

Investigating Human Impacts on Local Water Resources & Exploring Solutions

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ABSTRACT

An in-depth curricular unit exploring the effects of human land use on local water resources was created as part of a Teacher Professional Learning Program at the University of Connecticut's Natural Resources Conservation Academy. This unit was designed to connect high school students to water resources in their community, both in the field and through the use of interactive mapping technology. These methods engage students in science and technology using multiple disciplines and can help them better understand how their local water resource is affected by the surrounding landscape. In this unit, students explore the dynamics of local water resources and the anthropogenic issues that affect them through field and open-access online inquiry-based activities. The varied lessons within this unit were purposefully created to align with the Next Generation Science Standards and to fit within either an earth science or a biology course. They use existing online geospatial tools and can be tailored to any geographic area of interest.

Key Words: environment; geospatial technology; natural resources; Next Generation Science Standards; NGSS; place-based learning; sustainability; three-dimensional learning; water; web-based resources.

○ Introduction

Water resources are essential and irreplaceable for humans and for life in general (Cosgrove & Loucks, 2015). Yet rapid population, economic, and technological growth has made humans a primary driver of environmental change at global scales, marking a shift into a human-dominated geological epoch, the Anthropocene (Lewis & Maslin, 2015). Moreover, such growth is affecting water resources at local, regional, and global scales. Human-driven climate change is affecting the amount, intensity, and spatiotemporal distribution of precipitation events across watersheds. Coupled with land-use changes associated with development and agriculture that increase runoff into surface waters, humans are altering the quantity and quality of these resources (Cosgrove & Loucks, 2015). Water-related issues – such as droughts, flooding, and water contamination – impinge on the livelihoods of humans both physically and

economically. As such, water-related case studies allow students to explore and understand how science and technology can play a role in addressing issues important in their communities, regardless of geographic location.

Leveraging the theme of water, a multidisciplinary team at the University of Connecticut developed a three-day professional development workshop on Water & Sustainability for secondary science teachers with curricular resources. The team's expertise in water resources, land use, climate science, science education, and geospatial technology was integrated to create an in-depth curriculum unit exploring anthropogenic effects on local water resources and potential solutions to mitigate negative impacts. This investigative unit connects water resource science and issues at the global, state, and local scales, with the goal of addressing several key teaching and learning challenges identified by national education reports (e.g., Bransford et al., 2000; National Research Council, 2012) and the *Next Generation Science Standards* (NGSS; NGSS Lead States, 2013). The highly contextualized curriculum encourages place-based learning, which is situated in specific places or regions, and is focused on natural and cultural features, processes, phenomena, history, and challenges to sustainability (Coleman et al., 2019).

Throughout this unit, two elements are woven together that, in different ways, are relevant and even ubiquitous in everyday life: the subject matter of water resources and the use of interactive online resources. A water theme facilitates the connection of larger-scale issues (i.e., global and state natural resources) to local environmental problems such as water availability, water quality, and emerging contaminants. In addition, a water theme affords a clear connection to related issues of land-use change, climate change, and sustainability. This emphasis is logically designed with the *Framework for K–12 Science Education* (National Research Council, 2012) and NGSS in mind, giving priority to engaging students in science practices (e.g., modeling, developing explanations, and designing solutions) and using disciplinary core scientific ideas to explain phenomena or solve problems of societal concern (in this

case, those identified in the NGSS Earth and Human Activity Disciplinary Core Idea; see Table 1). Within the context of water resources, the curriculum uses a combination of real-world field experiences and interactive online decision-making tools to make the global-to-local connection by grounding learning in the learners' surrounding environment. Furthermore, the free and open-access online mapping tools used in the curriculum allow for a highly personalized and accessible end-user experience. Leveraging technology in this way is engaging and can be useful when field experiences are not feasible.

○ Unit Overview

The curricular unit was created by a multidisciplinary team of researchers in water resources, land use, climate science, science education, and geospatial technology. It was designed for, and used by, secondary earth science and biology teachers in Connecticut as part of a USDA-funded teacher professional learning program. The unit was beta-tested and refined with 47 teacher participants from 43 schools over a two-year period. Some existing experience may be required to confidently carry out the lessons we outline below. However, we offer an extensive list of detailed resources on our program website (<http://s.uconn.edu/WaterUnitResources>) to provide teachers with content training and facilitate the successful implementation of this unit.

The unit planning template (<http://s.uconn.edu/WaterUnit>) was developed in alignment with Stroupe and Windschitl's (2015) framework for Ambitious Science Teaching (AST), which focuses on "1) planning a unit around a 'big science idea,' 2) eliciting and activating students' ideas about a puzzling phenomenon (for the purpose of adapting instruction), 3) helping students make sense of science activities, and 4) pressing students to construct evidence-based explanations." As such, each of these facets of AST is detailed in the unit planning template and individual lesson plans. Drawing on STEMscopes (2015), the unit planning template provides suggestions for effectively integrating this unit in an earth science, biology, or environmental science course. The unit planning template also includes the example anchoring phenomenon, the target explanation of the phenomenon, driving questions, and central concepts relevant to the Connecticut landscape, while also, importantly, providing guidance for teachers to adapt the unit to their own particular local area.

The unit outline below is flexible; teachers are encouraged to adjust the lessons to best fit the needs of their course. For example, days 2–5 apply online tools to compare land-use effects on local water quality, while days 7–9 focus on the different ways humans depend on, change, and interact with their environment. Day 10 could be used as a stand-alone lesson on land-use decision making at different scales.

○ Assessment

The following framework was used to think about and plan for formative assessment: (1) anticipating and eliciting students' ideas, (2) evaluating students' ideas, and (3) crafting next steps in instruction that account for students' ideas and support students' learning

Table 1. Unit-specific standards and performance expectations of the Next Generation Science Standards.

Standards
<ul style="list-style-type: none"> ● HS-ESS3.C. Human Impacts on Earth Systems ● HS-LS2.C. Ecosystem Dynamics, Functioning, and Resilience ● HS-LS4.D. Biodiversity and Humans ● HS-ETS1.A. Defining and Delimiting Engineering Problems ● HS-ETS1.B. Developing Possible Solutions
Performance Expectations
<ul style="list-style-type: none"> ● HS-ESS3-3. Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity. ● HS-ESS3-4. Evaluate or refine a technological solution that reduces impacts of human activities on natural systems. ● HS-LS2-2. Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales. ● 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-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity. ● HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts. ● HS-ETS1-4. Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

(Sabel et al., 2015). Throughout the unit, text items in red indicate where formative assessment is planned for as part of instruction. The unit assessment strategy was designed on the basis of calls from the National Research Council to ensure that classroom assessments are an integral part of instruction that reinforces learning envisioned in the *Framework* and NGSS (National Research Council, 2017). The assessment section at the end of the unit planning template includes a sample rubric and prompts that were developed for the summative assessment of a final group model or individual students' evidence-based explanations. For instance, students can be asked, "What about the model stood out to you as most important for explaining the water quality of these areas?" The summative assessment prioritizes how well students' models support their explanation of why their water resource is healthy or unhealthy.

In addition, the unit planning template provides an outline for each step of the NGSS Assessment Development Template (Penuel et al., 2016) and sample questions that can be used as part of a teacher-generated summative unit assessment. Teachers can also refer to a comprehensive study specific to this unit that examines student learning outcomes in the context of modeling and explaining the phenomenon (B.-Y. Park et al., unpublished data). More specifically, student modeling outcomes from pre- and post-group models were assessed to demonstrate significant improvements in student groups' model-based explanations about water and sustainability issues over time, while also revealing important trends in how students use models.

○ Unit Outline

Day 1: Introduction to the Phenomenon: Modeling the Health of Three Local Water Resources

The lesson is initiated by introducing the phenomenon (e.g., three different stream sampling sites surrounded by differing land use or land cover). The first component of the phenomenon presentation consists of aerial photos of three different areas surrounding the study sites. When presented with the aerial photos, students are asked, "What do you predict is the *state* of the local water resources at the three sites, and why?" The *state* can be described as the water quality or the level of biodiversity, among other characteristics. This is the very beginning of eliciting student ideas. Following the introduction of the phenomenon and a series of think/pair/share and group brainstorming exercises, the students are supported to construct their initial group models of the phenomenon. In their models, students try to explain the differences that might be found at each of the sites due to the surrounding land cover (e.g., agricultural, forest, urban) and other factors they may think are important. While models can take many forms, teachers may want to encourage the use of SageModeler (<https://sagemodeler.concord.org>), a free, web-based tool for modeling systems dynamics that is designed for middle and high school students. The lesson concludes with a group discussion of the initial models followed by the development of a "driving question board." The framework for the driving question board should be titled "Questions we have about the water resources" and include the following three major headings, with space left open for an additional heading: water quality; ecosystems; human impact on land and water.

Days 2–3: Health of Local Water Resources: Determining Water Quality & Biodiversity

Students visit stream sites during a field trip, determine the boundaries of the system that they are investigating, and make predictions about physical parameters of the water at the site. They then decide what information is important for determining the health of the water resource and record qualitative and quantitative observations of the water source and its surroundings (e.g., temperature, turbidity, dissolved oxygen, conductivity, stream width, speed of current). Students collect water samples in different locations at each site to test water quality (e.g., pH, phosphate, nitrate/nitrite,

ammonia) in the classroom. Students also collect and identify macroinvertebrates, which serve as indicators of biodiversity and water quality.

If a field trip is not practical, student groups make observations from matching site photographs and water samples – or through a Google Earth tour (<https://earth.google.com/web>) and using the USGS Current Water Data website (<https://waterdata.usgs.gov/usa/nwis/rt>). Student groups are then given a water sample from each site in order to test water quality in the classroom as described above. Students record all data and then add to their summary tables, which they will use as evidence as they continue to investigate what affects the health of these water resources. The class summary table includes the activities, patterns observed, students' explanations, and how the information helps explain the phenomenon.

Days 4–6: Modeling Water Flow through Ecosystems

The teacher begins day 4 by introducing WikiWatershed, an interactive online watershed-modeling tool (<https://wikiwatershed.org>). Students first explore a runoff simulation to determine the relationships between land cover, hydrologic soil groups, runoff, infiltration, and evapotranspiration during a storm. Students then choose a land-cover category to represent the dominant land-cover classification for each of the study sites (e.g., forest, grasslands, open/pasture, developed). They decide which data to collect (e.g., amount of precipitation, runoff, infiltration, evapotranspiration, soil group), and select a method to illustrate these data (e.g., bar graphs, line graphs, pie charts) in order to visualize and compare what happens during storm events. On day 5, students use the "Model My Watershed" simulation (<https://modelmywatershed.org>) to collect and analyze data (e.g., land cover, types of soil, amounts and types of agricultural animals, and non-point-source pollution) in relation to water health at their actual site. Students then use the "Site Storm Model" (<https://wikiwatershed.org/help/model-help/site-storm-guide/>) to explore and compare different storm scenarios. On day 6, students build from the previous two days with a "claim, evidence, reasoning" (CER) activity. For example, students may claim that high-development land cover has the greatest amount of runoff and the least evapotranspiration. As part of the activity, they create a list of questions that need to be answered to strengthen or refute their claims, and then participate in a whole-class discussion of the different groups' CER and questions. The lesson concludes by revisiting and adding to the class summary table and the driving question board.

Day 7: Human Impacts on Land & Water

Students explore the Multi-Resolution Land Characteristics Consortium interactive map (<https://www.mrlc.gov/viewer>) or, in the case of Connecticut, where the unit was originally developed, the Connecticut's Changing Landscape story map (<http://clear3.uconn.edu/viewers/ctstory>), to gain a better understanding of how the landscape has changed as a result of human activity, and to connect these changes to possible consequences for water resources. Students decide what data to collect to illustrate how the landscape around their water resource has changed over time and how this might relate to its health (e.g., changes in the amount of

surrounding agriculture, tree canopy, or development). Students share their findings with the class in a whole-group discussion facilitated by the teacher. The focus is on how change in a landscape affects water quality.

Days 8–9: Ecological Functions & Services

Day 8 begins with a “turn and talk” in which student pairs share ideas about different ways that humans depend on ecosystems. Next, as part of a whole-class discussion, the teacher lists “ecological goods and services” that the students have identified, which are defined as any positive benefit that wildlife or ecosystems provide to people (e.g., clean drinking water, timber, purification of air and water, maintenance of biodiversity, greenhouse gas reduction, and aesthetics). Students then spend the remainder of day 8 and half of day 9 reading assigned sections of a particular article (<http://s.uconn.edu/WaterUnit>, p. 15) on ecosystem functions and services. Once students have finished reading the article on day 9, they participate in a whole-group discussion about the importance of ecosystem services and apply what they have learned to their sites. Students should make claims about the ecosystem services that they have investigated and substantiate their claims with evidence about costs and benefits. Students end the lesson by revisiting and adding to the class summary table.

Day 10: Human Decision Making

Students begin this lesson by briefly discussing with their teammates what they think are possible threats to ecological systems (e.g., housing/industrial development, deforestation, emissions from coal and oil plants, acid rain, point-source and non-point-source water pollution), with examples of how they are impaired or harmed. After their discussion, a brief video clip (four minutes) illustrates the history of the Cuyahoga River, from when the river burned in the 1960s to its present-day restored quality. Students then read about the structure of land-use planning frameworks in the United States and two articles about the Clean Water Act. Students make a claim about the effectiveness and value of this legislation (see suggested articles in the unit planning template). Students should substantiate their claim with evidence from the articles and reasoning why this evidence supports their claim, including applicable scientific principles. Students share their CER with a partner who gives them feedback, and then write a revised CER.

Days 11–12: Revisiting Models

During the first half of day 11, students use their individual summary tables to participate in a class discussion to review and update the completed class summary table. Then, using the class summary table as a guide, the class decides on their final/revised “gotta have list” (i.e., the essential information needed to explain the phenomenon). During the second half of day 11, students break off into small groups to revise their initial model from day 1. This includes a written explanation of their phenomenon at the bottom of the model. Day 12 is designed to allow each group to present their model to the class, followed by a class discussion to share notes on each group’s revised model. The rest of the class is spent constructing a class consensus model. This is accomplished by students

determining which features they all agree should be included in the final model.

○ Extending the Unit

The unit planning template includes additional, optional lessons beyond day 12 that can expand the curriculum to apply what students have learned thus far to (1) an environmental justice issue and (2) a real-world problem through engineering design. Lessons for days 13–15 incorporate the Ecojustice Science Teacher Toolkit (<https://teacherecojusticetoolkit.weebly.com>) to explore the question “Does everyone in the United States have equal access to clean water?” Students will explore historical and present-day ecojustice issues that have occurred in places such as Triana, Alabama; Warren County, North Carolina; Flint, Michigan; and Standing Rock Sioux Reservation. Days 16–18 introduce students to the topic of low-impact development (LID) through research and design of an LID project (e.g., rain gardens, green roofs, bioretention areas, porous pavers) for the school’s water resource, which they present to the class. If possible, students can carry out their designs during days 19–23 by building and testing an LID prototype. In days 24–26, students combine these two extension topics to investigate patterns of racism related to the environment where people live using EJSCREEN (<https://www.epa.gov/ejscreen>), an environmental justice screening and mapping tool.

○ Conclusion

The cornerstone of NGSS – using disciplinary core ideas to explain phenomena and develop solutions to real-world problems – was a catalyst for the creation of this curriculum. Although there are many benefits to engaging in instruction in the way outlined in this unit, chief among them is the focus on constructing, critiquing, and refining explanations of events that happen in the world as an important representation of the way scientists engage in their day-to-day work (Ford, 2008). Additionally, the focus on supporting learners to consider and begin to propose socio-ecological actions that mitigate the ways in which the Anthropocene is threatening water resources locally, regionally, and globally – especially in ways that disproportionately affect the most vulnerable – is important for a sustainable future led by informed citizens.

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○ Online Resources

Visit our program website to access a curated list of resources organized by lesson that includes links to additional materials such as water-quality testing instructions and macroinvertebrate identification manuals: <http://s.uconn.edu/WaterUnitResources>.

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