CASE STUDY 1

Economically Disadvantaged Students and the Next Generation Science Standards

Abstract

The economically disadvantaged student population in the U.S is growing. More than 20% of the children in the U.S. currently live in poverty, with the greatest concentrations in cities. Despite that the NAEP results for this demographic group show steady increase in science achievement, the achievement gap between poverty and non-poverty remains unchanged. The Next Generation Science Standards are more rigorous than the standards that came before. Thus, teachers of economically disadvantaged students will have to narrow the achievement gap while also meeting the higher expectations presented by the new standards. Based on the research literature, effective teaching strategies for economically disadvantaged students include (1) connecting science education to students' sense of "place" as physical, historical, and sociocultural dimensions in their community; (2) applying students' "funds of knowledge" and cultural practices; and (3) using project-based science learning centered on authentic questions and activities that matter to students. The vignette of high school chemistry instruction with economically disadvantaged students highlights how these strategies facilitate understanding of disciplinary core ideas, scientific and engineering practices, and crosscutting concepts as described by the Next Generation Science Standards.

Vignette: Developing Conceptual Models to Explain Chemical Processes

While the vignette presents real classroom experiences of NGSS implementation with diverse student groups, some considerations should be kept in mind. First, for the purpose of illustration only, the vignette is focused on a limited number of performance expectations. It should not be viewed as showing all instruction necessary to prepare students to fully understand these performance expectations. Neither does it indicate that the performance expectations should be taught one at a time. Second, science instruction should take into account that student understanding builds over time and that some topics or ideas require extended revisiting through the course of a year. Performance expectations will be realized by utilizing coherent connections among disciplinary core ideas, scientific and engineering practices, and crosscutting concepts within the NGSS. Finally, the vignette is intended to illustrate specific contexts. It is not meant to imply that students fit solely into one demographic subgroup, but rather it is intended to illustrate practical strategies to engage all students in the NGSS.

Introduction

Lincoln High School has the following demographics: free or reduced price lunch 63.9%, English language learners 7.9%, students of color 74.8%, and special education students 13.6%. In the vignette below, the students in Ms. S.'s 9th grade chemistry class reflect the overall demographics of the school. The students study matter and its interactions through multiple investigations about the structure and properties of matter. They are challenged to be precise with their scientific language and adapt their conceptual models as new evidence is presented. The students gain experience with some of the practices and core ideas of the NGSS over 14 school days of science instruction (adapted from Windschitl, Thompson, & Braaten, 2008-2013). Throughout the vignette, classroom strategies from the literature that are effective for all students, particularly economically disadvantaged students, are highlighted in parentheses.

As with all of the case studies associated with Appendix D, this unit was used in an actual classroom setting. In addition, the teaching methodology described in the vignette was a component of a research study that collected data on its effectiveness. The original case study was recorded in a 9th grade classroom with outcomes that now correlate to the middle school level of the NGSS. This shift is to be expected as schools transition to more rigorous standards. Therefore the writers have chosen to portray this vignette as originally recorded, with the caveat that the lessons should be seen as building a foundation for high-school-level coursework. As with all good instruction, it is important for the teacher in the vignette to first ascertain the level of understanding that incoming students have, and then to build toward a more advanced understanding.

Economically Disadvantaged Connections

The students in Ms. S.'s 9th grade chemistry class built on their prior knowledge of the particle nature of matter to further explore the behavior of atoms and molecules. The learning outcomes of the unit included the concept that matter, specifically a gas, is composed of particles called molecules that move faster or slower, depending on the temperature of the gas. In addition, the students extended their learning to incorporate a relationship between the relative speed of the particles in a system and the pressure exerted on the sides of the container.

The teacher promoted student learning through real life examples and student-constructed models. She enabled the students to develop their own conceptual models, use the models in predicting relationships between the model components, and evaluate the models for their explanatory power (NGSS practice of Developing and Using Models). As the students gained understanding of the core ideas through use of the additional NGSS practices of Planning and Carrying out Investigations and Obtaining, Evaluating, and Communicating Information, they addressed the limitations presented in the different models and worked together to revise the models as new evidence came to light.

Developing an initial conceptual model. Ms. S. started a unit on matter and its interactions that involved analysis of the forces between atoms and molecules, but wanted to first find out if her students had an understanding of the molecular nature of matter. She used a whole class discussion to bring out students' prior knowledge. They reviewed phase change and molecular movement in relation to temperature. Based on this informal assessment, she learned that some of the class remembered previous experiences with phase changes that occur with water.

The teacher began by asking the quietly listening class to describe what they already knew about how gases behave and related the questions to investigations that the students had completed. "We looked at air, carbon dioxide, and water vapor. What do you know about the molecules of a gas? How do they move? What affects their movement? What is a gas?" As students volunteered, she wrote down several students' responses on a chart paper, for example, "Gases expand when heated." "As a liquid evaporates, it becomes a gas and the molecules move rapidly." "There is a difference in density." "Gas is a phase." *(The teacher elicited students' prior knowledge and built on their funds of knowledge as a resource for further questioning and investigating.)*

“Molecules are small for gas and large for solid,” Canyon offered. Ms. S. asked Canyon if he had any examples of his idea and he said, “No examples.” She stated, “That’s a question,” and wrote Canyon’s words on the question side of the chart paper. She added, “Does anyone want to comment on Canyon’s remark?” Lorenzo contributed that he thought molecules stay the same size and that as molecules heat up, they move faster. After listing many student responses, Ms. S. asked the driving question, “How do gases and their behavior affect matter?”

Ms. S. next presented the class with a real world scenario, using photographs and video. (Practice: Obtaining, Evaluating, and Communicating Information.) In the video, a railroad tank car (tanker) was washed out with steam and then all the outlet valves were closed. The video revealed the tanker dramatically imploding the next day. After watching the video twice, the students began to speculate why the tanker crushed. They thought that the car froze, exploded, or compressed, and the steam caused the tanker to collapse inward. An understanding of the cause and effect concept helped students make sense of this phenomenon. (*Analyzing real-world events using project-based learning is an effective teaching strategy*.) (CCC: Cause and Effect.)

Rick called out, “Okay, that’s crazy!” Ms. S. asked the class to write in their journals their descriptions of why the tanker was crushed. “Do you want to guess?” she asked. “I have no idea,” one student replied.

The teacher encouraged the class by asking them to continue to think and work in groups. Four groups of four students were created. The group’s task was to decide on one model to explain why the tanker imploded, making sure the drawings included molecules and force arrows. Ms. S. circulated among the students and asked guiding questions, such as, “What happens when water vapor turns into liquid?” She directed students to include their ideas in the models they were creating. The students were drawing and discussing their models in their groups. “Steam inside is moving fast.” “Maybe it was cold.” “Didn’t explode; it imploded,” clarified a student. “Big, but sealed. Nothing in it but air and steam in there,” said another. (Practice: Developing and Using Models.)

Lorenzo decided that there was a tornado inside. Ms. S. directed the group to review what happens when steam turns into a liquid. She reminded students of a previous balloon experiment where they had identified a pressure difference and asked, “What would cause pressure or a pressure difference?” She also encouraged students to incorporate the observation that heating a substance adds more pressure. Circulating among the four groups, she asked students about their drawings, “Why did the tanker crush the next day? How do temperature changes affect molecules? Is there pressure against the walls? Why?” Cristiano answered, “Pressure in air is more than inside,” and his partner Jasmine offered, “The steam inside turned to liquid.” Ms. S. redirected their conversation with a new question, “Why would it implode?” Jasmine answered immediately, “Heat expands molecules!” “The molecules are getting smaller,” contradicted Cristiano. After thinking a moment, he said, “They *don’t* do that, do they?” *(Asking authentic questions in project-based learning is an effective teaching strategy.)*

Ms. S. asked the group about the air pressure arrows at the top of the tanker, “Why only at the top of the tanker?” Cristiano ventured, “There’s more air on top, not at the bottom.” Al added, “Molecules combine to take up less space.” Ms. S. emphasized, “When molecules combine, they make new substances.” Jasmine reminded the group that temperature has to do something. Ms. S. moved over to another group that had just broken into laughter and asked what was so funny. Rick related, “I see smashed cans all the time. I think an airfoot stomped the tanker down. And the molecules transformed into a molecule foot.” Ms. S. asked, “What is this imaginary foot?” Latasia answered, “Air.” Ms. S. guided the students, “Let’s add that idea to the model." *(The teacher validated the use of place [smashed cans in the neighborhood] to keep the students engaged and make a connection of science and neighborhood, an effective strategy.)*

As the discussions continued, several students began making connections between the steam turning to liquid overnight and the resulting changes in collisions of molecules with the walls inside and outside of the tanker. Through further questioning and reminders of previous learning that contradicted students' claims, Ms. S. pressed the students to prioritize evidence while, at the same time, allowing them to generate their own incomplete conceptual model. Ms. S. was well aware that students must be allowed to construct an understanding of phenomena by putting their ideas together. She also knew that through guided experiences and meaningful dialogue students would adapt their model and demonstrate authentic learning.

Gathering new evidence to evaluate and revise conceptual models. The following day Ms. S. encouraged students to reflect on how their ideas had evolved from the beginning of the unit. She wondered whether changes in students' ideas would be apparent in their developing models: air molecules slow down; water changes phase to liquid; pressure arrows show the collisions of molecules against the edge of the tanker; and when the gas molecules turn to liquid, there is less pressure on the inside causing the tanker to crumple. Reviewing the driving question from the day before, "What would cause pressure or a pressure difference?" the class identified two key factors: temperature and pressure. (DCI: MS-PS1.A Matter and Its Interactions.) The molecules that made up the steam were also hitting the inside of the tanker, balancing the air molecules hitting the tanker on the outside. (Practice: Developing and Using Models.)

Ms. S. asked the class a new question, "What caused the pressure inside the tanker to change?" The students did not respond at first. Then Lorenzo concluded that outside air pressure pressed on the tanker to crush it. Ms. S. asked, "Why would it do that?" This question led Ms. S. to introduce the pop can investigation. She asked the class to make predictions, "What will happen to the pop can if water is heated inside, and the pop can is rapidly cooled?" Students called out their predictions, "It's going to do what the tanker did." "Crush!" "Implode." Jasmine asked, "Are we going to seal the container?", showing her understanding of the variables involved.

Working in their groups, the class prepared for a simulation of the crushed tanker using an aluminum soda can. The can was filled with a small amount of water, heated to boiling on a hot plate, and then submerged upside down in an ice bath using tongs. The can immediately crushed. The enthusiastic reactions from the students included: "OOO" "It's cool!" "Awesome, it sucked it in!" (Some comments were based on incomplete understanding.) The teacher asked the students to draw new models by showing the molecules of gas in the can and writing down their ideas in their science journals. *(The cultural context of the soda can was an effective use of place to connect to students' experiences in their community.)*

The following day, Ms. S. provided students with a checklist to guide their review of the can implosion investigation from the day before. The checklist included: movement of molecules (speed), phase of matter, and causes of pressure inside and outside of the can. Students were asked to write answers in their science journals. Then they discussed their ideas in groups. As she met with each group, Ms. S. pressed students to verbalize core ideas about the behavior of molecules, and left the group with questions to consider. Finally, students were directed to write about their ideas so far. Ms. S. provided a scaffold for writing complete ideas by giving the class this sentence: *When ________, the can crushed more because ________.*

As their understanding grew, students refined their models and discussed changing the variables for further investigations. (Practice: Planning and carrying out investigations.) Calling the class back together, Ms. S. summarized the variables suggested by the groups: amount of water in the can, temperature of the water bath, amount of time on the hot plate, size of the can, and amount of seal when the can is flipped into the bath. Ms. S. also reminded the students of the connection between the tanker implosion and their can implosion: the molecules of air hitting on the outside were not balanced with the molecules of steam hitting the inside.

Using literacy, discourse, and argumentation to develop a shared understanding. The following day the investigations continued, using students' ideas. Ms. S. asked questions as to why more steam caused more pressure. The class regrouped to perform five experiments with each group taking one idea: amount of water, temperature of bath, time on hot plate, volume of can, and amount of seal. Each group identified three variables to test in order to help develop a more causal explanation. As the groups worked, the teacher questioned the students on their predictions and probed for specific answers. Lorenzo offered, "Steam vapor cools down inside the can when the can is placed in the ice bath and turns into water." "Water liquid molecules move slower than water gas molecules and the water liquid molecules take up less space because the gas condensed into water," added Jaylynn. (Practice: Constructing explanations.)

The group that turned the can upward in the ice water bath was surprised the can did not crush. Latasia thought there was too much space, so the can did not crush. Mia thought that with more air there was more space because of the ratio between the air and space. As shown in Mia's response, Ms. S. had identified a gap in students' understanding of pressure differences. She assigned a reading assignment on air pressure for homework. (Practice: Obtaining, Evaluating, and Communicating Information.)

When students returned the next day, they drew a model of air pressure on people in their science journals. Alicia described her picture of pressure on Earth and pointed out that higher up there was less pressure due to fewer molecules. The class reviewed the meaning of forces and how force arrows explained pressure in the model they were refining for the tanker question.

Student responses became more confident as the lessons continued. Students used a computer simulation of pressure vs. temperature and were asked to predict what would happen; the class buzzed with conversation. Next, the students improved their models. Again, students were given incomplete sentences to finish and reflect on what happened with their soda can investigations. Ms. S. reminded students to provide evidence for their explanations, "What are the molecules doing? Let's say the molecules are at a popular hip-hop concert trying to see the band. What would the molecules be doing?" Jaylynn conjectured that the quantity of molecules influenced the pressure in the can, "The kids would be pushing each other to get a better view of the band. So in the can more molecules would mean less space in the can. Alicia offered, "And molecules hitting the can from the outside would not be able to push the can in." Canyon added, "When the steam cooled in the can, it meant less steam and less pressure. Because fewer molecules were hitting the inside of the can, the can collapsed." The students' responses showed they understood the concept that as the temperature decreases, the molecules move slower with fewer collisions. *(The teacher applied a cultural reference of a popular hip-hop concert, an effective strategy.)*

The students compared the results of the soda can investigations with the implosion of the tanker. As they constructed explanations, their understanding of gas behavior concepts was evident and their models were more complete. "The tanker imploded and the can got crushed because the number of air molecules hitting the outside far exceed the number of air molecules or water molecule hitting the inside." "It is the number of molecules that hit the side that causes pressure." The students concluded that under normal conditions, the tanker would not implode because the number of molecules hitting the outside would equal the number hitting the inside.

Application of scientific knowledge to an engineering problem. At the end of the two-week unit, Ms. S. challenged the teams to apply their knowledge of thermal energy and pressure to design a tanker that would not implode after cleaning. The design constraints included the use of local materials, and a feature that would ensure even poorly trained technicians would not accidentally cause the tanker to implode. Ms. S. led a discussion about how to evaluate the competing design solutions, and the class agreed upon two criteria: cost effectiveness and no implosion. (DCI: ETS1.B Developing Possible Solutions.) The students were given additional aluminum soda cans to allow them to test their ideas. After about 30 minutes of small-group brainstorming, designing, and building, each group had a model to test. (CCC: Structure and Function.) (Practice: Developing and Using Models.)

Cristiano, Jasmine, and Al proposed keeping the tanker in a warm room after cleaning so that it would cool very gradually. To test their idea, they immersed it in warm water, not ice water. It imploded very slightly. Al suggested, "Let's use hot water instead of warm. Then it would cool off very slowly." The group agreed to try that.

Lorenzo's group punched a small hole at the opposite end of the can. When the can was immersed in the ice bath (with the punched hole just above the waterline), the can did not collapse at all. Lorenzo and Latasia whooped for joy! Mia reacted, "Wait! What happens to the liquid inside if there's a hole in the tanker?" "What do you mean?" asked Lorenzo. "Well, if the tanker has something like oil in it, the oil will evaporate out of the hole!" The others agreed, but liked their design anyway, and thought that the problem was not that important.

Canyon, Alicia, and Jaylynn whispered together for a long time before asking Ms. S. for materials. Jaylynn argued successfully to immerse a room temperature can (not heated) in ice water. When the group tried that, the can did not implode. Alicia was worried, "Do you think we're cheating?" Ms. S. pointed out that it was a design worth considering and asked the group if they could think of any problems with this design. Canyon offered, "This design is great! But what if the tanker had a liquid inside that would not clean well with cold water?"

Rick's group made a sign that they said they would paint on the tank, so it would never come off. The sign said: "After cleaning, open all doors." They demonstrated how it would work by immersing the can right side up, so that cool air could flow into the tank.

Ms. S. concluded the class by pointing out that engineering problems often had many solutions, with some better than others. The next day, the groups presented their design solutions. The class discussed which of the solutions was best based on the two criteria that they had established earlier. (Practice: Engaging in Argument from Evidence.)

NGSS Connections

The NGSS vision of blending disciplinary core ideas, scientific and engineering practices, and crosscutting concepts is exemplified in this vignette. The learning progressions of the NGSS disciplinary core ideas allow teachers to assess whether students have the needed foundation for the new concepts. The teacher presented engineering practices when she introduced the tanker design engineering problem. Students were asked to apply the evidence from the soda can experiment to the real-world problem of preventing a tanker from crushing if maintained properly.

Performance Expectations

MS-PS1-4 Structure and Properties of Matter
Develop a model that predicts and describes changes in atomic motion, temperature, and state of a pure substance when thermal energy is added or removed.

MS-ETS1-2 Engineering Design
Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

The vignette also highlights that learning science has important implications in the real world. In the vignette, the worker who cleaned the tanks had no conceptual understanding – or at least no accurate mental model – of what would happen if he/she closed all the valves after steam cleaning the tank. That was an expensive mistake for the company, and the worker might have lost his/her job over it. This is a lesson about the importance of science in using and maintaining equipment and illustrates the interdependence of science, technology, and engineering.

Disciplinary Core Idea

PS1.A Structure and Properties of Matter
Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.

ETS1.B Developing Possible Solutions
There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.

Scientific and Engineering Practices

Developing and Using Models (by the end of grade 8)
Use and/or develop models to predict, describe, support explanations, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales.

Planning and Carrying Out Investigations (by the end of grade 8)
Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation.

Constructing Explanations (by the end of grade 8)
Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena.

Construct an explanation using models or representations.

Engaging in Argument from Evidence (by the end of grade 8)
Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.

Obtaining, Evaluating, and Communicating Information (by the end of grade 12)
Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem. Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.

The students in the vignette engaged in many science and engineering practices, thereby building a comprehensive understanding of what it means to do science. The scientific practice of *developing and using models* is highlighted throughout the vignette. In the course of study, the students constructed two conceptual models: the first for the tanker's implosion and the second for the implosion or lack of implosion of the soda can. The second model was more sophisticated and built on the first model, as new evidence was presented. A third model was based on the concepts from the other two and illustrated a design solution. Throughout the unit, the students were challenged to modify and revise their models as they gained an understanding of the disciplinary core ideas of the pressure and temperature variables. In addition, the students were engaged in the scientific practices of *planning and carrying out investigations* and *engaging in argument from evidence*. In small group and whole group discussions, the students *constructed scientific explanations* for the tanker implosion, revised their explanations as they synthesized the tanker information, used their understanding of core ideas to construct a design solution, and supported or refuted claims. Students completed assignments by *obtaining, evaluation, and communication information* about pressure differences and design explanations.

Crosscutting Concepts

Cause and Effect 6-8
Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Structure and Function 9-12
Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.

The NGSS crosscutting concept of *cause and effect* was highlighted in the vignette as students described the effect of the forces applied on the tanker and soda can, and made comparisons. The students' observations guided them to provide evidence for the causality of the tanker and soda can collapse. They made predictions about scientific phenomena based on their developing understandings of effects of molecular movement and causes for phase changes. Later the NGSS crosscutting concept of *structure and function* applied to the purpose of engineering a solution to prevent the implosion of a tanker.

CCSS Connections to English Language Arts and Mathematics

The NGSS supports an interdisciplinary approach to science learning in order to provide experiences across disciplines. It is for this reason that each science standard explains its connections to the CCSS for ELA and math.

The students in the vignette grappled with core ideas in physical science while meeting the CCSS for ELA by discussing, writing and revising explanations and evaluating the scientific arguments presented by others.

- **RST.9-10.9** *Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts.*
  Students had reading assignments throughout the unit: pressure and how pressure differentials are established.

- **RST.11-12.9** *Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.*
  Students synthesized information from the video of the tanker, their experiments, and the gas pressure vs. temperature simulation.

- **SL.9-10.2** *Integrate multiple sources of information presented in diverse media or formats (e.g., visually, quantitatively, orally) evaluating the credibility and accuracy of each source.*
  Students analyzed the simulation and compared the results of the simulation questions to their models.

- **W.9-10.7** *Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.*
  Investigations of the soda can questions were short research projects.

- **WHST.9-10.1** *Write arguments focused on discipline-specific content.*
  With the help of the teacher, the students wrote arguments about their models and their learning.

The unit also addressed grade appropriate CCSS for math throughout the exploration with core ideas in physical science. In the vignette the students strove to successfully combine math and science practices to present valid explanations.

- **Math Practice 2** *Reason abstractly and quantitatively.*
  In the vignette, student models reflected abstract reasoning, using a symbol system including comparisons of relative pressure.

- **SP** *Investigate patterns of association in bivariate data.*
  Students drew the conclusion that as one variable (temperature) increased, the other variable (pressure) increased.

- **S.IC** *Make inferences and justify conclusions from sample surveys, experiments, and observational studies.*
  Students inferred the properties of matter from their observations and experiments and justified their conclusions using the models they created.

Effective Strategies from Research Literature

The discourse of poverty is often framed by limited resources and problems in need of fixing. While these realities are part of the education landscape, they focus on deficits – what youth and their teachers and schools are lacking. Emerging literature, however, highlight resources that students bring to the science classroom and possibilities that teachers and schools can create to engage youth in science. This literature points to three effective strategies that promote science learning for economically disadvantaged students: (1) the "place" of urban and rural science education (2) funds of knowledge and cultural practices, and (3) project-based learning to make science relevant to the students.

First, as students interact with their community, the place of science education accounts not only for the physical spaces of the community but also for the historical and sociocultural dimensions (Avery, 2013; Calabrese Barton, Tan, & O'Neill, in press). The psychological, social, and physical connections to place are both sources of knowledge and critical leverage points of the emotional connection to place. Urban and rural youth's knowledge of place and their relationship with that place are powerful sources of sense-making in both formal and in informal science learning environments. Alongside their capacity to navigate the physical and social spaces of their community, their scientific understandings constitute expertise that they use to make meaning of new science content, apply that content to their everyday lives, and share their knowledge of issues with community members.

Second, pedagogical practices should bridge the students' worlds with the school science world in ways that are empowering and relevant to the students. An effective teaching strategy is for teachers to validate and apply the "funds of knowledge" (González, Moll, & Amanti, 2005) that students bring from their homes and communities to the science classroom. Youth have a rich store of funds of knowledge and local practices that are reflective of their cultural and linguistic backgrounds and their local communities. When teachers have understandings of students' funds of knowledge, they are able to engage pedagogical practice that fosters authentic engagement by their students. When students are provided with opportunities to leverage cultural practices in support of developing scientific knowledge and practice, they engage in higher-level scientific reasoning and participate productively in scientific inquiry.

Finally, project-based learning is centered on authentic driving questions and activities that matter to students (Krajcik & Blumenfeld, 2006). Teachers who practice project-based learning create learning environments where students socially construct knowledge based on readily available resources. It is through these connections that students, who have traditionally not embraced science, recognize science as relevant to their lives and future, deepen their understanding of science concepts, and develop agency in science.

Context

Demographics

The American Community Survey report from the U.S. Census Bureau summarized the poverty data (U.S. Census Bureau, 2011). Overall 21.6% of children in the U.S. live in poverty, the highest poverty rate since the poverty survey began in 2001. The poverty rate was the highest for Black at 38.2% and Hispanic at 32.3%, compared to White at 17.0% and Asian at 13.0%.

Students are identified by school districts as economically disadvantaged if they receive free or reduced price lunch, or if they qualify for other public assistance (Elementary and Secondary Education [ESEA] Act, 2001). According to ESEA, poverty is measured by the number of children ages 5 through 17 who are eligible for free or reduced price lunch under the Richard B. Russell National School Lunch Act, the number of children in families receiving assistance under the State program funded under Part A of Title IV of the Social Security Act, the number of children eligible to receive medical assistance under the Medicaid program, or a composite of such indicators. The National School Lunch Program (NSLP) is a federally subsidized program administered on local school campuses across the nation. Students are eligible for free lunch if they come from families with incomes less than 130% of the federal poverty level. Students are eligible for reduced price lunch if their families have incomes less than 185% of the federal poverty level. For example, for the period of July 1, 2010 through June 30, 2011, for a family of four, 130% of the poverty level was $28,665, and 185% was $40,793 in most states.

According to the *Common Core of Data* report, 48% of students were eligible for free or reduced price lunch in 2010-11 compared to 47% in 2009-10 (National Center for Education Statistics [NCES], 2012a). In 2010-11, eligibility ranged among states from a low of 25% in New Hampshire to a high of 79% in the District of Columbia. The US territories are also eligible for free or reduced price lunch. Finally, a greater number of students live in poverty in the cities compared to other areas: 59.8% in cities, 39.6% in suburban areas, 51.8% in towns, and 43.9% from rural regular public elementary and secondary schools (NCES, 2012a). *Low-poverty schools* are defined as public schools where 25% or fewer students are eligible for the free or reduced price lunch (NSLP) program; *mid-low poverty schools* with 26% to 50% students, *mid-high poverty schools* with 51% to 75% students, and *high-poverty schools* with 76% or more students (NCES, 2012b). The percentage of low poverty public schools decreased from 31% in 1999 to 20% in 2010, whereas high poverty public schools increased from 12% in 1999 to 20% in 2009. High poverty schools are concentrated in the cities compared to the town or rural areas. In 2009-10, approximately 25% of students were in high poverty schools (NCES, 2012b).

Science Achievement

National Assessment of Educational Progress (NAEP) collects data on student eligibility for the National School Lunch Program (NSLP) as an indicator of family income. *The nation's report card: Science 2009* looked at science performance for students in grades 4, 8, and 12 (NCES, 2011). In 4th grade, 15% of students who were eligible for free lunch and 25% eligible for reduced price lunch scored at or above proficient in science achievement, compared to 48% of students not eligible who scored at or above proficient. In 8th grade, 12% of students who were eligible for free lunch and 22% of students who were eligible for reduced price lunch scored at or above proficient, compared to 41% not eligible who scored at or above proficient. In 12th grade, due to possible underreporting of data, students' eligibility NSLP was not included.

Economically disadvantaged students face challenges with academic success. According to a 2004 study by the RAND Corporation, socioeconomic factors such as family income, neighborhood poverty, parental education levels, and parental occupation were more significant in explaining differences in educational achievement than traditional factors such as race, ethnicity, and immigrant status (Lara-Cinisomo et al., 2004). One of the greatest challenges to schools with a high proportion of economically disadvantaged students is overcoming these challenges.

Educational Policy

Title I of the Elementary and Secondary Education Act (ESEA) is the largest federally funded educational program. This program, authorized by Congress, provides supplemental funds to school districts in order to assist schools with the highest student concentrations of poverty in meeting educational goals. The purpose of Title I is "to ensure that all children have a fair, equal, and significant opportunity to obtain a high-quality education and reach, at a minimum, proficiency on challenging state academic achievement standards and state academic assessments." This can be accomplished by ensuring alignment of rigorous academic standards with high-quality academic assessments, accountability systems, teacher preparation, and professional development, and instructional materials. Then students, parents, teachers, and administrators can measure progress against common expectations for students' academic achievement.

References

Avery, L. M. (2013). Rural science education: Valuing local knowledge. *Theory Into Practice, 52*(1), 28-35.

Calabrese Barton, A., Tan, E., & O'Neill, T. (in press). Science education in urban contexts: New conceptual tools and stories of possibilities. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research in science education* (2nd ed). Mahwah, NJ: Lawrence Erlbaum Associates.

González, N., Moll, L. C., & Amanti, C. (2005). *Funds of knowledge: Theorizing practices in households, communities, and classrooms*. Mahwah, NJ: L. Erlbaum Associates.

Krajcik, J. S., & Blumenfeld, P. (2006). Project-based learning. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences.* New York: Cambridge.

Lara-Cinisomo, S., Pebley, A. R., Valana, M. E., Maggio, E., Berends, M., & Lucas, S. R. (2004). *A matter of class: Educational achievement reflects family background more than ethnicity or immigration*. RAND Corporation. http://www.rand.org/publications/randreview/issues/fall2004/class.html

National Center for Education Statistics. (2010-2011). Common core of data: Public elementary/secondary school universe survey, 2009–10. Washington, DC: U.S. Department of Education.

National Center for Education Statistics. (2011). *The nation's report card: Science 2009.* Washington, DC: U.S. Department of Education.

National Center for Education Statistics. (2012a). *Numbers and types of public and secondary schools from the Common Core of Data: School year 2010-11*. Washington, DC: U.S. Department of Education.

National Center for Education Statistics. (2012b). *The condition of education 2012* (NCES 2012-045). Washington, DC: U.S. Department of Education.

No Child Left Behind Act (2001). Public Law No. 107-110, 115 Stat. 1425. http://www2.ed.gov/policy/elsec/leg/esea02/pg1.html#sec101

U.S. Census Bureau. (2011). *Child poverty in the United States 2009 and 2010: Selected race groups and Hispanic origin.* Washington, DC: U.S. Department of Commerce.

Windschitl, M., Thompson, J., & Braaten, M. *Tools for ambitious science teaching, 2008-2013* National Science Foundation, Discovery Research K-12, tools4teachingscience.org

MS-PS1 Structure and Properties of Matter		
MS-ETS1-2 Engineering Design		
Students who demonstrate understanding can: **MS-PS1-4. Develop a model that predicts and describes changes in atomic motion, temperature and state of a pure substance when thermal energy is added or removed.** **MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.**		
The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:		
Science and Engineering Practices	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Developing and Using Models Modeling in 6–8 builds on K–5 and progresses to developing, using, and revising models to support explanations, describe, test, and predict more abstract phenomena and design systems. • Develop a model to predict and/or describe phenomena. **Engage in Argument from Evidence** Engaging in argument from evidence in 6–8 builds from K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world. • Evaluate competing design solutions based on jointly developed and agreed-upon design criteria**.**	**PS1.A: Structure and Properties of Matter** • In a liquid, the molecules are constantly in contact with other; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations. • The changes in state that occur with variations in temperature or pressure can be described and predicted using these models of matter. **ETS1.B: Developing Possible Solutions** • There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.	**Cause and Effect** • Cause and effect relationships may be used to predict phenomena in natural or designed systems.

CCSS Connections for English Language Arts and Mathematics
RST.9-10.9 *Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts.*
RST.11-12.9 *Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.*
SL.9-10.2 *Integrate multiple sources of information presented in diverse media or formats (e.g., visually, quantitatively, orally) evaluating the credibility and accuracy of each source.*
W.9-10.7 *Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.*
WHST.9-10.1 *Write arguments focused on discipline-specific content.*
Math Practice 2 *Reason abstractly and quantitatively*
SP *Investigate patterns of association in bivariate data.*
S.IC *Make inferences and justify conclusions from sample surveys, experiments, and observational studies.*