CASE STUDY 2

Students from Racial and Ethnic Groups and the Next Generation Science Standards

Abstract

The student population in the U.S. is increasingly more diverse racially and ethnically. The U.S Census collects data on race based on demographic groups of non-Hispanic White, Hispanic, Black or African American, American Indian or Alaska Native, Asian, and Native Hawaiian or Other Pacific Islander. Although the National Assessment of Educational Progress (NAEP) Science scores have improved in recent years, significant achievement gaps by racial subgroups persist. Current policies address these shortfalls by implementing guidelines for tracking the progress of underrepresented groups of students in science and by calling to address science achievement gaps. Effective strategies for students from major racial and ethnic groups are categorized as follows: (1) culturally relevant pedagogy, (2) community involvement and social activism, (3) multiple representation and multimodal experiences, and (4) school support systems including role models and mentors of similar racial or ethnic backgrounds. The vignette below illustrates effective science teaching for students from major racial and ethnic groups as they engage in the NGSS.

Vignette: Constructing Explanations to Compare the Cycle of Matter and the Flow of Energy through Local Ecosystems

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

Sequoiah Middle School is a large 6^{th} – 8^{th} grade urban school. Many of the students bus to school because they live more than a mile away. Students from a government subsidized housing neighborhood on the edge of the city also bus to Sequoiah Middle School because their neighborhood has no nearby middle school. Another portion of the students come from the small residential neighborhood surrounding Sequoiah Middle School. The school is 65% non-White. In the vignette, 20 of the 29 students are from major racial or ethnic groups as described by U.S. Census.

The teacher, Ms. C., exemplifies effective teaching strategies that motivate her students to participate in the science community and meet unit objectives. Ms. C. is well loved by students because of her nurturing personality. The students, knowing they will be welcome in her classroom, often drop in for help before and after school. Despite Ms. C.'s easy-going nature, she insists on maintaining high expectations for all students. She knows that being scientifically literate means that her students should not only understand science, but also have connections to the important impact the scientific world has on their lives. In the vignette, she makes a point of connecting the students' community and real world issues with disciplinary core ideas. The Life Cycle Assessment "walk through" is based on the unit from the Great Lakes Bioenergy Research Center (GILBRC, 2007-2012). The vignette highlights classroom strategies (in parentheses) that are effective for all students, particularly for students from diverse racial and ethnic groups.

Racial and Ethnic Connections

Building on students' background knowledge. Many of Ms. C.'s students had already studied the carbon cycle in 7th grade, but considering the high rate of student mobility, she couldn't take for granted that every 8th grade student had mastered the challenging concept. For that reason, she reviewed photosynthesis the previous week. Together, they had constructed explanations for the role of sunlight as the energy source that plants use to produce sugars from carbon dioxide and water.

This week Ms. C. moved on to alternative energy and handed out corn chips to her surprised and delighted 8th grade, third hour students. She was aware that food would immediately grant her "favorite teacher" status. She had just completed an interactive multi-media presentation to review the carbon cycle, using it as a springboard for a discussion about alternative fuels. *(Ms. C. used technology to present information in multiple modes of representations.)*

Every one of Ms. C.'s five classes had its own unique character. Her third hour class was especially dynamic, and she looked forward to the fast-paced interchanges each day. Ms. C. had worked hard to engender a respectful atmosphere for discussion, and the 29 students had a relaxed rapport that reflected their respect for each other's individuality. Hand raising was not required in Ms. C.'s room. She had come to realize, over the years, that a lack of formality encouraged participation from those less likely to contribute in traditional settings. She used creative ways to foster individual responsibility for learning, such as picking names, share-outs, and cooperative grouping. To reinforce personal and collective responsibility in cooperative groups, Ms. C. employed a technique called roll-a-number. She assigned numbers 1 to 6 to the members of each team and then solicited arguments from the team members whose number was rolled (based on Hollie, 2011).

Ms. C.'s classes had students from many different racial and ethnic backgrounds, reflecting the overall makeup of the middle school. She continually reinforced the idea that scientific discussions become more robust when there are lots of different perspectives. And she reminded the class that it was each student's responsibility to enhance the group's knowledge by contributing her/his own perspective.

The day before – the first day of the alternative energy unit – an ecologist and friend of Ms. C., who had just returned from a global conservation exchange in Nigeria, presented a slide show about two countries in Africa. The ecologist used the slide show to describe some social and environmental impacts of the oil industry on Nigerian ecosystems. He showed photos depicting the devastation of oil spills on the aquatic system. The class was clearly captivated by his presentation; many of them had not previously considered where their oil came from.

Bisma crunched on her chips while sharing her personal memory of oil rigs in the Middle East. “They completely cover the land,” she said. “Everywhere you look, it looks like those ducks that go into the water. What are they called, the dipping ducks?”

Ivy, a Nigerian-American, had listened carefully to the presentation. She said that her family had come to the United States because of their religion, and she had never been told about the oil companies.

Nayeli added her experience with oil rigs: “The air has a smell; it’s like heavy. Sometimes I could feel oil in the air. The oil in the air *sticks* to you, and it messes with your hair.” She had recently moved from Texas.

Some other students were discussing a new piece of information they had learned in the multi-media presentation – lip gloss is made from petroleum products.

Ms. C. generously passed around salsa to her hungry class, asking, “Why do you think I brought in the *corn* chips to go with my PowerPoint?” After a few joking comments, Kody responded, “We are going to talk about corn in gas. I think I saw an ad where they put corn oil or something in their gas, ethanol. It is like corn. They said that the ethanol was better for the environment.”

Delonné was surprised by that. “I like to pump the gas sometimes, and I saw that ethanol sign,” she said. “I didn’t know that the ethanol came from corn, why *corn*?” Sarah answered, “It’s cheaper.” Delonné examined her corn chip and made a face, and a few students laughed. It *was* a really weird idea.

Ms. C. told the students that corn was subsidized by the government, which made corn very inexpensive and also resulted in high fructose corn syrup being added to lots of food. Suddenly, a lot of students had something to say, so Ms. C. had to revert to calling on hands. Students shared concerns of corn being used for fuel when people needed it to eat, and they said that high fructose corn syrup was unhealthy. Many students suggested that other alternative fuels are better because they are not sources of food. Ms. C. was impressed that many students described alternative ways to make fuels, such as solar energy, wind energy, water energy, and even geothermal energy. She wrote them all down on a list to refer to throughout the unit.

Ms. C. gave the class two open-ended homework assignments: to think about where some of the different fuels they used came from, and to generate a list of food items in their homes that had corn as one of the ingredients. Also, as part of the weekly assignment, she asked each student to look up one alternative fuel that was developed or was being developed locally and to write down facts about what they learned.

After 13 years of teaching, Ms. C. had learned to capitalize on the joint familiarity of the neighborhood and school as a bridge to form common understandings. She believed that place-based pedagogy was an effective way to reach her students since they came from diverse cultural backgrounds. (*Ms. C. used culturally relevant pedagogy by connecting the science curriculum to the students’ cultural experiences*.)

Definition of efficiency. The next day, Delonné had an announcement to make to the class. She told the class that she had pumped gas for her mother’s car yesterday and that the pump had said 10% ethanol. She was very excited to report this. She also took the moment to reiterate her concerns about taking corn out of production as a food source. She thought that the price of food would go up if too much was used for fuel, especially considering how many foods contained corn. Delonné was an African American student who maintained a high level of participation in class. One of the other classes in Delonné's schedule was AVID (Advancement Via Individual Determination), a program intended to support college-bound minority and economically disadvantaged students in taking higher-level classes. *(AVID is a school based support system for students of diverse racial and ethnic groups.)*

Several students brought in lists of foods in their homes that contained corn. Amira, another AVID student, brought in a list of 50 items and stated she was shocked at the number of foods that contained corn. Madison found only four items in her home because her mother made a conscious effort not to buy food with corn or corn products added. Marcus actually brought several packages of candy with him as evidence that all candy seemed to contain corn syrup. Tom confirmed Marcus' statement as he had found the same information. Tom was a second generation Mexican-American who rarely spoke in the group, but he was a natural leader when working on a smaller team. Many students, following Delonné's lead, voiced their concern about rising food costs if corn was used as fuel. Kody, however, solidly rebutted, "It's better for the environment." Not easily intimidated by dissent, Kody held his ground during class discussions.

Ms. C., enjoying the animated discussion, jumped in and seized on the last comment that corresponded to her learning goal for the day, "Why do you think we say that some fuels are better for the environment? Are some fuels more efficient? How could we decide?" She wrote the driving question on the interactive whiteboard: "Are some fuels more efficient than others?" The purpose of the activity was for students to explore their definitions of efficiency.

Ms. C. passed out the biofuels pre-assessment questionnaire, *Thinking About Plants as Transportation Fuel* (GLBRC, 2007-2012). Students discussed the questions from the sheet in their self-selected teams. The questionnaire aimed at sparking discussions about types of fuels, their carbon output, impact on the environment, and energy to produce the fuels. Also, the questionnaire directed the self-selected teams to represent their own simplified carbon cycle model to explain the production of ethanol from plant biomass, using pictures and words. (Practice: Developing and Using Models.) This model would be revisited repeatedly as the students improved their understanding of matter and energy, and the student teams used the model to record thinking, test new claims, and drive questions.

Next, the small teams of three were partnered up to share their thoughts. Walking among the groups, Ms. C.'s biggest concern was one of categorization: Students confused matter with energy, or used gasoline and energy interchangeably. For example, one group wrote in their narrative under their drawing, "Plant biomass goes to energy from the plant and becomes ethanol, then goes to the refinery, then to gas station, then to car." They had picked up some appropriate terms for the process, but would need to develop a greater understanding of the complicated set of chemical reactions. A few students attempted to use chemical equations to express their understanding of what was happening during photosynthesis or combustion in a car engine.

Interesting discussions emerged from the "true or false" statement: "Creating ethanol from plant biomass contributes to climate change." Kody was resolute that ethanol was not harmful to the environment. However Andrés insisted, "If it came out of a car, then the carbon was definitely harmful carbon."

The class unanimously agreed that a person could judge the efficiency of a fuel based on how many miles per gallon it got compared to how much carbon it released into the environment when "burned." But Bisma commented, "Even though gas is more efficient than ethanol, because it gets better miles per gallon, it also isn't good for other countries like Nigeria. Efficiency isn't the only important thing!" Some other students nodded. Ms. C. asked, "Can our definition of efficiency include impacts of production?" After a long pause, she wrote down the preliminary definition of efficiency and told the class that it would be revised as they learned more: "Efficiency means: how many miles per gallon a fuel gets compared to the carbon emissions per gallon." She wrote Bisma's comment about considering other factors in the definition of efficiency on the interactive whiteboard's parking lot.

At the close of the hour, Ms. C had students consider alternative energy options by asking questions that could lead to further investigations. (Practice: Asking Questions and Defining Problems.) Jarek asked a question that he had been pondering: "Ms. C., in your presentation you said that the energy for gas is from when the sugar from the plant reacts with oxygen. Could that be true for any plant, not just corn?" Ms. C. nodded encouragingly. Jarek offered an idea, showing his understanding of the flow of energy in an ecosystem, "We should just collect grass and turn that into fuel— everyone is talking about needing corn for food, but nobody really eats grass!"

Revising the model and constructing explanations. For a few days, students read, discussed and presented articles and preliminary research about ethanol and other alternative fuels. They also observed the products of a "burning candle" using a projector camera. Then, the class teams worked together to participate in a "walk through" – an initial model for the life cycle of the matter in ethanol. The students themselves acted out the life cycle assessment of ethanol. The students held cards that had the names of molecules on them, using yarn to track their "journey." They had already completed this modeling activity, representing matter transformation with purple yarn, but Ms. C. decided to return to it to address lingering questions and to begin to think about the flow of energy as well.

Some students were confusing the words 'matter,' 'fuel' and 'energy,' and were using them interchangeably. They were unclear about the relationship between energy and matter throughout the process. Although energy can be traced similarly to matter in the ecosystem, she needed them to see how energy is fundamentally different from matter in basic ways. Through understanding this relationship, students would be able to see that the transfer of energy drives the cycling of matter, and the transfer of energy can be tracked as energy flows through a natural system. (CCC: Energy and Matter.) (DCI: MS-LS2D Ecosystems, PS1.B Matter and Its Interactions.)

As the 8th grade class streamed into the science classroom and found their seats at the tables, Ms. C. opened the file with names of the week's project teams on the interactive whiteboard. She strongly believed in randomly rearranging team groupings, thereby giving her students the opportunity to interact and learn from both self-selected and dissimilar sets of peers. She also ensured, through maintaining the self-selected partnerships, that she could foster a vital social support system for students. She used the interactive whiteboard application to combine the smaller self-selected teams of 2 or 3 with one other team.

Ms. C. had already posted three now-familiar ethanol production "stations" on the classroom walls, marked by large printed signs and home-made blown-up pictures of local areas: (1) a farm field, (2) a refinery, and (3) the gas station near the school. She had a copy of the *Life Cycle Assessment Process Tool* (based on the Matter and Energy Process Tool developed by Anderson et al. of the Environmental Literacy Project) and planned to model matter and energy separately to drive home the idea that they could be traced separately. These stations represented key points for inputs, outputs, and transformation of matter and energy as crops are grown, converted into and used as fuel. The class had researched that ethanol production is a fermentation process – the microbes (yeast) digest the sugar and produce ethanol and carbon dioxide (CO_2) as by-products. (Practice: Obtaining, Evaluating, and Communicating Information.) This activity would help students test their understanding of how matter is cycled by living and nonliving components of an ecosystem through the process of fermentation and the overall life cycle of a biofuel.

As the class talked through the *Life Cycle Assessment Process Tool,* Ms. C. used the same photos from the stations on the interactive whiteboard, drew three rectangles, and wrote their designations: farm, refinery, and car. She drew straight purple lines to indicate matter input and output, and wavy red lines to indicate energy input and output. She had cut purple and red yarn for students to represent and track the journey that matter took throughout its life cycle.

Ms. C. then announced, "Last week, we traced matter input and output for the carbon cycle of ethanol production and combustion, and we had some unanswered questions. Today, we are going to see where energy fits into the process." (*Ms. C. chose a class modeling activity that involved student movement, a strategy that uses a multi-modal experience to increase student engagement.*)

She laid out the matter cards face up on the table, using the document camera, so the class could read them as she laid them out. Each card had a word (e.g., water) and the chemical formula (e.g., H_2O) in clear black letters. "We are at the farm. Who will be matter input for the farm? Michael, you are Carbon Dioxide (CO_2) input for photosynthesis, okay?" Ms. C. used the interactive whiteboard application to help her randomly choose students for this activity. Michael, CO_2, and Kayla, H_2O, together found the Carbon Dioxide and Water cards on the table, and two pieces of purple yarn. Then, they each gave one end of their yarn to Axel who, when called up, was ready with his Sugar, Starch, and Cellulose card, standing under the farm picture.

The yarn depicted the tracing of matter in a concrete way and represented the path that matter takes to contribute to corn biomass. Ms. C. suspected that using another color yarn for energy would clear up the confusion many students were having. The class resumed tracing the plant biomass matter to the refinery, with Delonné holding the Sugar, Starch, and Cellulose card and the other end of Axel's yarn under the refinery station. Then the matter path led to the car at the gas station, where Ivy held onto the other end of Delonné's yarn and an ethanol card. Finally, the path resumed to show that the ethanol created from the plant biomass reacted with oxygen to form carbon dioxide, Austin's card, as the fuel was burned in the car.

Marcus still held on to the one H_2O matter card. His team had not been sure where it went. They placed their unresolved question in the parking lot: "Does H_2O go with the refinery or the farm – as an output – or does it go as output for the car?" Ms. C. rewrote the question on the interactive whiteboard screen. Each of the three students in Marcus's team had made convincing arguments for water to go in all three stations.

Ms. C. had been looking forward to this discussion. "Did anyone have any more thoughts about the last water card?" She looked pointedly at Shamaya, who had struggled with the carbon cycle and the life cycle of ethanol. This morning, she had told Ms. C. that she now "got it" and knew where the last H_2O went. She directed her words to Ms. C. and then to her team: "I got this. It goes as an output of the car!" She was confident, saying, "there is steam that comes out of the car and you can see it. The smoke isn't carbon dioxide; it's steam – water!" Shamaya explained that she had made the connection the night before, "I used to think that the smoke that comes out of the car was carbon dioxide, but it isn't; it's steam." Doubtfully, Tom pointed out that the smoke that comes out of a car smells bad, and steam doesn't smell like that. But

Shamaya was undaunted, "Carbon dioxide is invisible, so the smoke coming out of the car is maybe a mixture of carbon dioxide and steam. I know it seems funny, like it should be the anti-water, but, like, burning the hot candle also made water." Shamaya was referring to evidence from the earlier burning candle investigation. (Practice: Engaging in Argument from Evidence.)

Ms. C. said, "Say more about that, Shamaya." Shamaya said, "When you burned the candle and put the glass bowl over it, it made black smoke; that was carbon, I think, and it also made steam, water drops, that were on the glass bowl and carbon dioxide." Jarek nodded, agreeing with Shamaya, and added that if they put a glass bowl over the pipe from the car, it might make water drops too. He suggested that since the last outputs and the first inputs are the same molecules, carbon dioxide and water, the people holding those cards could actually be the same person: carbon dioxide and water make sugar and oxygen, and then the sugar reacts with oxygen to form carbon dioxide and water. (Practice: Developing and Using Models.)

Ms. C. realized that Shamaya and Jarek were still working through their understanding of the processes at hand, but felt certain that this would be resolved as the unit progressed. What they were doing – connecting the cycling of matter to the processes of photosynthesis and combustion of materials – was helping the students construct an explanation about the cycle of matter. (Practice: Constructing Explanations.)

After checking for agreement and some negotiation, Marcus took his place under the picture of the car. To complete the circle, Marcus, the H_2O output from the car, gave an end of his second piece of yarn to Kayla, the H_2O input at the farm. They were satisfied that a spider web of yarn made an obvious circle from one station to the next, around the room. Following suit, Michael, the carbon dioxide farm input, and Austin, the carbon dioxide car output, also connected their yarn and closed the yarn circle.

Comparing the cycle of matter to the flow of energy in the carbon cycle. The students had modeled the cycle of matter for ethanol, but now they needed to use red yarn to add the flow of energy. Before more students got out of their seats, Ms. C. used the same stations (station 1: farm field, station 2: refinery, station 3: car) to discuss the energy involved. Considering and including the energy flow for the carbon cycle of ethanol was challenging but invigorating for the class. (DCI: MS-LS2D Ecosystems, PS1.B Matter and Its Interactions.)

For station 1, the farm, every group seemed very comfortable naming sunlight as the energy input. One team was unanimous that the energy was located in the bonds within the cellulose, starch and sugar. Ms. C. was quick to remind the students that energy was in the system, not exactly in the bonds. She held up a slack rubber band for a model, saying, "There is no energy in the rubber band until I stretch it." She had Tom pull the other end of the rubber band; "Now there is energy in the system."

There was some disagreement among groups as to whether any energy was lost during the first process of photosynthesis. Ms. C. added the question to the parking lot. At each step in the *Life Cycle Assessment Process Tool*, Ms. C. had groups of 4-6 students discuss their thoughts and commit to a decision. For students to share out with the larger group, Ms. C. used her engagement protocol, *roll-a-number,* and called out a team member's number to pick one person from each team to share the team's thoughts. This was how she communicated her expectation for individual responsibility from each team member.

At station 2, the refinery, the question of input and output of energy in fermentation of the plant-derived sugars resulted in a debate. Teams thought the plant product would need to be cut up, cooked or chopped up, and that would definitely take some energy. Bisma reminded the class about the information from one of the articles they had read. She remembered that enzymes are added at the refinery to start breaking down the matter like the enzymes in your saliva. Most heads nodded. The question about energy output at this station was written on the board for further investigation.

Sorting out the process of combustion resulted in another interesting discussion. Students disagreed about the energy output. Michael said, “The molecules break apart, and then they go into the air, the energy was in the system…and it is burned up.” Kody said, “What does the car do after we put gas into it? The car goes!” Ms. C. instructed students to think about other outputs that might be taking place during the last stage, asking “Does a running car produce heat? Does it produce any sound?” She was comfortable leaving some questions unanswered for the time being, so that she could pursue them throughout the course of the unit.

Application of core ideas. In the subsequent lessons, Ms. C. completed the walk-though activity with the same stations and the same process of converting corn into ethanol, and used red energy yarn to trace the flow of energy. The students again compared the relationship between matter and energy in the model. (CCC: Energy and Matter.) Ms. C. needed the students to grasp the core idea that matter is conserved and while energy is transferred throughout the process, it is also conserved. Ms. C. ended the unit with the students working in teams to predict the cycle of matter and the flow of energy for ethanol made from switchgrass (an alternative fuel, from native prairie grass, being investigated in their state) and defended their models with scientific argumentation. (Practice: Engaging in Argument from Evidence.)

The students also developed a list of other important factors for evaluating efficiency and usability when comparing fuels. This required more research about the societal and local impact of the use of corn as a fuel. (ETS1.B: Developing Possible Solutions; ETS1.C: Optimizing Design Solutions.)

Applying the results of the students' research on the impact of corn as fuel, Ms. C. had the class read a newspaper article about a proposal in the state budget to use biomass from the state's agricultural fields and local power plants to create energy. Each student composed a letter to their representative expressing their views for or against the proposal. They included other ideas they wanted their representative to consider before casting their vote. (*Ms. C. connected science to locally meaningful issues that could promote community involvement and social activism.)* (Practice: Obtaining, Evaluating, and Communicating Information.)

Finally, Ms. C. challenged the students to summarize what they found most meaningful in the unit. Delonné wrote a rap about the carbon cycle and ethanol versus gasoline as a fuel. The students loved it. Marcus and Axel sang the first few lines to Ms. C. every day when they walked past her to their lockers. Music is a shared experience and an integral part of youth culture, and it made the content engaging and meaningful to the students. Another group wrote a short play, and still another group engaged in a panel discussion. These efforts created a bridge for student engagement and were also culturally relevant. (*The teacher used culturally relevant pedagogy by connecting the science curriculum to the students' cultural experiences.)*

At the end of the unit, Ms. C. asked her students to write how the learning was important for them and how this lesson connected to their lives.

Delonné wrote, “This is so important to me, because when I am an adult, in my future there might be a crisis. And all the countries might run out of oil and all I will have left to put in my car is corn and switchgrass. Our parents are going to be gone soon and we will have to fix it. We have to come up with a solution to this!"

Kody explained his perspective, "This is going to affect my future because we use energy every day and we don't want the Earth to get so polluted. Ethanol may be a better solution to keep our Earth clean. Almost every kind of energy has some problems with it; we can still pick one that is the most efficient. Scientists can make better enzymes and protect what we have left."

Andrés wrote, "My dad needs gas for his car and uses ethanol in it. Then the car releases CO_2 and water in the air. It affects the planet and our world will change. We could have tornadoes and earthquakes."

Marcus wrote, "This connects to my life because I want to know my future and what adults have done wrong, so when we get older we can change it. And we need to know more about ethanol and gasoline and switchgrass because I want to drive my parents' cars and other people's cars. It is going to affect me because all of it is going to affect the environment I will live in for the rest of my life."

NGSS Connections

The NGSS aim to provide every student with a more comprehensive understanding of science by seamlessly combining disciplinary core ideas with scientific and engineering practices and crosscutting concepts. This blending allows students to participate in science in ways that reflect what scientists and engineers do in the real world. The teacher in the vignette, Ms. C., teaches students from diverse racial and ethnic backgrounds by employing effective strategies that enable the students to meet the standards.

In the vignette, the students had an opportunity to build toward understanding of the disciplinary core ideas and scientific practices to achieve the performance expectations from the middle school grade band in life sciences (LS1: From Molecules to Organisms: Structures and Processes), in physical sciences (PS1: Matter and Its Interactions), and with an introduction to some core ideas in ETS1: Engineering Design.

Performance Expectations

MS-LS2-3 Ecosystems: Interactions, Energy, and Dynamics
Develop a model to describe the cycling of matter and the flow of energy among living and nonliving parts of an ecosystem.

MS-PS1-3 Matter and Its Interactions
Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.

MS-ESS3-3 Earth and Human Activity
Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

MS-ESS3-4 Earth and Human Activity
Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's resources.

Disciplinary Core Ideas

LS2.B Cycle of Matter and Energy Transfer in Ecosystems
Transfers of matter into and out of the physical environment occur at every level. For example, when molecules from food react with oxygen captured from the environment, the carbon dioxide and water thus produced are transferred back to the environment, and ultimately so are waste products, such as fecal material. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem.

PSI.B Chemical Reactions
Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactant.

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.

ETS1.C Optimizing the Design Solution
The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.

Scientific and Engineering Practices

Developing and Using Models
Develop a model to predict and/or describe phenomena.

Engaging in Argument from Evidence
Respectfully provide and receive critiques about one's explanations, procedures, models, and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail.

Obtaining, Evaluating and Communicating Information
Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence.

Constructing Explanations and Design Solutions
Construct an explanation using models or representations.

Throughout the unit, the students developed mastery of scientific practices by authentically engaging with scientific ideas. Among the many scientific practices the students engaged with, only a few were specifically targeted in this vignette. Students *engaged in argument* regarding the validity of their scientific explanations, and incorporated their new thinking into their models. Students *obtained, evaluated, and communicated information* by researching alternative fuels and used some of the evidence they gathered to support their claims.

Ms. C. supported her students in *developing and using models* to *construct explanations* about the life cycle of matter and energy in the ecosystem. Then the students analyzed their model collaboratively and refined it as new information came to light.

Crosscutting Concepts

Energy and Matter *The transfer of energy can be tracked as energy flows through a natural system.* *Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter.*

The unit addressed learning outcomes for crosscutting concepts. Students used the crosscutting concept to understand that energy can be traced and that it is conserved. The students' understanding of the crosscutting concept of *energy and matter* was deepened through revisiting core ideas of energy and matter from earlier units in physical and life sciences, building on these core ideas, and reaching the grade level objective. Ms. C. selected driving questions that would facilitate cross-disciplinary connections to energy and matter.

CCSS Connections to English Language Arts and Mathematics

The NGSS promotes a vision of science learning as an interdisciplinary undertaking and each standard includes the CCSS connections to ELA and math. The vignette highlights the dynamic integration of science with ELA and math standards to ensure student learning across disciplines.

As part of the Energy and Ecosystems unit, each student conducted research on alternative energy sources and presented their findings to the class. This research enhanced the students' mastery of the science content by using a community context, and the activity gave students added practice of research, writing and presentation skills. The unit addressed the CCSS for ELA:

- **W.6.8** *Gather relevant information from multiple print and digital sources; assess the credibility of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and providing basic bibliographic information for sources.*

The unit also incorporated the CCSS for math standards. As the students compared the efficiency of various fuels, they discovered that more factors needed to be considered. Rather than just number of miles per gallon and carbon output, students also considered the carbon output of the heavy machinery used in production, the transportation and converting costs, and the social/environmental impacts, to name a few. For example, switchgrass, a native species of prairie grass, requires relatively little energy to harvest; yet the energy needed to transform the biomass to usable fuel is intensive. Students used mathematics to compare and contrast these data. The four CCSS for math that are appropriate for middle school and that are met through the course of the unit are:

- **MP.2** *Reason abstractly and quantitatively.*
- **S.IC** *Make inferences and justify conclusions from sample surveys, experiments, and observational studies.*

- **MP.4** *Model with mathematics.*
- **5.OA** *Analyze patterns and relationships.*

Effective Strategies from Research Literature

In addition to extensive literature about the importance of multicultural education in our increasingly diverse schools and classrooms, emerging literature presents classroom strategies specific to content areas, such as science. According to research, effective strategies for students from major racial and ethnic groups fall into the following categories: (1) culturally relevant pedagogy, (2) community involvement and social activism, (3) multiple representation and multimodal experiences, and (4) school support systems including role models and mentors of similar racial or ethnic backgrounds (Lee & Buxton, 2010).

First, culturally relevant pedagogy (Ladson-Billings, 1995) values and affirms the different cultures and backgrounds of the students in the classroom. The teacher integrates and connects the cultures of the students (including funds of knowledge, family and community histories, and linguistic backgrounds) to academic content and practices. Through culturally relevant pedagogy the teacher communicates high expectations that science is relevant and valuable for all students.

Second, community involvement and social activism in science involves creating meaningful, place-based lessons that may result in social activism. Connecting science concepts to the daily lives and futures of students from diverse backgrounds motivates them to learn science. Furthermore, they increase their participation in science when they see scientific knowledge as a way to gain entry to effect positive change in community contexts.

Third, multiple modes of representation include different forms of literacy like print, technology, and media, as well as aural forms. Multimodal experiences allow students to use senses and modalities to absorb material, including tactile, kinesthetic, and acting out scenarios.

Finally, school support systems are critically important for success in science achievement and careers for students of diverse races and ethnicities. School support systems include teachers, guidance counselors, mentors and peers from the students' own backgrounds who support science learning. They provide examples of success in science and ways to navigate school systems. School support systems also reach out to students' families and communities to address the important role they play in supporting the students. A key factor for students choosing a career in science is contact with successful, caring scientists from their own background.

Context

Demographics

According to the 2010 U.S. Census, 36% of the U.S. population is composed of racial minorities of whom 16% are Hispanic, 13% are Black, 5% are Asian, and 1% American Indian or Native Alaskans (U.S. Census Bureau, 2012). The student population in the U.S. is increasingly more diverse racially and ethnically. Forty-five percent of the school age population under 19 years old were minorities in 2010. It is projected that the year 2022 will be the turning point when minorities will become the majority in terms of percentage of the school-age population.

As an indication of changing demographics, the National Assessment of Educational Progress (NAEP) report card for racial and ethnic categories beginning in 2011 consists of these demographic categories: White, Black, Hispanic, Asian, Native Hawaiian/Other Pacific Islander, American Indian/Alaska Native, and two or more races (National Center for Education Statistics [NCES], 2012, p. 7).

Science Achievement

While the student population in the U.S. is becoming more diverse, science achievement gaps have persisted by demographic subgroups. At the national level, NAEP provides assessment of U.S. students' science performance that shows wide achievement gaps among racial groups. For example, on the most recent 2011 NAEP Science assessment administered to 8^{th} grade only, the average score for Black students was 129, Hispanic students 137, and White students 163 (NCES, 2012). The 2011 science performance also points to alarming underrepresentation of racial minority students in the Advanced Proficient (above 75%) category and overrepresentation in the Below Proficient (below 25%) category. In the Advanced Proficient category, 76% of the students were White, 10% Hispanic, and 4% Black. This trend reversed in the Below Proficient category, as 35% were Hispanic, 31% Black, and 27% White. Furthermore, science achievement gaps among racial groups persist over time, consistent at the 4^{th}, 8^{th}, and 12^{th} grades.

Educational Policy

The Elementary and Secondary Education Act of 2001 (ESEA) says that adequate yearly progress (AYP) should apply the same standard to all students in a state, with "separate measurable annual objectives for continuous and substantial improvement in each category including students from major racial and ethnic groups" at the 95% achievement level (Title I Part A Subpart 1 Sect 1111. (b)(2)(I)(ii)). The disaggregation would not be required in a case where the numbers in a category are statistically not significant or where the identity of an individual student would be revealed.

> Title I is intended for "improving the academic achievement of the disadvantaged" in order to meet "the educational needs of low-achieving children in our Nation's highest-poverty schools, limited English proficient children, migratory children, children with disabilities, Indian children, neglected or delinquent children, and young children in need of reading assistance." Part A states that, beginning no later than school year 2005-2006, the states were required to measure the proficiency of all students in science (Title I Part A Subpart 1 Sec. 1111 (b)(1) (C)) not less than one time during: grades 3 – 5, grades 6- 9, and grades 10- 12 (Title I Part A Subpart 1 Sec. 1111 (b)(3) (C) (II)) ESEA calls for educational agencies hold American Indian and Alaskan Native students to the same "challenging State student academic achievement standards as all other students are expected to meet." (ESEA, 2001 Title VII Sec. 701 Part A. Sec. 7102 (a))

In addition, the Race to the Top Priority 2: Competitive Preference Priority – Emphasis on Science, Technology, Engineering, and Mathematics (STEM) (Race To the Top, 2009, p. 4) is calling for schools to "prepare more students for advanced study and careers in the sciences, technology, engineering, and mathematics, including by addressing the needs of underrepresented groups and of women and girls in the areas of science, technology, engineering, and mathematics."

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MS-LS2 Ecosystems: Interactions, Energy, and Dynamics
MS-PS1 Matter and Its Interactions
MS-ESS3 Earth and Human Activity

Students who demonstrate understanding can:

MS-LS2-3. Develop a model to describe the cycling of matter and the flow of energy among living and nonliving parts of an ecosystem.

MS-PS1-3. Gather and make sense of information to describe that synthetic materials come from natural resources and impact society

MS-ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

MS-ESS3-4. Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.

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

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 describe phenomena

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 6–8 builds on K–5 and progresses to evaluating the merit and validity of ideas and methods.
- Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence.

Engaging in Argument from Evidence
Engaging in argument from evidence in 6–8 builds on 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.

Disciplinary Core Ideas

LS2.B: Cycle of Matter and Energy Transfer in Ecosystems
- Food webs are models that demonstrate how matter and energy is transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem. Transfers of matter into and out of the physical environment occur at every level. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem.

PS1.B: Chemical Reactions
- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the Reactants.

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.

ETS1.C: Optimizing the Design Solution
- The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.

Crosscutting Concepts

Energy and Matter
- The transfer of energy can be tracked as energy flows through a natural system.
- Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter.

CCSS Connections for English Language Arts and Mathematics
W.6.8 *Gather relevant information from multiple print and digital sources; assess the credibility of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and providing basic bibliographic information for sources.*
MP.2 *Reason abstractly and quantitatively.*
S.IC *Make inferences and justify conclusions from sample surveys, experiments, and observational studies.*
MP.4 *Model with mathematics.*
5.OA *Analyze patterns and relationships.*