Opportunities for Engaging Students in Science Through Civic Reasoning, Discourse, and Action

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Introduction

Motivation to learn increases when science courses connect curricular topics to challenges facing students' communities. Students care about their communities and the health of the planet. For example, 67% of the Gen Z population report that "climate should be [the] top priority to ensure [a] sustainable planet for future generations" (Pew Research Center, 2021, Figure: Gen Z, Millennials more active than older generations addressing climate change on- and offline). Instruction that connects science ideas and practices to students' lives and communities creates a pathway for civic engagement. Integrating science disciplinary ideas that support stewardship of the planet not only motivates students but also empowers them to engage in scientific discourse with peers and family members and to participate in civic actions to improve local environmental impacts. Broadening the conversation in science classes to include a wide range of perspectives on complex problems such as environmental stewardship can promote life-long learning by engaging students in distinguishing among alternative perspectives (Linn & Eylon, 2011) and recognizing the purposes and contributions of science to society.

Typical science instruction prioritizes discipline-specific content knowledge, and it neglects critical issues of equity and social context that are intertwined in the history of science, in current environmental dilemmas, and in many contemporary scientific practices (Bang & Medin, 2010). Giving students the opportunity to explore and discuss the ways that scientific issues impact their local communities and to consider multiple perspectives on complex situations can deepen understanding, illustrate how evidence is used by stakeholders, and increase students' understanding of why science is relevant to their lives, their communities, and their world. This not only strengthens scientific literacy but also builds students' identities as science learners (National Research Council, 2005).

Teachers in primary, elementary, and high school are exploring rich, science-related issues that are relevant to their local community. Examples include high school chemistry students exploring industrial pollution and waste disposal practices that disproportionately impact specific racial and ethnic communities (see Box A: Teacher Collectives Integrating Science and Civics); middle school students analyzing the relationship between pollution, asthma, and discriminatory real estate practices within their communities (see Box B: Chemical Reactions, Asthma, and Redlining); and primary school students exploring water quality and taking action to increase public awareness of health dangers (see Box C: Elementary School Students Increase Awareness of Polluted River). Further, numerous scientific societies, organizations, books, and magazines have publicized the importance of engaging students in local scientific activities, the need to broaden perspectives on scientific evidence, and the value of innovative methods to make sense of the complex systems impacting the health of our planet (Appendix A).

Including civic reasoning, discourse, and action in the classroom therefore provides opportunities for teachers to (a) increase student engagement, (b) strengthen connections to students lives, (c) explore critical issues of ethics, equity, and the nature of science, (d) enrich understanding of curricular standards, (e) illustrate the multiple methods that investigators use to gather evidence and distinguish among alternatives, (f) build student identities as a science learner, and (g) prepare students as engaged and empowered citizens in their community and society.

This report offers strategies for teachers to engage students in balanced, evidence-based discussion in which they develop criteria for determining what counts as evidence, learn to recognize and name bias, and make sense of the norms around civic discourse. The report explores these opportunities in three sections. The first section outlines the rationale for engaging science students in civic reasoning, discourse, and action. The second section provides detailed instructional examples, and the third and final section presents strategies for teachers who want to include civic reasoning, discourse, and action in the classroom.

Box A: Teacher Collectives Integrating Science and Civics

"*Education about inequities empowers my students to advocate for their community, [because] inequity is something that affects [them], their families and the school I work at*." [High School Science Teacher].

Chicago is home to thriving Black and Indigenous communities and also to vibrant immigrant communities from Latin America, Asia, Africa, and Europe. The city was built on the traditional Territories of the Three Fire Peoples – the Ojibwe, Odawa, and Bodewadmi – after decades of settler colonial violence. The development of Chicago relied on polluting industries like steel production, meat packing, and intermodal shipping. The city's growth was characterized by spillover effects from rapid industrialization as well as racist anti-Black housing policies and practices like red-lining and restrictive covenants. This combination of polluting industries and anti-Black housing policies resulted in legacies of environmental degradation and "environmental racism" (Bullard, 2001). In this urban and historical context, the Youth Participatory Science (YPS) Collective is a group of science teachers, scientists, community organizers, and youth supporting each other to lead classroom projects that bring together science learning with civic engagement around issues of environmental racism (Morales-Doyle, 2017). YPS merges youth participatory action research (YPAR) with citizen science in high school science classes to encourage students to take on local ecological concerns (Morales-Doyle & Frausto, 2021). Through YPS projects, high school students have (1) investigated the legacy of coal power plants closed by community organizing, (2) campaigned for their neighbors to check the safety of their drinking water delivered through lead pipes, (3) developed a plan to install solar panels on a community center across from their school, (4) tested the soil of community gardens and grocery store produce for heavy metal contamination, (5) demanded that lead-based paint on urban infrastructures be remediated, (6) considered whether a local chemical plant was emitting toxic pollution, and (7) tested air quality in a community fighting the relocation of a metal scrapping facility to their neighborhood–among other projects. The YPS collective has identified mutual support, learning together, and collaboration with each other as the most important elements to the success of their teaching. They have also found that science teachers who want to do this kind of civically-engaged teaching must work creatively with science learning standards while also prioritizing their own learning of the historical contexts of science, industry, and their communities. For the YPS collective, learning from grassroots environmental justice victories inspires the hope that drives their projects. *While YPS involved high school teachers, similar groups of elementary and middle school science teachers and community organizers have also addressed environmental hazards (e.g.,* *Box C: Elementary School Students Increase Awareness of Polluted River).*

Box B: Chemical Reactions, Asthma, and Redlining

"*I want students to have a space to connect science to their own lives.*" [Middle School Science Teacher]

Classroom teachers, learning scientists, computer scientists, and community leaders partnered to design a science unit where students investigate relationships between gasoline and factory emissions, asthma, and historical redlining policies.[1] They explore how the location of freeways and refineries inside redlined areas resulted in Black Americans experiencing unjust exposure to pollutants (Gerard et al., 2022b). This open-source unit addresses middle and high school Next Generation Science Standards (NGSS) for matter and its interactions as well as earth and human activity. Teachers have also addressed the relationship between the incidence of asthma and particulate matter pollution in primary grades (e.g., Mensah, 2001).

Students begin by hearing stories from local scientists and activists in Richmond, CA. They share what they love about living in Richmond and why they are frustrated by the poor air quality from local freeway, railroad, and refinery pollution. They recount actions they have taken to improve the air quality. Students predict the impact of living near the refinery and freeways on residents' health. The unit supports students to discover new ideas about air quality and geography by examining interactive maps depicting cities, freeways, and the quantity of particulate matter pollution in each neighborhood. Then students analyze the same maps that now include historical information about redlining. They distinguish between neighborhoods in redlined areas and those in adjacent areas. They discover factors that contribute to higher incidences of asthma in redlined communities such as proximity to freeways or refineries. As one student remarked, *"Now I know what redlining is, it's definitely not fair. I think it causes a lot of problems."* Using data analysis tools, the activity guides students to distinguish among the impacts of redlining on local communities. The unit encourages students to jointly form and debate conjectures about what is happening and why. Finally, the unit engages students in reflecting on their investigations and in developing action plans that leverage science knowledge about pollutants and alternative fuels to address issues related to people's rights.

Box C: Elementary School Students Increase Awareness of Polluted River

''*When I was doing the metal test [of the water in the river] and I was like wow, so this is how they [environmental scientists] do their work.*'' [Primary school student]
"So we need to make sure that we're doing these tests [of water quality] for ourselves." [Primary Science Teacher] who wants students to interpret public documents and to corroborate the findings (Stromholt & Bell, 2018)

A primary school grade teacher partnered with learning scientists to engage her fifth-graders who are primarily from marginalized communities and mainly speak a language other than English at home, to study a local, polluted river. Her students navigate texts written for the adult public, gather their own data, and build identity as science investigators. The team designed a year-long unit about the local polluted urban river, designated by the Environmental Protection Agency (EPA) as a Superfund site. To help her students make the connection between school science and their community, over a three-month period, the students planned activities, took field trips to the site, gathered samples, and analyzed the water quality using a variety of tests. They created a book reporting their findings and met with scientists who understand their community to develop an action plan. They designed signage

[1] The unit can be customized and viewed here.

for the site to warn of the potential danger from drinking or swimming in the water and presented their book and recommendations to the mayor of the city (Stromholt & Bell, 2018).

Rationale for Civic Reasoning, Discourse, and Engagement In Science

Instruction that builds on students' social and cultural backgrounds enables full and authentic participation in the sciences because the sciences are embedded in society (Sadler & Dawson, 2012). Designing instruction that supports full, interactive participation in society incorporates the practices, ideas, communities, and institutions of science, connects them to students' lives, and prepares students for civic engagement in the decisions and public activities of society.

Narrow conceptions of scientific knowledge in the classroom can trivialize the perspectives, values, and knowledge of marginalized groups, and thereby narrow the opportunities that students have for linking science learning to their roles as active members and citizens in their communities. Including discussions of the impact that the application of science has had on students and their communities enables students' full civic participation. Teachers can inspire curiosity and encourage meaningful participation through empowering students to ask relevant questions. For example, why water quality varies by neighborhood, how city leaders can organize efforts to control pollution, and what is the best way to create an action plan to warn citizens about a polluted river? Science classes generally seek to encourage questioning and critique, and these skills are part of the science standards in most states. A civic orientation extends this practice to include inquiry into social and ethical implications of science.

Science has political and ethical implications even though it is commonly portrayed as being value neutral, and scientific ideas and methods are frequently presented as universal ways of knowing about the world without considering their limits. Research has demonstrated that all people bring their various ways of knowing and experiences to learning, experts and novices alike (Bang & Medin, 2010). For example, the multiple ways of explaining the distinction between living and nonliving things can enrich scientific discourse (see Box D). Understanding a view of science and the methods of science requires transparency around the assertions that are made and the social context in which science knowledge is constructed. This entails connecting to the various ways of knowing that result in actionable evidence for scientific reasoning (see Appendix A).

Box D: Exploring Beliefs about Living and Nonliving Things

Exploring the cultural and experiential beliefs about the distinction between living and nonliving things can strengthen respect for the views of individual students and communities and advance understanding of social issues. Students often have multiple ideas about what is living and what is not, based on experience, cultural philosophies, literature, and instructional experiences. They may draw on distinct ideas depending on the context. Science classes might benefit from considering these perspectives while exploring complex environmental issues.

As children develop, they often base the distinction between living and nonliving things on observation, describing living things as having movement, the ability to grow, eat, breathe, reproduce, and respond to stimuli. Thus they might hypothesize that rivers and fires, among other entities, are living things because they move, grow, and respond to their environment. Responding to classroom instruction students may describe living things as having cells, brains, or metabolism, while still retaining earlier ideas (Carey, 1985).

Students may encounter multiple perspectives on what is living in their culture and depictions of other cultures in literature or drama. In some communities, individuals believe that animals, plants, the Earth, rivers, or other aspects of the environment have human agency and that interactions with them must be based on respectful relationships. These beliefs underpin commitments to share and not waste food and to only harvest what is needed. Considering the plethora of cultural and experiential perspectives can help students build a more robust understanding of the environment. For example, students might analyze a situation in New Zealand/Aotearoa where rights of personhood have been granted to the Whanganui River, following pressure from Māori groups. This action has improved legal protections for the environment (Brondízio et al., 2021).

When civic engagement is discussed during science instruction, there is often an assumption that science will solve societal problems (e.g., climate change), without addressing the entanglements of science with these problems. For example, the fields of geology, chemistry, and physics have been developed in conjunction with the identification, extraction, and combustion of carbon-based fuels. Further, many of the scientific innovations in society (e.g., cars) are now also contributing to societal concerns (e.g., air quality, water quality, and energy use). In the case of plastics, when they were invented in 1907 in New York by Leo Baekeland, who coined the term plastics, they were viewed as a miracle material. Today, because they do not decompose, single use plastic items are a major threat to the planet (e.g., Chen, et al. 2021).

By ignoring the broad impacts of science, we limit students' capacity to develop sophisticated understandings of the complex relations between science and society. Students should be supported and nurtured in science classrooms to explore these relationships, including how the varied motivations of scientists/the scientific enterprise dynamically shape the projects, experiments, methods, and ultimately the scientific knowledge and outcomes. Students benefit from identifying the stakeholders that shape science including individual scientists, for-profit organizations, and policy makers. They benefit from analyzing the cultural, economic, and political contexts in which science is practiced. And, they benefit from learning how foundational advances in science get translated into the ultimate products of the work. Teachers may guide students to make sense of the varied goals and uses of science by introducing research that emphasizes how scientific knowledge is put to use (see Box E).

Box E: Incorporating Relevant Science Methods

The focus on basic (discovery of the Bohr atom) *or* applied research (germ theory of disease) neglects investigations that explore the uses of basic theoretical and applied discoveries (Stokes, 2011). One example is the research on fermentation that led Pasteur to the discovery of pasteurization and development of the rabies vaccine. Other efforts to combine fundamental research with applied research are sometimes referred to as tinkering or design research. Tinkering is essential for making design innovations practical as is clear for computer innovations that have gone through many iterations. Introducing the varied research methods used to make scientific innovations practical and useful helps students understand the tradeoffs associated with making science relevant for everyday life.

Investigating the political and economic impacts of innovations requires expanding the types of methods used in science classes. Science classes can introduce new methods, often from the social sciences, for appropriately analyzing sources such as newspaper articles, surveys, Geographic Information System (GIS) maps, computational models, interviews, and historical documents (see Example B; Appendix B).

Science instruction that incorporates these sources allows students to see how scientific information is used to justify decisions that have substantial implications for the well-being of their communities and the planet. It is especially crucial to help students see the tradeoffs that often emerge in their communities. While plastics have the potential to reduce food waste, for example, plastics also increase pollution. Celebrating scientific advances without attending to the complexities of investigating the use of these advances to address societal problems obscures the implications of science in personal, political, and economic contexts.

Examples: Connecting Civic Reasoning and Science in K-12

Incorporating civic reasoning and discourse into science instruction ensures both an integrated understanding of scientific onsets and principles as well as the ability to transfer this scientific knowledge to real-world problem-solving. In this section, we illustrate connections between civic reasoning and science in two detailed examples that span primary, middle, and high school grade levels.

Example A: Water Quality

Love Canal[2] (Gibbs, 2011; Levine, 1982) and the Flint water crisis[3] (Erickson, 2019) illustrate the connection between civic reasoning, water quality, and science. The story of Lois Gibbs and neighbors living near Love Canal, a working-class community in western New York, foreshadows the struggles of communities decades later as recently seen in the Flint water crisis.

Lesson Outline: Love Canal

Love Canal originated in 1892 when William T. Love proposed digging a canal, roughly six miles (9.7 km) long, to connect the upper and lower Niagara Rivers via an engineered waterfall and thus generate power. Love wished to build a carefully planned industrial city with convenient access to inexpensive water power and major markets. Because of economic woes, the project was not completed. Instead, Love left behind a partially dug section of the canal, which was approximately 9,750 feet (2.9 km) long, about 50 feet (15 m) wide and 10 to 40 feet (3 m to 12 m) deep.

From the 1920s until 1953, the empty canal was used as a regular dumping location— first for municipal refuse, followed by World War II military wastes (which included nuclear waste), and then by the Hooker Chemical and others for chemical waste. The 21,000 tons of waste, including highly toxic, cancer-causing chemicals, went as deep as 10 to 25 feet. By 1953, the dump was closed and covered with a thin layer of soil.

Today, the waterway that gave the neighborhood its name is buried under a plastic liner along with clay and topsoil in a fenced area declared permanently off-limits, and the 239 homes closest to the canal were demolished. However, catastrophic medical problems persisted for families whose homes were not among the 239 that were demolished. The Love Canal experience raises many questions including: Why was the toxic waste unsafely dumped? What responsibility did the government have to protect the health of the local residents and environment? Do the benefits of making chemicals that cannot be safely disposed of outweigh the negative health impact on humans and the environment? Who should be responsible for the negative effects of hazardous waste?

Teachers can engage students in role playing of the many stakeholders, including curious outsiders, by asking each other questions to understand each person's perspective. Role players can explain how they reached their conclusions. For example, a student taking on the role of a government official could ask a student taking the role of community member to explain why they believe that something is wrong with the drinking water. The community member could ask the government official what makes them believe that the drinking water is safe.

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[2] See a lesson plan for Loval Canal at https://serc.carleton.edu/integrate/teaching_materials/freshwater/unit5.html.
[3] See a lesson plan for the Flint water crisis at https://www.tandfonline.com/doi/full/10.1080/07370008.2019.1624548.

Lesson Outline: Flint Water Crisis
The story of Flint, Michigan illustrates how communities with limited political power and those marginalized by racism and economic dispossession, are disproportionately exposed to environmental contamination and health hazards. This pattern underlies the idea of environmental racism.

In 2014, Flint, Michigan was forced to switch to getting its drinking water from the Flint River by state-appointed emergency managers. This decision was made to cut costs; however, it led to the city's water being contaminated by dangerous bacteria and toxic lead. The fact that these events transpired, the slow pace of response, and the resistance that the city of Flint faced from the managers in the state, are emblematic of the injustice and disproportionate harm suffered by communities that lack political and socio-economic power. The Flint water crisis also highlights the differences in standards of scientific evidence required of different groups arguing for change. The Flint water crisis persisted because the communities impacted lacked the necessary political and socio-economic power. Studying the Flint crisis through NGSS-aligned lessons enables primary and secondary teachers to engage students in understanding how scientific and civic reasoning are intertwined with each other and with racism and politics (Davis & Schaeffer, 2019).

Teacher resource: (W)holistic Science Pedagogy (Williams & Gray, 2021).

Connecting a Science Lesson to Components of Civic Reasoning
The partnership designing the lesson connecting water quality and civic reasoning considered the knowledge, dispositions, ethics, and developmental needs of the audience.

Knowledge – Because water is connected to all life on earth, either as a force or resource, it is a topic that connects rigorous science knowledge, civic reasoning, and discourse. Across grades, students study concepts including the water cycle, ecosystems, photosynthesis, chemistry, and physiology that are entwined with topics including healthy ecosystems, clean drinking water, agriculture and food availability, public health, flooding, manufacturing, and power generation. In the story of Love Canal and of Flint, Michigan, teachers can address many state standards (see Table 1).

Table 1: Water Quality and State Standards[4]

Grade Level	Example Lesson Focus	Example State Standards[5]
3-8	**Water cycle**: *Exploring the helpful and harmful impacts of canals on the water cycle (e.g., flood mitigation, land irrigation, reshaping landscapes)*	▪ Alabama: SCI.6.7.3; B.8.4 ▪ California: MS-ESS2-4 ▪ Florida: SC.5.E.7.1 ▪ Texas: SCIENCE.4.10.A
5-12	**Ecosystems**: *Understanding how healthy, local ecosystems are created, maintained, and can be*	▪ Alabama: SCI.7.8.1; B.7.2

[4] See also an online standards comparison tool, available at: https://issuu.com/achieveinc/docs/standards_comparison_tool_july_1_20/5.
[5] Please note that this is not an exhaustive list of state standards.

	harmed	■ California: MS-LS2-4 ■ Florida: SS.912.G.5.6 ■ Texas: SCIENCE.5.12.A
5-12	**Physiology:** *Investigate how environmental toxins impact the health of living organisms, including humans*	■ Alabama: SCI.7.11.4 ■ California: HS-ESS3-1 ■ Florida: SC.912.L.17.16 ■ Texas: SCIENCE.5.12.C
9-12	**Chemistry**: *Understanding how water becomes contaminated and the process for making clean drinking water*	■ Alabama: ES.10.2 ■ California: HS-ESS3-4 ■ Florida: SC.912.L.17.11 ■ Texas: SCIENCE.AQUA.10.C
9-12	**Physics**: *Explore the ways that nuclear power is generated and the various waste products that are produced*	■ Alabama: ES.1.2 ■ California: HS-PS1-8 ■ Florida: SS.912.A.6.11 ■ Texas: SCIENCE.IPC.8.C

Dispositions – Creating opportunities for students to explore an array of data sources and take on the interests and perspectives of the stakeholders, builds on student dispositions such as having an appreciation for the complexities of evidence, scientific processes, and the nature of inquiry as well as openness to alternative ideas impact the interpretation of evidence. Students can observe how stakeholders interpret evidence and how the positionality of stakeholders impacts the uptake of evidence (see Box R). For instance, for Love Canal, evidence comes from municipal approval documents and the design plan for the canal; personal accounts from community members about their experiences since the canal was built and used; and military and government documentation of the waste products in the canal. The evidence from each source comes from a different perspective. Similar health problems within the Love Canal community convinced residents that something in their shared environment was the cause. Meanwhile, the government officials who approved the abandoned Love Canal as a safe waste disposal site implied that the toxic waste in the canal could not pose a risk to the community. The story also highlights how the relationships of power in the community impeded solutions to the problems created by pollution. Lois Gibbs, who brought the Love Canal issue to public awareness was referred to as a "hysterical housewife". The observations she brought as evidence for government officials were discredited as invalid. The history of Love Canal reveals ways that stakeholders interpreted evidence and refined their understanding from their positions of power and influence. In Flint, Michigan those in power also responded slowly to devastating reports and resisted efforts to improve the situation. Analyzing these sources develops valuable capabilities such as (a) distinguishing justifiable beliefs from opinion, (b) assessing the validity of observations, and (c) refining understanding in light of new evidence.

The Love Canal story and the Flint, Michigan story provide numerous opportunities for students to develop the ability to ask crucial questions and understand why stakeholders might or might not be open to valuing each form of evidence. Students can evaluate how different pieces of evidence relate to one another and to consider how the disposition of each stakeholder impacts their interpretation. Thus, both Love Canal and Flint, Michigan enable students to assess how scientific evidence, relationships of power, and openness to alternative interpretations impact the resolution of conflicts.

Ethics – The Love Canal story and the Flint, Michigan story open opportunities to explore and discuss ethical issues such as (a) where the responsibility lies for the known and unknown harms that result from decisions to dump waste, (b) what types and how much information should be shared to help the public make informed decisions, and (c) how environmental racism and other forms of bias impact decision making. Engaging such issues in a science class requires keeping the focus not only on the evidence but also on the historical and political context of the issues at hand (see Box H: Productive Discussion Practices; Herrenkohl [2006]).

While the actions of the Hooker Chemical Company and local government in the Love Canal story may seem reprehensible and wrong today, at the time, no laws were broken and all transactions were legally acceptable. Only after the story received national attention, and many years later, were laws and regulations made to hold companies accountable for actions that harm people and the environment (e.g., the federal Comprehensive Environmental Response, Compensation and Liability Act of 1980). Exploring complex social issues in science class helps students appreciate the roles that scientific knowledge play in societal decision making. Students benefit from guidance to appreciate how stakeholders interpret and apply scientific knowledge, one of the primary goals of scientific inquiry.

The Love Canal story illustrates how decisions informed by scientific knowledge require analyzing information about the potential benefits and harms as well as interpreting the insights gathered from people with varying perspectives. How might the story of Love Canal have differed if Lois Gibbs had been taken seriously? What might have occurred if people buying the homes near the canal knew about the buried toxins, or knew how those toxins could contaminate the local environment? What different decisions might the city officials have made if the Hooker Chemical Company shared details about how they disposed of waste in the abandoned canal?

The Flint, Michigan example differs from Love Canal in that city and state officials broke federal law by failing to treat the water properly. As a result, lead leached out from aging pipes into thousands of homes. Independent tests found that a significant proportion of samples had lead levels well above the "action level" for lead set by the U.S. Environmental Protection Agency. In fact, some samples showed lead levels more than 100 times the action level (Denchak, 2018).

Developmental Needs – Science instruction that includes civic reasoning and discourse not only enables students to deepen their understanding of the science content, but it also engages them as productive learners, scientists, and citizens. Depending on the grade level, teachers might connect the Love Canal story or the Flint, Michigan story to the water cycle (primary school standards), or to the reactants and products associated with nuclear power generation (secondary school standards). Love Canal could prepare students to foresee the implications of using an abandoned open-air water canal as a landfill for toxic waste. Using the complex story of Love Canal as the context for exploring these science ideas encourages students to look for science connections in their everyday lives. Using the Flint, Michigan story can help students appreciate how environmental racism and power relationships among stakeholders impact outcomes. These examples give students confidence that they can understand and navigate competing evidence and perspectives. These experiences build identity as a science learner and prepare students to take action as citizens to protect their community from harm or to argue for action when they see that harm has occurred.

Example B: Henrietta Lacks and HeLa Cells
Creating curriculum materials that link civic reasoning and science benefits from a partnership who respectfully combine their expertise in classroom teaching (to ensure that materials take advantage of age appropriate teaching practices), the disciplinary topic (to ensure that the science information is relevant and accurate), civic reasoning (to connect to local civic contexts), and learning science (to align with relevant pedagogy) as documented in research studies (e.g., Freire, 1970; Inhelder & Piaget, 1958; Linn & Eylon, 2011; Morales-Doyle, 2017). We illustrate this process for the story of Henrietta Lacks and HeLa cells (Skloot, 2017).

For Henrietta Lacks sample lesson plans, please see:

- Henrietta lacks, HeLa cells, and health inequities: Making student research relevant and authentic (grade level: 6-8)
- Who was Henrietta Lacks? (grade level: 6-12)
- The Immortal Life of Henrietta Lacks: An Introduction to Jim Crow and the Great Migrations (grade level: 6-8)
- Genetics, Cell Division, and Henrietta Lacks (grade level: 6-12) ADD

Lesson Outline
Henrietta Lacks' cancer cells were the source of the HeLa cell line, the first immortalized human line of cells that reproduce indefinitely under the right conditions. Identifying the HeLa cell line is arguably the most important cell line discovery in all of medical research. Although new immortalized cell lines exist today, the HeLa cell line led to important pioneering discoveries. In 1965, Henry Harris and John Watkins created the first human-animal hybrid by fusing HeLa cells with mouse embryo cells. This enabled advances in mapping genes to specific chromosomes that led to the Human Genome Project.

Henrietta Lacks (born in 1920) was an African American female cancer patient at Johns Hopkins Hospital in 1951. At the time, there were no consent standards for taking and using tissue samples from patients. Neither Henrietta Lacks nor her family were informed or compensated for the taking, use, distribution, or propagation of her cell line, while fame and fortune have come to many of the researchers who used HeLa cells. Henrietta Lacks and her family received none of these accolades and had no idea until recently how important their mother was to so many influential discoveries.

Designing a science unit based on Henrietta Lacks' story involves the integration of biological science content knowledge, as well as civic and ethical reasoning related to (a) who owns the tissues in your body once they have been removed from your body, (b) patient rights about giving permission for medical procedures, and (c) assessing the costs and benefits of research use and the commercialization of cell lines. It also fundamentally raises issues concerning a fair, just, and appropriate treatment of the Lacks Family.

Teacher resources: These sources demonstrate a range of approaches and views for a guided discussion on the differences between the approach that scientists have taken and the views from the broader community relating to the HeLa Case Study.

- An open-source HeLa cell unit (see Box G: Hela Cells: Genetics, Cell Division and Permission

for Using Cells)
- Researched book and resulting film dramatization (starring Oprah Winfrey)
- Legal determination on what sorts of tissues belong to a patient and what sorts do not belong to a patient including others who have faced some of the same issues when their personal tissue proved valuable to science.

Connecting a Science Lesson to Components of Civic Reasoning

Knowledge - The HeLa Cells case study aligns with biology and health science standards related to genetic mutations, microscopy, and cancer. Connecting a lesson that aims to address civic reasoning and discourse to current grade/subject teaching standards makes clear to administrators, parents and other members of the interested public that civic discourse is integral to science instruction.

At the elementary level, teachers might focus on key biology outcomes in the "Inheritance and Variation of Traits" core science idea in the NGSS, while focusing on questions of fairness and emotions in terms of ethics. Questions might ask students how they feel if it was their family whose cells were involved. Would they feel that they had been cheated, sad that their family was not recognized or paid or even asked, or proud that their family's genes resulted in much medical and scientific progress? At the secondary level, the key biology outcomes and core ideas would become more nuanced, while the ethical considerations might move deeper into questions of systemic injustices in medical research such as the Tuskegee Syphilis Study[6] and other examples where medical research has been conducted without the consent or knowledge of the participants, often to their harm.

Dispositions–The HeLa Cells case study illustrates the complexity of establishing sources of reliable scientific evidence and the challenge of supporting students' dispositions to analyze the issues. Sources such as the National Institutes of Health and Johns Hopkins University, normally considered to be reliable information sources, are implicated as being biased in their treatment of Henrietta Lacks and her family although both have since re-evaluated that treatment[7]. The review of past decisions in the scientific community is an example of Feynman's view that science is: "…rechecking by new direct experience, and not necessarily trusting the [human] race['s] experience from the past." (Feynman, 1968, para. 95)[8]

The HeLa Cells case study provides an opportunity for students to reflect on the different perspectives of stakeholders including Henrietta Lacks' family, medical researchers, and people with diseases that could be treated based on research with HeLa cells. Understanding these different perspectives encourages students to engage in perspective taking, which is a key disposition for engaging in civic reasoning. The case facilitates students' appreciation for and understanding of complex issues, ability to develop empathy, and capacity consider emotional inputs beyond purely rational reasoning.

Ethics – The Henrietta Lacks case raises many ethical questions including, "What would be a fair, just, and appropriate treatment of the Lacks Family, given the immense professional and societal benefit that has come from her cells?" The case also illustrates controversial and unresolved issues across many stakeholders, and it has led to disagreements about the way the HeLa story is told, including how to

[6] See the USPHS Untreated Syphilis Study at Tuskegee at https://www.cdc.gov/tuskegee/index.html.
[7] See a video from Johns Hopkins Medicine at https://www.youtube.com/watch?v=SPLSp7Tf3bw.
[8] Resources: Helpful definition of evidence, CrashCourse series on Navigating Digital Information, Richard Feynman: What is science?

fairly represent the experience of all concerned. Engaging students in ethical discussions of these issues involves establishing norms for respectful, supportive, and constructive disagreement. Teachers can use the practices and guidelines in Box H to refine their own rules for classroom discussion.

Box G: Hela Cells: Genetics, Cell Division and Permission for Using Cells

The HeLa open-source unit[9] draws on the design perspectives of Knowledge Integration pedagogy (Linn & Eylon, 2011; Matuk & Linn, 2023):

Making science relevant by personalizing instruction.
Students analyze a case study of an adolescent boy named Eric who lives with cystic fibrosis. He, and his parents, were asked to join a clinical trial. When examining the data and permissions involved in Eric's clinical trial students reflect on the power dynamics and patient rights in their own healthcare. *What types of permission do you give when you visit the doctor for a routine physical? Who owns the tissues in your body once they have been removed from your body?*

Making the reasoning of all the stakeholders visible using interactive models, simulations, diagrams, experiments, narratives, and other techniques.
The unit guides students to consider the different perspectives of each person involved. Scientists for example will analyze the cell line to understand how CF develops; Eric's parents want to understand if Eric will experience pain from participating in the trial; Eric wants to know if his participation in the trial will help reduce his CF symptoms. Students use role play to raise additional stakeholder concerns (e.g. will Eric or his family be compensated for additional time?) and negotiate criteria for a clinical trial that supports each person's interests.

Engaging students in learning from each other, appreciating their cultural and experiential perspectives using negotiated decision making and critique.
The teacher guides students to think together about the use of HeLa cells in medical research today. The teacher prompts students to reflect on their experiences with healthcare and use that to talk together about questions such as: In the 1950s, most of the people who used free public wards for medical care were people of color. How do you think their care was different from wealthy, white patients who could go to private doctors? How is that similar or different from peoples' experiences today? The teacher listens, elevates students' different views, and guides students to share how they arrived at their perspective.

Promoting autonomy by encouraging learners to resolve discrepancies, sort out alternatives, and reflect on their experiences.
The unit scaffolds students' analysis of evidence, contemporary research using HeLa cells, and students' own experiences with data privacy and healthcare to form a point of view. How could the choices made about how to use HeLa cells bring out certain emotions in the family of Henrietta Lacks today? Would they be angry about this, excited about this, no emotions? How would you feel? What would be a fair, just, and appropriate treatment of the Lacks Family?

Developmental Needs – Teachers can facilitate the development of students' identities as science learners by illustrating ethically challenging situations starting in elementary school. Teachers can help

[9] See https://wise.berkeley.edu.

students develop an understanding of the complexity of inequality and prejudice and how they have infiltrated many aspects of human activity, including science. At the same time, teachers can put the HeLa case in perspective by pointing out evidence of progress in this area of science. The kinds of biological and ethical questions that might be explored evolve from the elementary grades into the secondary grades. The questions can support students to become capable learners who think critically about evidence and engage in productive conversations about the Henrietta Lacks case.

Box H: Productive Discussion Practices

Productive discussions in science can be supported by building on Reisman's (2017) practices for facilitating discussions in history. The recommendations below are ordered in terms of ease of use. When initiating instruction linking science and civic reasoning, teachers (especially in the primary grades) may want to start with the recommendations at the top of the list.

Practice #1: Orienting Students to One Another
To encourage students to acknowledge and build on one another's ideas, teachers can communicate that the work of understanding is collective. Teachers can emphasize that students' own understanding will be enriched by listening, challenging, and building on their classmates' ideas.

Teacher strategies:

- Use the "popcorn" process where the speaker calls on the next student and expects the student they select to respond to them.
- Incorporate a student's comment into a follow-up question.
- Design a range of sentence starters that students could consult depending on whether they wished to agree, disagree, paraphrase, clarify, or build on another student's comment.
- Support students in attending to one another's ideas (e.g., ask one student to repeat another student's claim).
- Display a pro/con-chart or continuum representing the various positions that students could hold in a particular discussion.

Practice #2: Orienting Students to the Text, Class Experiments, Personal Experience
Rigorous discussions require evidence. In science, teachers can orient students to texts as well as experiments, simulations, personal experiences, and other forms of evidence that allow them to base their claims on evidence.

Teacher strategies:

- Ensure that students comprehend the main ideas of a given text or other source of evidence (e.g., "What is the main argument in this passage?"; "Summarize the results of the experiment.").
- Encourage students to use evidence from an experiment, simulation, personal experience, or observation to support their position.
- Remind students to ground their claims in evidence from the text or other evidence (e.g., "Can you find evidence in the document to support your argument?").

Practice #3: Designing a Compelling Central Question
Evaluative questions that ask students to analyze and judge a key question, actor, or event are most likely to launch productive whole-class discussions. Choose questions that require students to use

evidence available in the lesson in order to judge wisely.

Teacher strategies:

- Engage class in identifying evidence on both sides of a question such as, "Is a river alive? Or "Why does metal feel colder than wood in the classroom"?
- Develop evaluative questions that: (a) point students back to the text/evidence being explored, (b) appeal to students' interpretation of text/evidence rather than their moral judgments, and (c) involve students in the problem as decision makers.

Practice #4: Stabilizing the Content

Teachers can clarify the content through taking a brief pause in instruction to address confusions and re-center discussions so that each student understands the claims and ensure that the discussion proceeds on the basis of accurate information. This approach helps students to delve into misunderstandings or misinterpretations that threaten to lead them away from rich evidence-based understanding.

Teacher strategies:

- Guide students to integrate new knowledge into their interpretation of the texts/evidence.
- Monitor students' understanding. If many students are confused about the topic or text under discussion, pause to review or clarify essential information. Create lessons that reveal inconsistencies and help students resolve alternatives.
- Advance students' learning by highlighting the various ways that historical or isolated instances may differ from the present.
- Ask students to consider the context more closely when they misunderstand a particular text/piece of evidence— pointing to excerpts from the text or other familiar/related events.
- Re-center the discussion within the context of the past to guard against students making assumptions about how people thought or behaved that do not align with historical context. Use caution and avoid correcting each confusion. Rather, guide students to sort out the evidence during the discussion. Empowering students to resolve their confusions promotes agency and identity.

Engaging Students in Civic Reasoning and Science: Strategies

Teachers report valuable strategies for engaging students in civic reasoning and science. Many capitalize on students' passions about local scientific issues such as polluted water (Example A) or increased incidence of asthma in neighborhoods adjacent to freeways (see Box B: Chemical Reactions, Asthma, and Redlining). Others explore inspirational collaborations with local communities (see Box A: Teacher Collectives Integrating Science and Civics). Teachers often leverage students' motivation to address local issues to increase interest in state and local science standards (Box I: Creating a Civics-Enhanced Science Lesson). The following sections touch on these issues and offer concrete strategies for developing learning opportunities that engage students in examining the intersection of science and civic reasoning.

Box I: Creating a Civics-Enhanced Science Lesson

<table>
<tr><th colspan="2">Curriculum Dimension</th><th>Lesson Building Recommendation</th></tr>
<tr><td>Knowledge</td><td>Ethics</td><td>1. Select a topic that has social, public health, environmental or other impacts and connect it to teaching standards. Or consider working with local government, libraries, museums, zoos, farmers, community gardens, environmental science groups to collaborate on classroom activities/materials.</td></tr>
<tr><td colspan="2">Knowledge</td><td>2. Outline the basic science content of the topic – tell the story.</td></tr>
<tr><td colspan="2">Dispositions and Use of Scientific Evidence</td><td>3. Identify a key question that the topic raises and formulate it as a question to be discussed in class using a format/classroom management method of your choice.
4. Encourage a collaborative, respectful discussion of the topic before research begins.
5. Establish what will count as "evidence" and how that evidence will be collected (best done collaboratively within the class). Recognize that the definition of evidence may need to be revised as discussions develop.</td></tr>
<tr><td colspan="2">Developmental Needs</td><td>6. Initiate research with the goal of responding to the key question you have identified sticking to standards of evidence that have been agreed upon in step 3.</td></tr>
<tr><td>Developmental Needs</td><td>Ethics</td><td>7. Be sure to introduce evidence of progress towards ethical choices, fairness, equity, and justice – "Bending the arc".</td></tr>
</table>

Selecting Starting Points

Shifting classroom pedagogy to engage students in civic reasoning and discourse may take many forms. For example, teachers can start small by asking reflective questions that connect the curriculum to their students' interests. They can give students time to write about and reflect on social issues related to the topic they are studying. In addition, teachers can engage students in discussion with one another and encourage students to explore connections between their classroom learning and their communities.Teachers also can enable students to explore, consider, and raise possible issues around the data they collect, including issues that connect to their lives (see Box J: Data Science). Encouraging students to reflect on social justice and science topics may stimulate important discussions related to the social world.

Box J: Data Science

Data Story Bytes or "DataBytes" are discussion activities, in the spirit of "number talks," to critically analyze and interpret data visualizations in ways that connect to students' lives and to important issues in society. Using any data-rich visualization (including ones from media sources, or that are connected to or from students' existing science materials), elementary and secondary teachers can ask a series of questions designed to guide students through:

1. *Making sense* of trends and relationships in the data or visualization, what these patterns mean, and how they connect to key science concepts.
2. Building *personal connections* by considering how students' own lives and communities may be impacted by or reflected by the patterns found in data.
3. Reflecting on the *context and history of the data*, how it was collected, by whom (including what gets "counted" and why), how it is visualized, what might be missing/hidden, and what questions the data can and cannot answer.
4. Envisioning *future uses* of data and visualization to expand the investigation, explore different perspectives, and highlight the importance of understanding what is happening in the world around us in multiple ways.

Teachers often start by taking inventory of the resources that they already have at their fingertips. For example, the existing, approved curriculum may have optional or suggested lessons or activities that were skipped in the past. Or other teachers in the school or district may have already incorporated civic issues in their teaching. Primary teachers may start with existing activities such as Data Bytes (see Box J), and secondary teachers may start with existing activities created by partnerships with teachers or by other teachers such as the Asthma lesson (see Box B: Chemical Reactions, Asthma, and Redlining) or the Henrietta Lacks case (Example B).

Civic reasoning, discourse, and action do not necessarily require a new curriculum. Science is integrated into all aspects of life from the atomic to the molecular to human bodies and environments. Teachers can build connections to their existing activities and curriculum by looking out for content that could bridge science and civic engagement. Possible connections abound across the curriculum. Examples include the following.

- Ecology—discover how best to manage invasive species and balance priorities between the environment, food production, and urban growth (see the Learning in Places lessons for more ideas).
- Chemistry—explore issues of and interactions between manufacturing, water quality (see Example A), and pollution (see Box B: Chemical Reactions, Asthma, and Redlining).
- Physics—study the mechanism of global climate change and address issues of urban heat islands (see the ARISE-OPEN Urban Heat Islands unit).
- Genetics—evaluate perspectives about genetically modified foods or food production (see lesson plan on Evaluating Perspectives about GMOs).
- Algorithms—explore the complex relation between algorithms and social decision-making in

Artificial Intelligence (see AI literacy resources curated by CRAFT at the Stanford University).

Furthermore, the connections are not all situated in the present. Historical examples such as Love Canal (Example A) raise important issues in terms of social embeddedness, historical construction, ethical implications, and cultural context.

Establishing an Open Classroom Climate for Productive Discussions

An open classroom climate that encourages each student to contribute respectfully can foster an atmosphere for productive discussions. It serves as an influential setting that affirms students' unique identities and experiences as well as enhances students' academic, social emotional, and civic-related learning (Wang et al., 2021; Barber et al., 2021). Establishing routines and norms for speaking and interacting with one another can promote empathy and connection (see Box H: Productive Discussion Practices). Primary school teachers may want to start a discussion with an example of a dilemma faced by a typical student in their classroom. Secondary school teachers may want to begin there and then expand to broader segments of the population.

To succeed, teachers think ahead about the goals for teaching and learning in each lesson. When teachers reveal their own vulnerability and compassion they create an atmosphere that allows students to be vulnerable and compassionate in the science classroom as well. They affirm and value students' efforts to consider the perspectives of others and to explore evidence that may counter their beliefs. Teachers may monitor students' emotional engagement in the lesson, such as by anticipating when and where students may need time to process their thinking individually before sharing with a whole group. They may identify common personal or shared experiences to elicit student thinking.

Learning how to facilitate productive discussions takes time and practice. Establishing an equitable classroom climate for discussions early in the term sets the tone for discourse. The first lesson can serve as an onramp for teaching civic discourse in future lessons. Teachers benefit from finding colleagues to serve as thought partners in reflecting on the teaching of science and civic reasoning as well as on their identities as science teachers.

Each lesson is part of a longer path of integrating civic reasoning and discourse in science teaching practice. Teachers need indicators of student progress that capture students' trajectories. For example, they might regularly ask students to write (briefly) about and reflect on social issues that surround the topic they are studying. Teachers can use informal methods to assess how student experience engaging in civic discourse creates robust understanding of science. For example, classroom consensus building routines can make public the accurate, scientific ideas that students are figuring out (see Box K).

Box K: Class Consensus Discussion: Elevating Ideas Towards Group Understanding

Description: The routine described below is a way to ensure that the accurate scientific ideas are made public and visible to each student. It requires skillful teacher facilitation, as it is important to not tell students what they need to know, and instead, supporting students as a class in using the information they have from investigations, their models, and texts in order to figure out and state important ideas. This routine is equally effective for primary and secondary classrooms.

Starting Position: Groups have completed their investigative work which may include an explanation, model, or lab.

Action Pattern:
1. Select a few different groups to share their work.
2. The first group shares their work. Sharing can be done by:
    a. projecting using a document camera
    b. copying the models to be shared and passing them out to the class
    c. taking a picture of each model and projecting them as slides
3. Another person in class repeats or reiterates what the first group shared.
4. Class members ask clarifying questions about the work.
5. Repeat for each group that is sharing work.
6. Everyone confers in table groups.
7. Engage in whole-class discussion about the ideas that were shared, in order to come to agreement.

Criteria:
- One group shares while all others watch and listen.
- Everyone is responsible for making sense of the ideas presented, in service of figuring something out together.

(Select the criteria that are appropriate for your class and the task at hand.)

Variations: Once this routine is well-established in a class, students can often take on the facilitation and orchestration of discussions.

Supporting Students to Develop a Critical Eye

Developing critical thinking is regularly hailed as the hallmark of science instruction. Further, while science methods are often portrayed as neutral or formulaic, as discussed in the Rationale section above, their limitations are due to many factors including historical and social context, availability of funding, opportunities for dissemination of controversial findings, and the power of stakeholders to shape the discourse. Understanding the political and ethical implications of how scientific information is generated and portrayed enables students to dig deeply into news articles and other information sources. Teachers can engage their students as informed and active citizens in the discussions, debates, and decision making that impacts their communities and world with focusing questions (see Box L: Focusing Questions). Teachers can reframe the nature of science for students by asking questions about the sources of evidence. They can engage students in discussions around the choice of questions to investigate, the gaps in available information, the obstacles that stand in the way of some lines of investigation, and the assumptions that govern the use of certain science methods. These activities may help students appreciate the complexities of using science methods for civic reasoning. Classroom activities, such as role playing and debate, can reveal how scientific discourse involves multiple perspectives and bring to life the underlying issues regarding the design of investigations involving civic discourse and the nature of the available evidence. These activities can support the widely valued ability to think critically.

Box L: Focusing Questions

The list of questions below can help focus class discussions about formal and informal evidence sources. When initiating instruction linking science and civic reasoning, teachers (especially in the primary grades) may want to start with the recommendations at the top of the list.

- What are you basing your idea on? What makes you believe this?
- What information supports your idea?
- What counts as evidence (in what contexts)?
- How is the use of evidence related to the use of power?
- What is the history of how this evidence was created?
- Who cares about the outcomes? Who are the stakeholders?
- How do the views of multiple stakeholders get incorporated into science?
- Why do you think people studied this topic?
- What interests, perspectives, or agendas have informed what has been studied?
- What has been ignored in the research or data to date?
- How are our conclusions affected by political propaganda and misinformation campaigns?

Teacher resources:

- Introduction to Crash Course Navigating Digital Information
- Civic online reasoning for the science classroom
- What Productive Talk Looks Like in the Elementary Grades
- Intellectual Role Taking: Supporting Discussion in Heterogeneous Elementary Science Classes

Localizing to Promote Agency

Introducing civic reasoning around a local issue that is relevant to the students can promote agency and help students identify with the dilemma. Teachers can draw on personal experiences; local news articles; or issues championed by their school (See Box A: Teacher Collectives Integrating Science and Civics, Box B: Chemical Reactions, Asthma, and Redlining, Box M: Leveraging Local School Issues to Support Science and Engineering Practices and Sensemaking in Elementary Classrooms). Localizing science can capture students' interest and motivate them to take action (See Box N: Teacher's Personal or Local Experiences). Teachers also can draw on resources from community organizations (such as downloadable data sets); data visualizations (such as a graph from an online data repository); or from "citizen science" materials (for lessons relevant to their location). Preparing to teach about civics and science includes anticipating what students know about local issues. Teachers can gather their students' ideas while also engaging their students in identifying and localizing science issues by (a) providing multiple avenues for students to express their ideas, (b) engaging students in reflecting on their personal and collective goals for civic reasoning, and (c) anticipating and reflecting on students' sense-making emotionally and intellectually.

Anticipating student knowledge of local issues. Anticipating students' prior knowledge of local issues can help teachers recognize the edges of their own knowledge about the topic. They can plan how to build on these ideas and encourage students to deepen their understanding. Many teachers are eager to learn more about both the history of the issue in their neighborhood and its current impacts (e.g., Morales-Doyle, 2017) (see Box O: Questions to Consider). Teachers report they often feel more confident about the science mechanisms, and uncertain about the historical and societal factors that contributed to the local situation (Bradford et al., 2023; Gerard et al., 2022b). Resources can provide historical and contemporary information about local issues to support teachers in this work.

Providing multiple avenues for students to express their ideas. To promote student agency, it is advantageous to give students multiple ways to share their thinking. They might share privately with the teacher or with another student. The teacher might prompt students to record their thoughts using an audio recording, in a picture, or in writing. Teachers might use collaborative technologies such as a digital forum or a digital wall such as a Jamboard (https://jamboard.google.com/).

Local examples of civic reasoning and science may help both students and teachers connect with the issues. Further, these local issues have the potential to raise concerns of injustice, thereby developing student agency to find remedies. Issues local to the school are especially valuable, such as ways to conserve water or reduce energy usage.

By eliciting students' ideas using varied instructional techniques, the teacher (a) makes sure every student has a chance to contribute, (b) takes time to organize the different perspectives, and (c) plans activities that incorporate the diverse ideas of their students.

Reflecting on personal and collective goals for civic reasoning. Reflecting on purposes for connecting civic reasoning and science can help students build both personal and collective goals. For example, students in the Asthma unit reflect on a data visualization illustrating racially disparate asthma rates in Richmond, CA. They share their ideas with other students using a Padlet (https://padlet.com/). They are prompted to explain what they think might be the reason for the disparity and what information they were drawing on to inform their perspective (e.g., how have your life experiences shaped your perspective and the information available to you to interpret the visualization?). Students then identify an idea different from their own that was contributed by another student. They reflect on criteria they used when considering the views of others (e.g., what would make you more or less likely to incorporate a new idea into your perspective?). Then, students discuss the support they need to engage in discussions of social issues with peers.

After engaging their students in reflecting on the purposes for studying civic reasoning, teachers might reflect on their personal bias when teaching science (see Box O). Teachers might ask themselves: Which facets of my identity feel most salient when teaching about this topic? How does my own history intersect with the history brought into this lesson? How does this relate to my students' varied histories?

Anticipating and reflecting on students' sensemaking emotionally and intellectually. Building a new lesson is an exciting and long process of planning, teaching, reflecting, and refining. Teachers can connect the topic to student thinking by anticipating some of the questions, interests, and ideas their students may bring to the lesson. When teachers identify the key ideas in the lesson they can build on their students' initial ideas. They can elicit ideas that students might need to better understand the key ideas. They can also focus the activity on engaging students in distinguishing their initial ideas from the key ideas.

Shaping the lesson involves setting goals and identifying ways to support students to connect a science lens to a science and civic reasoning lens. Criteria for learning from a science and civic-reasoning perspective are emerging. For example, teachers might seek lessons that connect to their students' first-hand experiences. They might imagine the responses of some of their students. A first activity could elicit ideas from some or all of the students in a brief free write about the topic or in informal conversations with students or family members. Teachers might then identify an activity for the lesson, jointly reflect on possibilities, or partner with researchers to build a lesson.

Box M: Leveraging Local School Issues to Support Science and Engineering Practices and Sensemaking in Elementary Classrooms

In a 4-week NGSS-aligned curricular unit that integrates engineering design and computational thinking within science classrooms, upper elementary students were challenged to redesign their school to reduce water runoff. Students conducted hands-on investigations of water runoff and created computational models to help them iteratively test and refine their design solutions. Teachers were able to effectively leverage students' high level of familiarity with their school campus to help them engage in a range of science and engineering practices (SEPs) by providing pragmatic support (how to do a SEP) as well as epistemological support (when and why to do a SEP). Engaging in problem-solving of a localized and familiar issue created additional opportunities for teachers to draw upon one or more additional SEPs beyond the focal SEPs in the lesson to support student learning. Specifically, the focal SEPs outlined in the lesson were planning and carrying out investigations, constructing explanations and engaging in argument from evidence, and analyzing and interpreting data. Yet, teachers also were able to support students in defining problems, developing and using models, and using mathematics and computational thinking. In turn, this SEP support enabled students' sense making of the natural phenomenon of water runoff and the impacts for their school and community (Lilly et al., 2022).

Box N: Teacher's Personal or Local Experiences

In the Asthma unit (see Box B), a teacher shared how their grandparents were not given a loan to purchase a home in a particular neighborhood in San Francisco due to redlining policies. This meant the family purchased a home in another neighborhood that had poor air quality due to the neighboring refinery. Today people living in these neighborhoods continue to be impacted by this policy. This local experience encouraged the students to investigate possible remedies. Another teacher shared their experience of the wildfires in their state and described how it impacted their breathing. The students wanted to figure out how to prevent this problem in the future. Eliciting these reactions created an authentic dilemma, providing an opportunity for the students to negotiate a plan to address stakeholders and meet the needs of the community.

By sharing their own experiences and historical knowledge, teachers can localize science issues for their students. For example, as students analyzed map-based data of asthma rates across neighborhoods relative to the redlining map of the Bay Area in one 7th grade classroom, students raised their concerns. The teacher offered their own experience in response. "*So when I first heard about redlining I had a pretty strong reaction too. I heard about it as an adult because I didn't have the privilege to hear about it as a middle schooler. And I say privilege because we can do something about it. My history is in all of that. My family would have been considered undesirable. And if there were a lot of people like me in an area it would be considered undesirable because of the color of our skins or the country where we're from... I was kind of appalled but I also have hope because as 7th graders you can do something about it and I can do something as a middle aged woman.*"

By offering up their own experience, these teachers elucidate the relevance of the issue. Through the lesson they forefront how science can be used to understand and address the impacts of a discriminatory housing policy.

Box O: Questions to Consider

Teachers might consider the following questions to localize the discussion. Once again, when initiating instruction linking science and civic reasoning, teachers (especially in the primary grades) may want to start with the recommendations at the top of the list.

- How does this issue intersect with the lives of my students specifically?
- Who is missing from this story and why?
- What would be different if.......?
- What resources are available for me to introduce these topics?
- How can I localize science to community concerns?
- What is the history of this issue in my community?
- How can I bring in stakeholders/interested groups such as local leaders or organizations to help?
- What connections can I build to other disciplines, such as literacy?
- How are scientific ways of knowing both useful and limited, potentially helpful and harmful in understanding and addressing community issues?

Considering Issues of Race, Social Class, and Other Inequalities

Many issues related to science in the community intersect with issues of race, social class, and other inequalities. Acknowledging and considering these inequalities as part of the discussion allows students to understand the challenges. Clarifying the relevance of these issues for science is essential. Students can identify with the real-world suffering that is central to those challenges. The Flint water crisis in Example A and the redlining example in Box B on Asthma are good examples for secondary schools, while the Henrietta Lacks example and Box G are good examples across grade bands. Students benefit from recognizing underlying issues of racism and injustice and exploring their implications. Understanding issues of racism and injustice enables students to make sense of the scientific consequences of actions and policies. When the classroom is open to these issues students will want to discuss the implications of policies leading to the situations explored in these examples (Box R). When engaging in challenging issues, such as racism and injustice, it is extremely important to create and maintain norms for a safe learning environment and for engaging in respectful discussions (See Box H and resources such as this issue of Creating Safe Environments [Circle Time Magazine, 2021]).

Box R: Positioning Communities and Impact

In the United States, science has intersected, and continues to intersect, with inequitable social dynamics that for many students are not abstractions but are part of their families' and communities' lived realities across history and in the present. These realities enable educators to show that science is not simply a body of knowledge but rather an active part of the fabric of society. The use of scientific knowledge is a part of social life that comes with significant complexities.

Educators have openings to engage with questions of who has benefited from scientific knowledge production and who has been harmed. Helping students balance the intersection of the needs and goals of communities impacted by environmental changes might start with a positioning activity where each participant describes their own experiences. Connecting one's own experiences to the experiences of the communities that are most frequently ignored or silenced strengthens understanding of social issues. In addition, science courses can complement other forms of civic engagement and democratic participation by helping students to gain insight into how scientific methods can advance students' understanding of complex issues and how these methods can be utilized for investigating and finding solutions to problems affecting their communities.

Developing Partnerships

Working in a community-connected and collegial way can facilitate connections between science and civic reasoning. Teachers who collaborate with each another can broaden support for navigating challenges of using new and potentially controversial curriculum materials. A science teacher may reach out to a history teacher who has taught about civic reasoning to co-design the lesson. Collaborating with a teacher who has involved family members in their lessons is an opportunity to build on experience in the school. For teachers who are new to a school, it is valuable to find a more experienced teacher to help integrate a newly designed lesson within the school's adopted science curriculum materials. A partnership enables continued interaction with different perspectives to jointly distinguish and refine new approaches. It can build comradery to jointly navigate obstacles and fuel a sustained and thriving commitment. Having at least one partner teacher has shown in prior research to contribute to teachers' sense of fulfillment when exploring new curriculum materials (Liu et al., 2010).

Teachers also can reach out to community organizations and colleagues who teach the same or different grade-level or content area to identify synergies or connections (See Box P and Box Q). For example, learning about a community organization's current campaigns provides ideas for framing a global issue within the local context. The organization can then provide an outlet for passionate and engaged students to keep working on the issue after the unit, project, or class ends. Community organizations also offer teachers a path towards constructing authentic opportunities for students to act on or share what they learn in science class. Collaborating with community organizations working on local issues enable students and teachers to engage authentically in civic and social issues, learning from the expertise of community members, and simultaneously uplifting the work of local organizations in schools.
For example, the asthma and pollution curriculum design (see Box B: Chemical Reactions, Asthma, and Redlining) involved community organizations (Gerard et al, 2022b). Box P "Partnering with a Community Organization" describes an afterschool program, where students think through the ethics of cryptocurrencies, and the pedagogical/curricular moves to support it. These efforts illustrate ways that teachers can enlist help from local organizations and highlight how partnering with community organizations is an important avenue to create meaningful civics/science learning projects.

Teachers might also collaborate with researchers to design units that link science and civics. For example, in designing a unit where students reviewed data on COVID-19 infection patterns and designed investigations to analyze patterns across counties, teachers found that students had many personal insights about difficulties in getting COVID tests, medical treatment, and even healthy food. In another example, a teacher interested in creating a unit about Urban Heat Islands found that their students suggested adding umbrellas, trees, grass, and fans to reduce the temperature on hot days. The teachers partnered with research teams to design tools that students could use to distinguish ideas. In one approach, the teacher exploring Urban Heat Islands collaborated with the researchers to design a computer model that featured the ideas generated by students and also supported students to distinguish between their own ideas and new ideas. For example, the model featured ideas students generated including adding reflective coating to windows and removing asphalt. This teacher tried the unit in their classroom and authored a paper reporting the experience (Bradford et al. 2022). In another example, teachers partnered with researchers to design a "thought buddy" that engaged their students in a dialogue to consider alternative ideas. The thought buddy was designed to encourage students to deepen their ideas about the topic (see Video; Gerard et al., 2022a).

The process of interweaving science and civics does not have a universal blueprint. It necessarily involves responding to local contexts and students' ideas. Collaboration with colleagues, community partners, and research teams is an exciting part of the work. Curricula that are widely disseminated can provide useful activities, frameworks, and lessons, and they are most effective when connected to local examples. Further, they need to build on the ideas and questions that students raise.

BOX P: Partnering with a Community Organization

The Young People's Race, Power, and Technology afterschool program partnered with the Lucy Parsons Labs, a community-based organization in Chicago focused on issues of digital security and transparency (The Tree Lab, n.d.). This partnership has been instrumental in cultivating learning that thoughtfully interweaves civic reasoning and computing. High school students work with undergraduate students to investigate the social and ethical dimensions of advanced computational technologies in their local community.[10] For example, in a recent partnership with the Kapor Center, high school students explored the ethics and civic connections of cryptocurrencies. Using the NGSS storyline approach, students developed a lesson plan for high school CS teachers that simultaneously supports civic reasoning and aligns with the K-12 CS Framework. The two lead students, both juniors in high school and recent immigrants from Nigeria, selected cryptocurrencies for their focal project based on their own personal interest and investment in NFTs (Non-Fungible Tokens). The students' interest in cryptocurrencies stems from their involvement with designing and selling NFTs. Further, their interest in digital currencies is also tied to their popularity in Nigeria, their country of origin. Their final lesson plan explored the technical aspects of NFTs, such as the blockchain, as well as the complex ethical issues when considering who digital currencies empower and who they potentially marginalize (Morales-Doyle et al., 2021).

Box Q: Partnering with Existing Networks

Many local practitioners, scientists, and government organizations offer support materials, speakers, and online tools teachers can use in classroom and out of classroom instruction. For example, these resources might enable students to interact with professionals who have interest or expertise about a topic of concern to the community. These resources can be extremely helpful, particularly for teachers who are new to leading discussions that involve civic reasoning and science. Examples of such resources include:

- State and local government offices
    - CLEAN
- Professional organizations
    - NSTA
- Local chapters of scientific organizations like:
    - Sigma Xi, The Scientific Research Society,
    - American Academy of Forensic Sciences.
- American Association for Anatomy
    - American Association of Geographers.

[10] See website for examples of student artifacts: https://tree.northwestern.edu/pages/yprpt-film-festival-2021/.

  - American Association of Petroleum Geologists.
  - American Astronomical Society.
  - American Bryological and Lichenological Society
- University researchers/departments
  - Carleton

Teachers also can partner with administrators, policy makers, and other stakeholders (e.g., Penuel et al., 2022) to help engage students as informed citizens (see Box S: Youth Engaging Elected Officials with Scientific Evidence). Partnerships require deft leadership because families, administrators, and community members may question why civic reasoning and discourse belong in the science classroom. They may argue that the science classes they remember from their own K-12 experience didn't address social and civic issues. A proactive approach offers promise. For example, teachers might include a goals statement in their syllabus explaining that they want their students to see science as personally relevant. They may explain that, to accomplish this, they want students to practice connecting scientific evidence to real-life issues such as access to clean water. Teachers can also invite administrator(s) to visit the classroom during a lesson that connects science and civic reasoning to experience it alongside their students. In selecting topics to address, teachers can explain the alignments with the state or national standards and the prescribed curriculum.

Box S: Youth Engaging Elected Officials with Scientific Evidence

For two years, middle grades students from a Chicago public school investigated the deteriorating viaducts that many of them walked under between home and school. Their investigation grew from aesthetic, environmental, and health concerns about the paint chips falling from the viaducts and getting stuck to shoes, dog paws, and stroller wheels. In science class, students learned about chemical composition and the toxicity of heavy metals while utilizing science and engineering practices in order to carry out an investigation of lead contamination in their community. For example, students used safe materials to study chemical properties as a way to understand why chemical engineers formulated paint and gasoline with lead until it was banned in the 1970s. When paint samples from the viaducts collected by their teacher were analyzed by a university partner, students were provided with the raw numeric data and had the opportunity to take up authentic data analysis practices in the context of a community concern. One student spontaneously calculated the lead concentration in the sample to be 170 times the legal limit for indoor paint. This led the class to wonder aloud *whom do we tell*?! Their question demonstrates that in order for their scientific evidence to make a difference in their community, they also had to understand the structures of government. They learned that, in Chicago, city council members (alderpeople) have substantial power with respect to infrastructure in their wards, so the students wrote to their alderwoman and invited her to attend a program prepared and presented by students, focusing on the need to remediate lead-based paint on the neighborhood viaducts. Students were affirmed that an elected official came to listen to the evidence they presented. They were proud of the ways they leveraged their scientific practices for civic engagement. But the city government ultimately responded with excuses about why the viaducts could not be remediated as they recommended. This is a hyper-local struggle that has not yet concluded, but along the way students have learned that the relationships between scientific evidence and public decision-making are complicated and deeply intertwined with issues of power (Frausto & Morales-Doyle, 2022).

Final Thoughts: Civic Reasoning in Science Realigns Roles with Goals

Teachers regularly look for ways to make learning relevant for students. Civic reasoning, discourse, and action are central to making science relevant. By exploring the choices, ethics, and impacts of science on local communities, science courses connect to the lives of students. Scientific understanding is essential in the making of good problem-solvers and responsible citizens. Science teachers who facilitate discussions about civics, engage students in making their world a better and more equitable place through their growing understanding of science.

Connecting science and civic reasoning involves rethinking the goals of instruction. To enable students to integrate their disparate ideas (see Box D) and to consider the intersections of science and civic reasoning (see Box R Positionality), the curriculum materials need to support a constructivist process of inquiry where students grapple with complex dilemmas that involve tradeoffs such as those illustrated in the examples about water quality and Henrietta Lacks. They need to regularly discover new ideas by exploring new forms of evidence including news articles, testimonies of community groups, and government documents. They need opportunities to distinguish among the many ideas they encounter and to reflect on their own learning.

This report suggests strategies science teachers can use to develop young people as productive, contributing citizens in a democracy by engaging them in civic reasoning, discourse, and action. It offers examples of curriculum materials that engage students in constructivist inquiry that supports knowledge integration. It also offers science teachers, curriculum designers, and research-practice partnerships tools to customize the materials they find to the needs of their audience. Developing effective instruction that links civics, science reasoning, and society is an ongoing process. Each group working on these issues is advancing our understanding. Each group is also regularly refining their approach.

Preparation for citizenship includes preparing all people, across age groups, for active, responsive, and critical participation their communities regardless of their histories, birthplace, or legal documentation. These strategies range from initial starting points to community partnerships. Ultimately, engaging students in civic reasoning, discourse, and action provides opportunities for teachers to realign and reconceptualize their roles and goals as teachers. When teachers engage their students in civic reasoning, discourse, and action they have the potential to increase their impact on the lives of their students and on society.

References

Bang, M., & Medin, D. (2010). Cultural processes in science education: Supporting the navigation of multiple epistemologies. *Science education, 94*(6), 1008-1026.

Barber, B., Clark, C., & Torney-Purta, J. (2021). Learning environments and school/classroom climate as supports for civic reasoning, discourse, and engagement. In C. D. Lee, G. White, & D. Dong (Eds.), *Educating for civic reasoning and discourse* (pp. 273–318). Washington, DC: National Academy of Education.

Bradford, A., Gerard, L., Lim-Breitbart, J., Miller, J., Linn, M. C. (2022). Computational Thinking in Middle School Science. In C. Chinn, E. Tan, C. Chan, & Y. Kali (Eds.), *Proceedings of the 16th International Conference of the Learning Sciences—ICLS 2022* (pp. 839–846). Hiroshima, Japan: International Society of the Learning Sciences.

Bradford, A, Gerard, L., Tate, E., & Linn, M.C. (2023). Incorporating Investigations of Environmental Racism into Middle School Science. *Science Education*, 107, 1628–1654 *https://doi.org/10.1002/sce.21824*

Brondízio, E. S., Aumeeruddy-Thomas, Y., Bates, P., Carino, J., Fernández-Llamazares, Á., Ferrari, M. F., ... & Shrestha, U. B. (2021). Locally based, regionally manifested, and globally relevant: Indigenous and local knowledge, values, and practices for nature. Annual Review of Environment and Resources, 46, 481-509.

Bullard, Robert D (2001). Environmental Justice in the 21st Century: Race Still Matters. *Phylon, 49* (3–4), 151–171. doi:10.2307/3132626

Carey, S. (1985). Conceptual Change in Childhood. Cambridge, MA: The MIT Press.

Chen, Y., Awasthi, A. K., Wei, F., Tan, Q., & Li, J. (2021). Single-use plastics: Production, usage, disposal, and adverse impacts. *Science of the total environment, 752*, 141772.

Circle Time Magazine (2021). Creating safe environments. *Circle Time Magazine, 1*(4), 1-20.

Davis, N.R., & Schaeffer, J. (2019). Troubling Troubled Waters in Elementary Science Education: Politics, Ethics & Black Children's Conceptions of Water [Justice] in the Era of Flint. Cognition and Instruction, 37(3). https://doi.org/10.1080/07370008.2019.1624548.

Denchak, M. (2018). Flint Water Crisis: Everything You Need to Know. Natural Resources Defense Council. Retrieved from: https://www.nrdc.org/stories/flint-water-crisis-everything-you-need-know#beyond.

Erickson, J. (2019). Five years later: Flint water crisis most egregious example of environmental injustice, U-M researcher says. Michigan News. Retrieved from: https://news.umich.edu/five-years-later-flint-water-crisis-most-egregious-example-of-environmental-injustice-u-m-researcher-says/.

Feynman, R. (1968). Richard Feynman: What is science? *The Physics Teacher*, 7(6), 313-320. Accessed at https://zoebirch.com/blog/2020/8/2/what-is-science on March 25, 2024.

Frausto Aceves, A., & Morales-Doyle, D. (2022). More than civil engineering and civic reasoning: World-building in middle school STEM. Occasional Paper Series, (48), 13-32. DOI: https://doi.org/10.58295/2375-3668.1473

Freire, P. (1970). *Cultural action for freedom.* Harvard educational review, 476-521.

Gerard, L., Bichler, S., Bradford, A., Linn, M. C., Steimel, K., & Riordan, B. (2022a). Designing an Adaptive Dialogue to Promote Science Understanding. In C. Chinn, E. Tan, C. Chan, & Y. Kali (Eds.), *Proceedings of the 16th International Conference of the Learning Sciences—ICLS 2022* (pp. 1653–1656). Hiroshima, Japan: International Society of the Learning Sciences.

Gerard, L., Bradford, A., DeBarger, A., Wiley, K., & Linn, M. C. (2022b). Cultivating Teacher Efficacy for Social Justice in Science. *Science Scope*, *45*(5).

Gibbs, L. M. (2011). *Love Canal: And the birth of the environmental health movement*. Island Press.

Herrenkohl, L. R. (2006). Intellectual role taking: Supporting discussion in heterogeneous elementary science classes. *Theory Into Practice*, *45*(1), 47-54.

Inhelder, B., & Piaget, J. (1958). *The growth of logical thinking from childhood to adolescence: An essay on the construction of formal operational structures* (Vol. 22). Psychology Press.

Levine, A. G. (1982). *Love Canal: Science, politics, and people*. Lexington, MA: Lexington Books.

Lilly, S., McAlister, A.M., Fick, S.J., Chiu, J.L., & McElhaney, K.W. (2022). Elementary teachers' verbal supports of science and engineering practices in an NGSS-aligned science, engineering, and computational thinking unit. Journal of Research in Science Teaching. https://doi.org/10.1002/tea.21751.

Linn, M. C., & Eylon, B. S. (2011). *Science learning and instruction: Taking advantage of technology to promote knowledge integration*. Routledge.

Liu, O. L., Lee, H. –S., & Linn, M. C. (2010). An investigation of teacher impact on student inquiry science performance using a Hierarchical Linear Model. Journal of Research in Science Teaching, 47(7), 807-819

Matuk, C., & Linn, M. C. (2023). Students' perceptions of the impacts of peer ideas in inquiry learning.*Instructional Science*, *51*(1), 65-102.

Mensah, F. M. (2011). A case for culturally relevant teaching in science education and lessons learned for teacher education. Journal of Negro Education, 80(3), 296-309.

Morales-Doyle, D. (2017). Justice-centered science pedagogy: A catalyst for academic achievement and social transformation. *Science Education*, *101*(6), 1034-1060.

Morales-Doyle, D., & Frausto, A. (2021). Youth Participatory Science: A grassroots science curriculum framework. *Educational Action Research*, 29(1). https://doi.org/10.1080/09650792.2019.1706598.
National Research Council. (2005). How students learn: History, mathematics, and science in the classroom. The National Academies Press.

Penuel, W., Allen, C., Manz, E., Heredia, S., Superfine, A. C., Goldman, S. R., & Ko, M. L. M. (2022). Design-based implementation research as an approach to studying teacher learning in research-practice partnerships focused on equity. *Teacher Learning in Changing Contexts: Perspectives from the Learning Sciences*. Routledge.

Pew Research Center (2021). Gen Z, Millennials Stand Out for Climate Change Activism, Social Media Engagement With Issue. www.pewresearch.org/science/2021/05/26/gen-z-millennials-stand-out-for-climate-change-activism-social-media-engagement-with-issue/

Reisman, A. (2017). How to Facilitate Discussions in History. *Educational Leadership*, *74*(5), 30-34.

Sadler, T.D., & Dawson, V. (2012). Socio-scientific Issues in Science Education: Contexts for the Promotion of Key Learning Outcomes. In: Fraser, B., Tobin, K., McRobbie, C. (eds) Second International Handbook of Science Education. Springer International Handbooks of Education, vol 24. Springer, Dordrecht. https://doi.org/10.1007/978-1-4020-9041-7_53

Segura, D., Morales-Doyle, D., Nelson, S., Levingston, A., & Canales, K. (2021). Sustaining Community-School Relationships Around Shared Visions of Climate Justice and Science Teaching. Connected Science Learning, 3(5), 12318702.

Skloot, R. (2017). *The immortal life of Henrietta Lacks.* Broadway Paperbacks.

Stokes, D. E. (2011). Pasteur's quadrant: Basic science and technological innovation. Brookings Institution Press.

Stromholt, S., & Bell, P. (2018). Designing for expansive science learning and identification across settings. *Cultural Studies of Science Education*, *13*, 1015-1047.

The Tree Lab. (n.d.). The Young People's Race, Power, and Technology Project (YPRPT). Retrieved from: https://tree.northwestern.edu/projects/yprpt.

Wang, M-T. L., Degol, J., Amemiya, J., Parr, A., & Guo, J. (2020). Classroom climate and children's academic and psychological wellbeing: A systematic review and meta-analysis. Developmental Review, Vol 57, doi.org/10.1016/j.dr.2020.100912.

Appendix A: Disciplinary Diversity of Science Methodologies and Questions

- Indigenous Science: Advances in science methods. https://www.smithsonianmag.com/science-nature/why-science-takes-so-long-catch-up-traditional-knowledge-180968216/
- *Crowd sourced evidence.* Cornell Citizen Science Project on Bird Migration. Crowd sourced opportunities for student and citizen science projects. https://www.birds.cornell.edu/citizenscience
- *Methods of Barbara McClintock*. McClintock received the Nobel Prize for her work on “jumping genes” using methods that were disregarded by the leaders during her years at Cold Spring Harbor. https://www.nature.com/scitable/topicpage/barbara-mcclintock-and-the-discovery-of-jumping-34083/
- *Broadening views of evidence.* Fox Keller, Evelyn. A Feeling for the Organism.
- *Science and social justice.* PBS: *Where science and social justice meet:* https://www.pbs.org/wgbh/nova/article/where-science-and-social-justice-meet/
- *Nature Magazine: Science must overcome its racist legacy* (One of the most prestigious and respected peer-review based science journals, a statement and a plan for addressing some of these issues in science investigations): https://www.nature.com/articles/d41586-022-01527-z?utm_source=Nature+Briefing&utm_campaign=c46a6c1955-briefing-dy-202200608&utm_medium=email&utm_term=0_c9dfd39373-c46a6c1955-44608633
- *Globe.Gov.* A source of different methods within science and different ethnic or national communities that is classroom ready: https://www.globe.gov/