition. While distinct, they are not mutually exclusive, but rather co-dependent in the learning process. The two forms of knowing are being compared and contrasted here for the sake of understanding; however, this dichotomy is artificial. Amie is the "science expert" in her family because she combines classroom learning with practice—that is, knowing that with knowing how. She explained:

> I like taking things apart. I look at it and research it on the computer. I see what part it is and how to put it back together because I take it apart. It's kind of like my own little factory just putting it back together.

Similarly, Nate acquired an accurate perception of the aspects of the engineering design cycle by both observing and assisting his father as he was working in his cabinet shop. He is able to make connections between the concept of simple machines that is taught in school and the existence and everyday use of such machines in the shop. When helping his mother fire pottery or while working with his father, Nate is able to make connections to engineering principles and concepts of science. He discussed his understanding of

Figure 5. Nate's picture of his mother's kiln.

simple machines that resulted from working with his father (learning and knowing how). We asked him if the work with his father helped with science in school.

> Well, my dad doing all of this helps explain simple machines and things. They are all simple machines that help with all the work so that it explains to me how this works. Then I connect it to simple machines which I'd done last year. I see this and connect. For example, this is a lever. This is a screw.

While Amie and Nate made a connection to the school curriculum through prompting in the interview process, another student, Rory, also illustrated the link between his grade 5 science class (knowing that) and application of knowledge (knowing how) around the home. However, in his case, he made the connection without prompting. Many of Rory's pictures included photos of large equipment used in firefighting and rescue (volunteer fire station and rescue squad) and tools used at home. In several instances, he connected these tools and equipment to his knowledge about simple machines. He described a scene at the local fire station, where volunteers (including his mother) were practicing taking off the door of a car that had been in an accident. Specifically, he was describing a piece of equipment called a "claw" that is used in the process (see Figure 6):

> This is my favorite. This was a practice run of how to fight a fire or get someone out of a car. They use a claw to tear apart a car and get someone out. They're taking the other door off with the claw. You hold the claw, move it to open up and close it, and push a button to tear apart. It spins around. It's spinning open when you turn the lever to pull out and then in.

When asked where he learned about leverage, he said he learned about simple machines in school last year. Later in the interview, he discussed a picture from a bridge construction site near the firehouse:

> Here a guy is using a jackhammer. He's ripping it apart and clawing stuff. Here's a backhoe, and they were working on it. I thought it would be cool because of how it works and moves. It's at the church across from the firehouse. The white thing [it looks like the back of a truck] is a control device for the other machines.

We asked Rory how he knew that. His explanation, "Dad told me. I ask questions, and he tells me," illustrates that learning how involves critical observation.

Rory's questioning of his father reinforces the idea that learning how is not imitation, but critical observation through engagement. He also showed us his picture of a clothesline pulley and made another link to learning about simple machines both from his father and at his school (see Figure 7).

> This is a picture of a pulley. It moves the clothesline. It's a simple machine. I also forgot to show you how the screw-in bolt or lock [deadbolt] is a simple machine too.

Cody often spends time on the weekends helping with chores on the family farm. In the interview, Cody talked about how his father and grandfather often fix their own farm equipment to save money. This particular example highlights the notion of pragmatic action inherent in the process of phronesis. In describing the tools used to remediate the rusting that occurs on the bolts of large tractor wheels, he demonstrated his learning how and knowing that:

> Yeah, my grandpa and uncle, they have tractor wrenches that are really big—like that long—and the thing spreads like that far [hand gestures of length] because there's really big bolts on the tires! A wrench, needle-nosed pliers, and something else… this greaser thing that's for four-wheelers and other kinds of tractors, like the tool and the hay baling thing that bales the hay. Sometimes the bolts get rusty, and they have to grease, and they put this, like, thing on. And then they press the handle and it greases it.

When asked, Cody explained that these experiences helped him in school especially "if we had to do something for science like writing about a garden or how to fix machinery." By implication, science and engineering contribute not only to technical literacy but also to oral and written expression.

It is important to keep in mind that this learning process is cumulative and iterative: it is not a linear progression like the path of an arrow, but more like a feedback loop or circuit, building on the experiences of the performer. Knowing how is decontextualized when it is used to teach in the classroom. Taking context-dependent knowledge and putting it in a format understandable to students (knowing that) is also a necessary part of teaching, and it helps bridge the gap between science, technology, engineering and mathematics (STEM) and local knowledge.

Another female student, Sadie, shows that the process of knowing how can be transformed into knowing that. She explained the process of linking performance of activities at home to achievement in formal education by describing how

Figure 6. Rory's picture of the "claw."

she watches her father taking cars apart in their driveway. While looking at her picture of the family car, she described to us how she once thought the car was just one whole unit (see Figure 8):

> Watching my Dad helped me understand how things go together to make one, and how it all contributes to help the car (or whatever it is) move or work to do what it's supposed to do. I used to just think it's just all one and it didn't have any parts to it—it was just one.

Sadie also told us that she wants to become a surgeon, and she described how her visits to the emergency room with her mother when she worked at the hospital influenced her. She described her interest in surgery in connection with activities with her father in repairing cars. She articulated *how* she developed an understanding that a *system* is made up of diverse and complex components:

> Like the bones, they can't just be thrown some place; they have to be put together in some order. I've learned how to do that, and I've watched that, and watching my dad putting stuff together, I knew that it had to be in a certain place. It can't just be anywhere you want it to be—it has to be in a certain place. I learned that it's the same thing for humans as it is for cars.

The illustrative cases of Purdy, Meyer, Amie, Everett, Cody, Nate, Rory, and Sadie demonstrate the dynamic process of learning as phronesis. Their knowledge

Figure 7. Rory's picture of a clothesline pulley.

arises as a practical consequence of their lives and home environments and has the potential to mutually reinforce classroom learning (knowing that) and experiential, place-based learning (knowing how).

Science and Engineering Concepts or Content

Each child articulated an understanding of at least two or three science or engineering concepts that they learned from their interactions in their home environments. Almost all of the concepts presented relate to the national and state standards in science, engineering, and technology that are associated with K-8 classrooms. The alarming finding is that the children did not explicitly connect their "home" knowledge to the science presented in class, and thus effective linkages with previous classroom learning (knowing that) was absent. For example, both Nate and Rory understood the concepts of engineering design and simple machines, and they were able to link home sites of engineering or technology to school and the New York State Scientific Inquiry and Engineering Design standards. Cody mentioned that gardening and large farm equipment are also linked to the Living Environment standards. The science and engineering content that children are learning has been recognized by scientific and engineering organizations such as the American Association for the Advancement of Science (AAAS), the National Science Teachers Association (NSTA), and the American Society of Engineering Education (ASEE), among others. When looking at what they are learning outside of school in a rural context, we see that it is neither isolated nor trivial.

Linking Learning That and Learning How (at School and Home)

Rory was the only child of the 20 who could explicitly link what he had learned outside of school to what he had learned in the classroom (e.g., simple machines). Most of the children made the connection only when directly probed. Nate described having a better understanding and an ability to remember simple machines from working with his father in his wood shop. Sadie was able draw parallels between her understanding of the inner workings of a car and the anatomical design of the human body. It's evident that when probed, the children were able to create rich connections between the two contexts. The fact that one student was able to make a connection on his own, without probing, raises the issue of how local knowledge based on rural experience can be translated or integrated into formal knowledge as imparted in school.

Implications

While the above examples of student learning suggest phronesis—that a strong link exists between classroom learning (imparted knowledge—knowing that) and learning

Figure 8. Sadie's picture of the family car.

outside of school (experiential knowledge—knowing how) — our findings also suggest that the translation from informal learning to formal science may be hampered. As noted earlier, only one student spontaneously made an explicit connection between classroom science learning and his observations of science and engineering in practice. Other students connected school science to their own experience through the pictures they took, but this connection was latent and was made explicit only through prompting.

By the term "translation," we suggest that children have a substantial bank of knowledge, but that, for whatever reason, this knowledge often does not make it through the classroom door. Translation of children's out-of-school experiences occurs when they link their local knowledge to their classroom learning. Such linkage involves recognition by the educational system of the value, legitimacy, and utility of this rural knowledge to the educational curriculum. It is the bridge between learning that and learning how in our pedagogical approach of phronesis as articulated above. A gap emerges between learning in school and the rural knowledge children possess when translation is not effectively achieved. Arguably, the failure to bridge this gap may lead to decreased student engagement in science and a poor attitude toward science and school in general. While our research cannot conclusively speak to the reasons why this gap exists, it points to the need to explore these pedagogical concerns through further investigation involving participation of teachers.

Some researchers (Padak & Rasinski, 1997; Payne, 2005) take a "deficit model" approach to explaining why some poor children do not succeed in school. Our study takes a different tactic. Rather than focusing on what poor rural families may lack, our findings indicate that rich environments *do* exist in rural spaces where children have engaged in significant science and engineering activities.

Conclusion

Our approach incorporated an ecological understanding of student perceptions of science and engineering outside of school. The photos taken by students are visual metaphors for local knowledge gained through their experiences of their habitat. The verbal explanations in the interview complemented the photographs, mooring student learning of science and engineering in the local context. Just as the words provide a context for the photographic images, the images give concrete meaning to these words. This interaction suggests the potential for a multiplicity of meanings or interpretations associated with a metaphor. We found that for these children, the interaction of the oral with the visual is pregnant with multiple meanings and with the possibility of transforming perceptions by linking knowing that with knowing how. Through the process of engagement between the researcher questioning and the student explaining the images, a feedback loop of learning was added. As the students articulated why they took certain pictures, they made explicit the connection between science and engineering taught in the classroom and their experience of science and engineering in their home environment.

This place-based approach could be used in the science classroom. All too often, however, the relevance of local knowledge is neither acknowledged nor cultivated in science classrooms (Semali & Kincheloe, 1999; Smith, 2002). When students do not see the applicability of science to their everyday life, they become disengaged (Barton, 2001; Gilbert & Yerrick, 2001). The result is a facile divide between classroom science and local science and engineering knowledge. Consequently, a student population that could potentially become society's future technicians, scientists, and engineers goes untapped.

We offer phronesis as both a constructive lens for place-based education and a tool for framing children's local rural knowledge. As a constructive lens, phronesis addresses the criticisms often faced by place-based educators—that place-based education is insular, reminiscent, and not outward looking (Corbett, 2007)—by anchoring school science in children's local knowledge and experience. The link made by Sadie between how the parts of a vehicle contribute to the whole system of a motor car and how human anatomy facilitates functions of the human body provides a compelling illustration that place-based education as described here is not parochial. Simply put, the pedagogical lens that phronesis offers can bridge the gap between children's local knowledge and school science. Thus, place-based education viewed as phronesis offers explicit opportunities to connect rural places to the larger global environment.

Phronesis also provides a means to frame the ways in which children learn in places outside of school. It provides a foundation for rural children's local knowledge. It illuminates the processes and details of how children "learn" and "know." In short, our findings make a compelling case for the contribution local rural knowledge can make to science-based curricula. This place-based knowledge, arising from a rural setting, is a significant untapped pedagogical resource, and represents a rich experiential habitat that can provide teachers and curriculum designers an engaging context for school-based science instruction.

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Appendix 1

Science and Engineering in My Home and Neighborhood

Dear Science Students,

We think that you use a lot of science and engineering knowledge in your daily life at home. In fact, we think that you know a lot about science and engineering.

We would like you to help us figure out how you use science and engineering knowledge at home.

For example:

- Have you ever helped a family member, friend or neighbor fix a lawnmower, car or a broken fence?
- Have you ever built a toy out of scraps or things that were lying around the house or yard? Have you ever taken your toys apart and put them back together again?
- Have you ever helped your parents, grandparents, a friend or neighbor fix something within or around the house?
- Do your parents/family members teach you things about science like how to plant a garden, do chores on the farm, take care of the pets, how to repair a car, or any other things like that?

Your task: Take a walk around your home and yard and look for ways in which you think science or engineering has been used.

Use the camera to take pictures of everything you see that you think may be an example of how science and engineering are applied in your home or yard and in your everyday life.

When we see you again, we are going to show you the pictures you took and ask you to tell us WHY and HOW you think the pictures are examples of science and engineering around your home. Please show us all that you know! We are so excited to see your pictures and to learn from you! Thank You!

Sincerely,

Dr. Avery & (Teacher)

Appendix 2

Examples of Science and Engineering Experiences Photographed and Reported by Five Students in Grades 5 and 6

Student	Learning Mode: Context	Science and Engineering Content	Samples of Student Responses
Purdy	By seeing and doing: home construction; taking things apart and putting them back together	Models Scientific method (process of science) Structures Systems Processes Engineering design Materials	"Well most of these pictures are actually like pictures of what I helped put together or like I saw getting made." "Then there's also like these stairs, I saw them being built. I saw them increase every day. Pretty much what they did was they took logs or slabs of wood and they put them down, and they cut them out so they go like this. Then they actually put up two pieces of wood that go like this. It does the same thing and it goes out, so it goes like this, and they put the slabs on it and they put it back here." "And then there's another picture—like right here. Here's a picture of the deck and the grill. And these are two things, because when we got the grill they ended up taking it apart to fit it in the car, so I got to see them put it back together. And then also the deck there. I also saw how that was all built. And there's also a walkway that comes out there and another deck that goes to the left and goes to the upstairs, and there's a door to the upstairs."
Sadie	By seeing: Dad's garage	Systems Engine systems Processes Engineering design	"Like I know that the engine's in the middle. I can't say the pipe or what the pipe's name is. I can't remember that yet but there's pipes that go into the middle, and underneath it there's—like it holds oil, it's a big circle thing that holds oil. I am not sure how to put them together, but I know what they are and where they go. I am not sure how to put them on there, but I've been watching my dad when he did stuff and I've seen a car that had no inside. I saw him put it together. Like each day, day by day, I walked in there and I saw him. It helped me to understand how things go together and how they work to be one thing to help the whole car."
Everett	By seeing and doing: Uncle's shop	Force and motion Electricity Engine systems Engineering design	"I took this picture because me, my brother and my uncle, we always fix my go-cart because it's always broken down." "This is the engine of my go-cart. That's the muffler, this is the engine part, that's the gas tank, and that's the spark plug. That's the spark cord, and that gives the engine its spark. Sometimes the gasoline tank here, sometimes the whole engine, sometimes this, and then you have to get a whole new part. And my chain breaks down. And one time we had to get a whole new engine, and we had to lift up the engine with a bunch of wires. We had a bigger bowl and we put washers under it, and that helped lift it higher. This reminded me of engineering because it's an engine."

Appendix 2 (continued)

Student	Learning Mode: Context	Science and Engineering Content	Samples of Student Responses
Nate	By seeing and doing: Dad's woodshop	Simple machines Technologies Engineering design Materials Processes	"These are tools my dad uses for such operations such as, this is a saw, and these are blades for the table saw and caps, that's a saw and I don't know what that is. Oh, that's for welding—a mask for welding. These are similar, saw, hammer, screwdriver, clamps—all these things which he uses daily." "Woodworkers have to design, and that would sort of make him an engineer." "Engineering is designing, building, as well as designing other things to be built. My dad has all of these to design things and then build them." "First, they [engineers] probably see it in their minds or draw a picture of it to see what they would have to do to make it actually work no matter how big it is. Then they would go sizing it down to see it work. Then they would see if would fit and make it as small as that, and then they would actually think about the casing and then put it all together."
Amie	By doing: Four wheelers/ ATV	Electricity Mechanics Engines and engine systems Fuel Starters	"For certain four-wheelers, there are different starters and for every four-wheeler there's a key. Not every four-wheeler has what a lawn mower has where you have to pull to get it started. This one, the one I took a picture of, has the starter like the lawn mower and then you have some four wheelers have lights and some don't. Like the little ones, smaller than mine, don't have lights. They are made for maybe 7-8 year olds but my dad doesn't let us drive unless we know how to drive." "When we go to buy four-wheelers, I look to see how they start, and some little four-wheelers have the pulls and some don't. Some have kick-starts and some don't. Kick-starts are like when you turn the key and press the gas, it doesn't turn on. That would be like a back up, like plan B for it. I like to sit on the big four-wheelers and pretend I am driving, and I know what not to press. If you press the gas, it runs the gas. No one really knows that. But if you just sit on it when it's turned off, you're wasting the gas, and just clicking the pedal, you're just wasting the gas."