From Global to Local

Connecting global climate change to a local ecosystem using a socio-scientific issue approach

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TROY SADLER

Weather station at Tucker Prairie.

The global scale of climate change may seem beyond many high school students' comprehension. To complicate matters, climate change has emerged as a political issue that pits candidates, neighbors, and sometimes teachers and students against each other (Kahan 2015).

The *Next Generation Science Standards* (NGSS Lead States 2013) call on science teachers to incorporate climate change concepts into their lessons, which can be a daunting task. This article describes one way to do so: an ecology unit that uses a socio-scientific issue (SSI) approach.

The science behind climate change

The science behind climate change is well established (Stocker et al. 2013). Carbon dioxide (CO_2) and methane (CH_4) (and some other gases) accumulating in the atmosphere serve as an insulator, trapping heat like a greenhouse, although via a different physical process. Historically, increases in atmospheric CO_2 and CH_4 concentrations occurred with large-scale changes in vegetation due to deforestation, volcanic activity, decomposition, and other causes.

Human-related (*anthropogenic*) emissions of both of these gases from burning fossil fuels, decomposition, and the digestive processes of livestock surpassed natural sources in the early 1920s and have continued to increase (Le Quéré et al. 2016). Global mean CO_2 concentration has increased annually during each of the past 36 years (Dlugokencky and Tans 2017). Global surface temperature data suggest that 2016 was the warmest year since modern record keeping began in 1880; this is the fifth such temperature record since 2000.

Engaging students

Students can engage directly with data on carbon accumulation and resultant temperature increases. The data, found on various governmental and nongovernmental websites, have been conveniently archived and made available for public use on our project website (see "On the web").

Figures 1 and 2 show examples of student data analysis of the increase in carbon dioxide and methane concentrations, respectively, since the 1980s, when standardized measurements of carbon gases began across the globe (Dlugokencky and Tans 2017). Figure 3 illustrates student data analysis of the global mean annual temperature change since 1880 (NASA 2017). Students can compare global temperature trends with local trends by using local climate data from NOAA National Centers for Environmental Information's *Climate at a Glance* (NOAA 2017a).

FIGURE 1

Global mean carbon dioxide concentration (PPM) 1980–2016. (Dlugokencky and Tans 2017)

Socio-scientific issues (SSI) as an instructional approach

With SSI, current events are used to integrate social issues into classroom instruction (Sadler 2011; Zeidler 2014). However, the complexities and potential controversy of some SSIs can be difficult for teachers to manage. We developed the Rigorous Investigation of Relevant Issues [RI]^2 teaching and learning framework, used in the unit described below, as a systematic approach to SSI instruction (Sadler, Foulk, and Friedrichsen 2017; overview, Figure 4).

FIGURE 2

Global mean methane concentration (PPB), 1984–2015. (Dlugokencky and Tans 2017)

Tallgrass prairie unit on local climate change

In this unit, after completing the data analysis described above in the classroom, students went on a field trip to examine the effects of climate change on a 60-hectare tallgrass prairie. (The complete module for this unit, including lesson plans, presentations, and student activities, can be found on our project website; a virtual field trip, in which students navigate a tallgrass prairie ecosystem through guided online exploration, is also available online; see "On the web").

Unit overview and instructional sequence

In groups of 15, students rotated through five stations on the prairie to explore soil science, plant biodiversity, fire ecology, woody/herbaceous plant competition, and insect diversity. Each station featured data collection and analysis (e.g., at the competition station, students measured light intensity and soil moisture at the boundaries of woody plant thickets within the prairie). Collectively, the stations helped students understand how climate change alters prairie soil moisture, which in turn promotes the succession of woody vegetation in the area.

The rest of the three-week unit was conducted back in the classroom. Students examined data from climate scientists and read scientific reports (National Academy of Sciences and Royal Society 2014; Melillo, Richmond, and Yohe 2014) along with pop culture articles (Goodell 2015) and discussed how social identity or political affiliation affects interpretation of climate data and reports.

Students explored socioeconomic factors driving the conversion of native prairie into productive farmland. Students did a web-based exercise (see "On the web" for the Prairie indicator species website) that illustrated how some prairie species benefit and others decline due to climate change. Figure 5, p. 43, provides a day-by-day overview of the lesson sequence.

FIGURE 3

Mean annual temperature change (°C), 1880–2016.

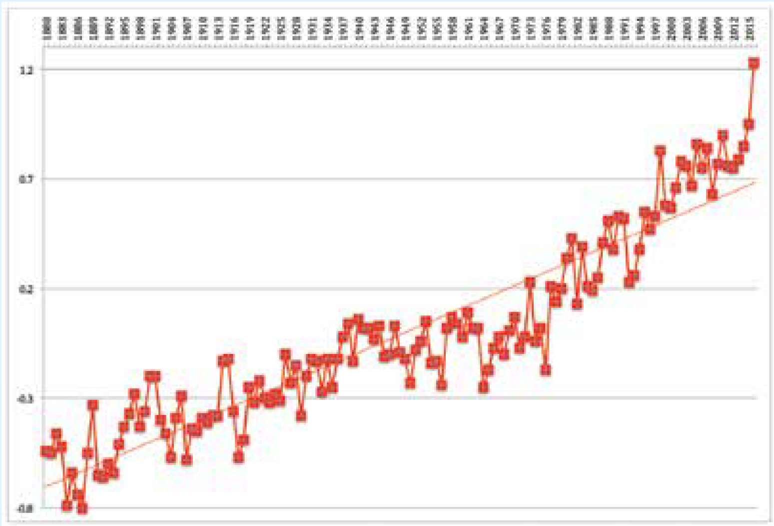
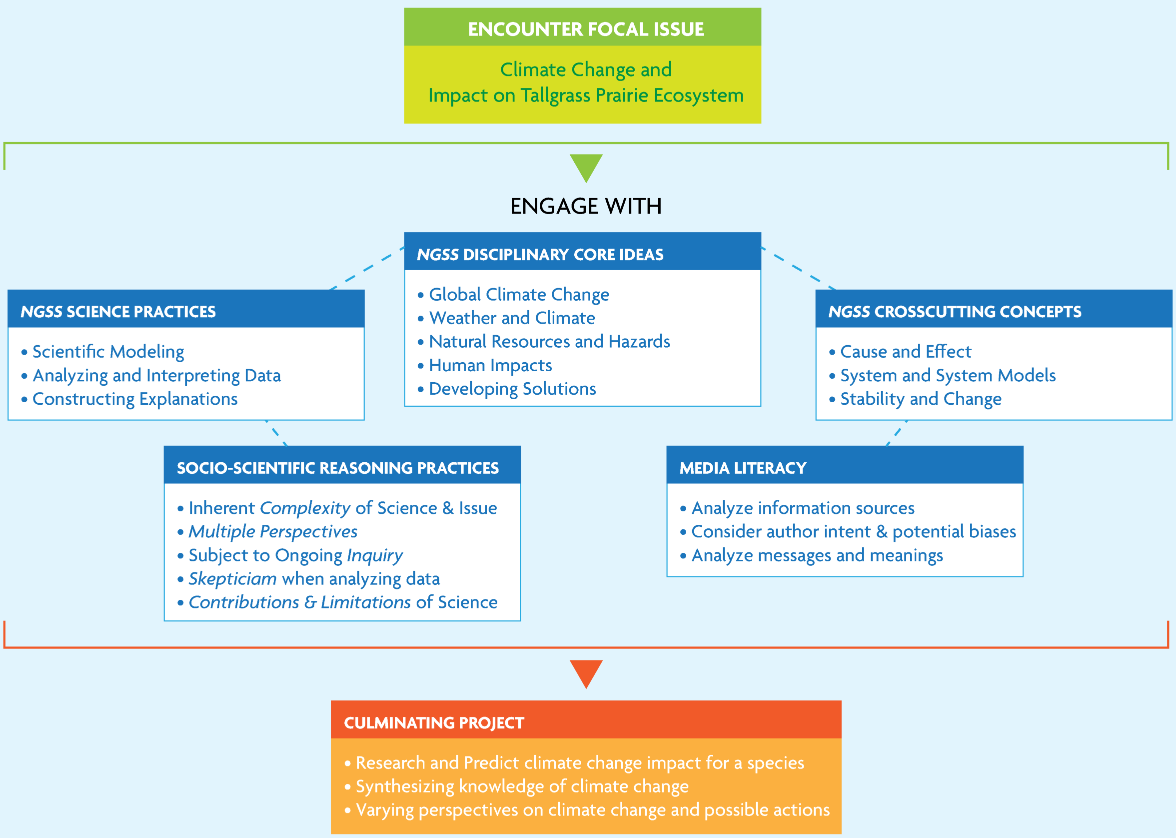


FIGURE 4

Teaching ecology through the [RI]² SSI instructional framework.



TROY SADLER

ABOVE: Students exploring biodiversity at Tucker Prairie. LEFT: Soil core from Tucker Prairie. Soil horizons show that the prairie was never plowed.

The carbon cycle

Understanding climate change requires knowledge of carbon cycling. We had students draw models of the carbon cycle, and, as the unit progressed, improve the models. As students revised their models, they addressed four questions:

1. Where does carbon come from and where does it go?
2. Consider carbon sources both above and below ground. Is the flow of carbon connected?
3. What are the most important things that might happen to carbon?
4. What actions and/or changes might carbon undergo, such as joining or breaking apart from other elements?

Figure 6a and 6b (p. 44) show how one student, "Alex," refined his model. The iterations, accompanied by written explanations not shown in the figure, were ideal for formative assessment. We focused on the *components* included in the models, *sequences* that linked individual components, and *explanatory processes* addressing the links between carbon cycling and climate change. Alex's first model shows awareness of components of carbon processes but does not illustrate or explain carbon cycling. His final model shows additional components, several complex sequences in which carbon can be traced through multiple transformations, and an explanation of the process. During lesson 10 (Figure 5), students specifically linked their carbon cycle models to climate change in an essay. Rubrics are available online (see "On the web").

The summative assessment involved the web-based activity in which students explored climate change effects on key prairie species. Students constructed a visual and written model predicting climate change impacts on a species of their choice. A detailed rubric is available online (see "On the web"). Figure 7, p. 45, addressing climate change impacts on coral reefs, is an example of a student visual model.

FIGURE 5

Lesson sequence (adapted from Zangori et al. 2017).

Lesson day	Lesson sequence	Learner objectives	Activity/assessment
1	Climate change and local ecosystem	Students develop an understanding of the importance of biodiversity and explore how climate change might affect a local ecosystem.	Field trip.
2	Introduction to scientific modeling	Students develop an understanding of the process of scientific modeling for sense-making, explanation, and prediction of scientific phenomena.	Introduction to modeling; develop first carbon cycle models.
3 and 4	Climate science	Students engage in data analysis and develop a basic awareness of, and interest in, the issues surrounding climate change.	Reading about, writing about, and discussing climate change.
5–7	Carbon cycling and photosynthesis	Students explore and explain the process of photosynthesis and its connections to cellular respiration and the carbon cycle, as well as how water acts as a sink for carbon dioxide. They also explore graphs of atmospheric CO_2 levels and the gas's impacts.	Evaluating initial model; revising and drawing second model.
8	Competition among plants on the prairie	Students explore the competitive dynamics between woody and herbaceous plants on a prairie (with an emphasis on access to water) and predict impacts of changing climate (which will likely lead to changes in precipitation patterns) on competition between woody and herbaceous plants.	Class exploration of factors that affect plant competition and predictions on how a changing climate will impact competition.
9 and 10	Trophic levels, climate change, and indicator species	Students develop an understanding of trophic levels within a local prairie ecosystem and predict changes over time due to climate change. Students revise carbon cycle models.	Students research specific prairie species to explore and explain; apply concepts of habitat, niche, food webs, and ecological pyramids; and use their understanding of the movement of matter and energy to evaluate and revise their carbon cycle model.
11–13	Culminating project	Students apply knowledge gained throughout the unit to predict the impact of climate change on a particular species.	Indicator species project: Students choose and research a species, then write a paper explaining climate change impacts on their chosen indicator species for the specific ecosystem.

Socio-scientific reasoning

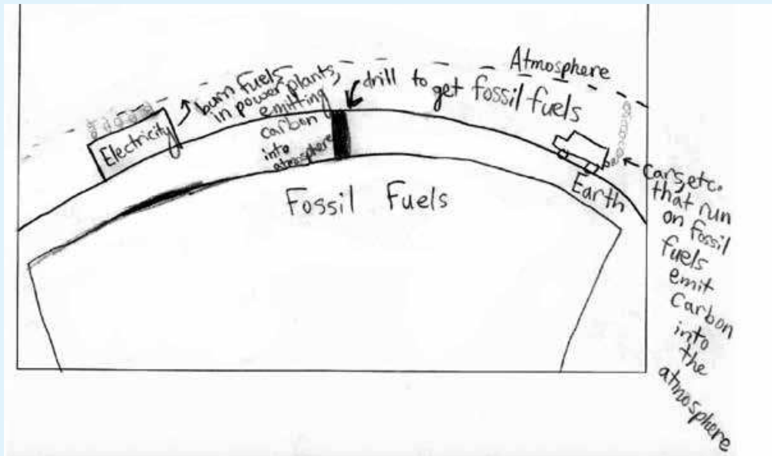
Below are five specific competencies (Sadler, Barab, and Scott 2007) referred to collectively as *socio-scientific reasoning*. Students can acquire these competencies during SSI units and apply them to other SSIs within and beyond school:

1. accounting for the inherent *complexity* of SSIs,
2. analyzing issues from *multiple perspectives*,
3. identifying aspects of issues that are subject to ongoing *inquiry*,
4. employing *skepticism* in analysis of potentially biased information, and
5. exploring how science can *contribute* to the issues and the *limitations of science*.

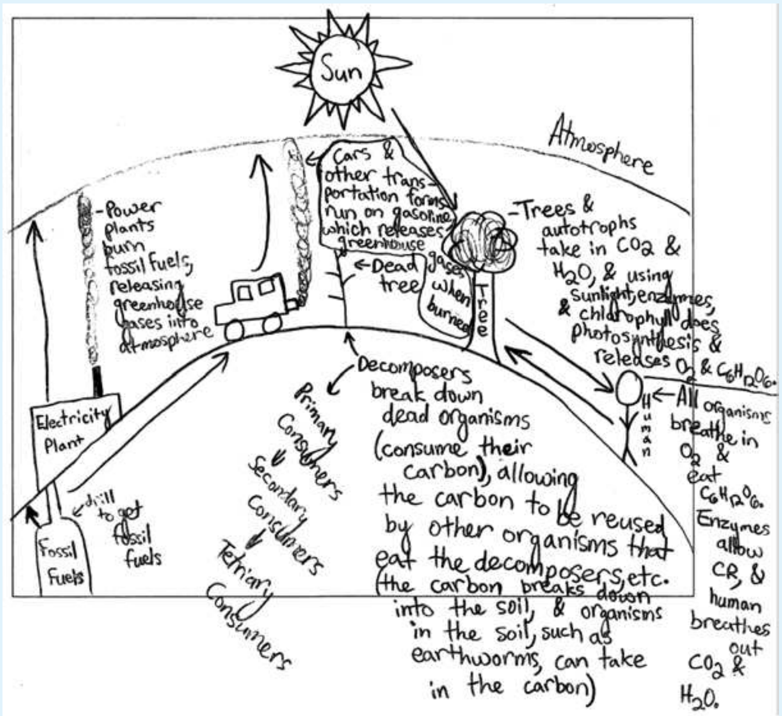
Students could develop these SSR competencies throughout our unit. For example, examining the social dimensions of climate change while learning science concepts illustrate the *complexity* of the issue. Role-playing scenarios in which students research and present the views of various stakeholders, such as farmers and wildlife managers, acquaint them with *multiple perspectives*. Critically examining media sources for potential bias fosters *skepticism*. Such activities help contextualize complex science and promote reasoning skills that extend beyond school.

FIGURE 6

A. Alex's initial carbon cycle model.



B. Alex's revised carbon cycle model.



Conclusion

For this ecology unit, we worked for three years with two or three teachers each year in multiple sections of a 10th-grade honors biology course involving some 250 students. At times, we used the field trip as a focal anchor and at other times the virtual field trip. Results suggest that the SSI framework supported student development of socio-scientific reasoning. In addition, embedding the practices of modeling within an SSI unit supported secondary students in building robust understanding of carbon cycling and its relationship to climate change. ■

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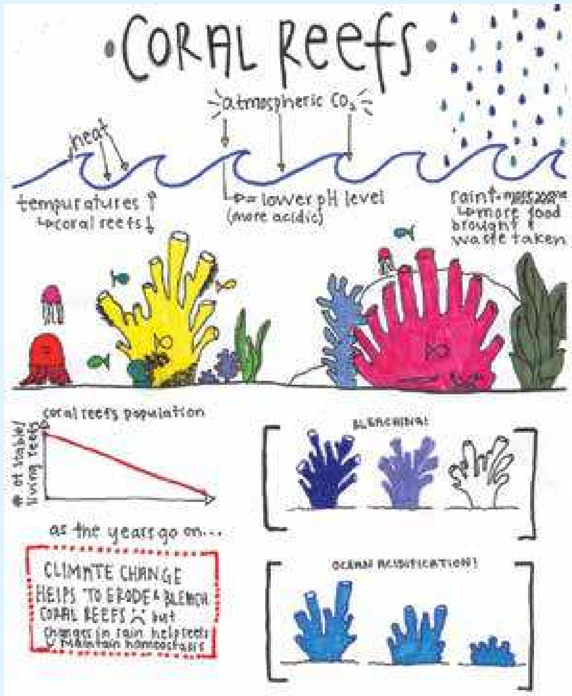
On the web

Additional resources: *http://bit.ly/2suW53S*
Carbon cycle model rubrics: *http://bit.ly/2sVvM7p*
Final project directions and rubric: *http://bit.ly/2rHQOmB*
NGSS connections, complete table: *www.nsta.org/highschool/connections.aspx*
NSTA position on SSI: *http://bit.ly/NSTA-SSI*
Prairie indicator species website: *http://restem4.wixsite.com/ssi-eco*
Species research links: *http://restem4.wixsite.com/learning-resources*
SSI readings and resources: *http://ri2.missouri.edu/going-further/related-reading*
The Vanishing Prairie SSI module: *http://bit.ly/2t0dCll*
Unit sequence and lesson plans: *http://bit.ly/2tynT5N*
Virtual field trip extension: *http://ri2.fieldtrips.missouri.edu*

FIGURE 7

Student predictive model for climate change impacts on coral reefs.



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Connecting to the *Next Generation Science Standards* (NGSS Lead States 2013).

Standards
HS-LS2 Ecosystems: Interactions, Energy, and Dynamics

HS-ESS2 Earth's Systems

HS-ESS3 Weather and Climate

Performance Expectations
The chart below makes one set of connections between the instruction outlined in this article and the *NGSS*. Other valid connections are likely; however, space restrictions prevent us from listing all possibilities.

HS-LS2-5. Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.

HS-LS2-6. Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.

HS-ESS3-5. Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current or regional climate change and associated future impacts to Earth Systems.

Dimension	Name and *NGSS* code/citation	Specific connections to classroom activity
Science and Engineering Practices	**Developing and Using Models** • Develop a model to illustrate the role of photosynthesis and cellular respiration. (HS-LS2-5) **Analyzing and Interpreting Data** • Analyze data using computational models in order to make valid and reliable scientific claims. (HS-ESS3-5)	Students iteratively develop visual models with written explanations to explain their understandings of carbon cycling and its connection with global climate change. Students analyze standardized data from NOAA and NASA.
Disciplinary Core Ideas	**LS2.C: Ecosystem Dynamics** • Extreme fluctuations in conditions….can challenge the functioning of ecosystems. (HS-LS2-6) **ESS3.D: Global Climate Change** • Though the magnitudes of human impacts are greater than ever, so too are human abilities to….manage impacts. (HS-ESS3-5)	Students explore trophic levels, energy, and matter cycling within a local prairie ecosystem and predict changes over time due to climate change. Students explore the process of photosynthesis and its connections to cellular respiration and the carbon cycle.
Crosscutting Concepts	**Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation. **Sytems and System Models** • Models can be used to simulate systems and interactions. (HS-LS2-5) **Stability and Change** • Much of science deals with constructing explanations of how things change. (HS-LS2-6)	Students explore the competitive dynamics between woody and herbaceous plants on a prairie and predict effects of changing climate on competition between woody and herbaceous plants. They explore trophic levels, energy, and matter cycling within this ecosystem.