

## Teaching and Educational Methods

# A Transdisciplinary Approach to Undergraduate Sustainability Education: Resource Economics by Way of Business and Science

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### Abstract

This article details a transdisciplinary teaching module using stakeholder mapping and role-play to engage students in complex environmental and economic analysis. Developed through NSF-funded collaboration across multiple institutions, the module uses the Mississippi River Watershed as a case study to teach concepts of externalities and resource management through three interconnected exercises: individual stakeholder mapping of nitrogen pollution impacts, a Town Hall role-play simulation, and collaborative whole-class system mapping. The exercise was taught over the 2020-24 academic years, with implementations spanning in-person, hybrid, and fully remote modalities. While designed to be adaptable across disciplines, the module's exercises engage students with concepts of externalities and resource management through a real-world case study that demonstrates the necessity of incorporating scientific understanding into economic decision-making. Our experiences demonstrate how this module helps students connect economic concepts to complex real-world sustainability challenges. Pre- and post-surveys indicate around 53 percent of students participating in the module increased their assessment of the importance of economics in solving the problem of pollution in the Mississippi River, with similar increases in additional disciplines (entrepreneurship, agronomy). Comprehensive teaching materials, including instructor guides, student worksheets, and assessment rubrics, make the module readily adaptable across disciplines and teaching modalities.

## 1 Introduction

Addressing pollution, resource management, and climate change requires a scientifically and economically literate citizenry, capable of integrating perspectives across disciplines. Yet many academic programs structure student learning in courses associated with discrete fields, providing limited exposure to the inter- and transdisciplinary approaches needed for complex sustainability challenges.<sup>1</sup> Economics is well-suited for this purpose of increasing transdisciplinary thinking in its role as a social science analyzing how and why humans make decisions in a world with unlimited wants but scarce and limited resources. The use of case studies within economics can highlight practical applications while asking students to grapple with thorny environmental questions.

The NSF-funded Business and Science: Integrated Curriculum for Sustainability (BASICS) project produces transdisciplinary curricular modules that can be used in assorted undergraduate and graduate

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<sup>1</sup> "Interdisciplinarity refers primarily to different academic disciplines working together in the context of shared problems and research goals... transdisciplinarity involves different academic disciplines engaging with each other and nonacademic collaborators to coproduce, from different types and sources of knowledge, insights and actions for shared research and applied problems" (Armitage et al. 2019, pp. 1-2).

courses—with a focus on economics, business, the natural sciences, and other STEM fields<sup>2</sup>—to help students develop the knowledge to tackle these problems. Szymanski et al. (2023) and Bender-Awalt et al. (2021) report positive results on the impact of these modules on student learning using pre-post attitudinal assessments. In this article, we describe implementation of the first curriculum module created by the BASICS team, “The Wicked Problem of Water Quality in the Mississippi River Watershed,” in microeconomics and environmental economics courses at two universities. The module consists of a common exercise and a course-specific exercise. The common exercise consists of an introductory lecture or reading, two stakeholder mapping exercises, a town hall role-play, and discussion/reflection. The course-specific exercise for microeconomic principles consists of four lecture topics and a homework assignment.<sup>3</sup> The course-specific exercise for Introduction to Environmental Economics consists of five lectures interspersed throughout the common exercise activities.<sup>4</sup> The common exercise takes approximately 1–2 weeks of class time, depending on how the module is implemented with respect to in-class and outside-of-class work, with the course-specific exercises expected to take an additional week. The common exercise does not require any prior economic knowledge, while the course-specific exercises developed by the authors fit best into introductory economics courses following coverage of supply and demand mechanics and basic welfare analysis of externalities. The module works well for small and medium-size classes (10–50 students), keeping the town hall role-play interesting but manageable, but could be adapted to larger classes that already incorporate group work.

The module was developed using the principles of backward educational design, in which learning goals are chosen prior to instructional and assessment methods (Wiggins and McTighe 2005). Both authors were involved in the first cohort of BASICS as faculty partners, participating in a week-long ideation process guided by the principal investigators (PIs) in summer 2020. Cohort 1 included economists, biologists, accountants, chemists, anthropologists, and experts in entrepreneurship. The team brainstormed topics related to the United Nations Sustainable Development Goals (UN SDGs) and sustainability issues that motivate their teaching, research, and personal interests.

The lens of analysis chosen by the PIs was that of the “wicked problem” and using systems thinking to break down such problems. The concept of wicked problems (Churchman 1967) refers to issues that are difficult to formulate and essentially impossible to fully solve due to conflicting interests of numerous stakeholders, often with incomplete or contradictory information. Wicked problems often exist at the intersection of human and natural systems, demonstrating the impact of economic activity on the world. One consistent theme that emerged was the team’s interest in water quality, equity, and social justice. Case studies are particularly valuable for teaching water economics because water issues are

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<sup>2</sup> STEM stands for Science, Technology, Engineering, and Mathematics.

<sup>3</sup> The four lecture titles are “Supply, Demand, and Government Policies,” “Consumers, Producers, and the Efficiency of Markets,” “Externalities,” and “Public Goods and Common Resources.” This material should be covered prior to assigning the course-specific exercise. The instructor’s slides are available at [https://serc.carleton.edu/basics/teaching\\_materials/mississippi/exercises/249687.html](https://serc.carleton.edu/basics/teaching_materials/mississippi/exercises/249687.html), but there is no requirement to use these particular slides if the instructor already covers similar topics.

<sup>4</sup> The first of these five lectures, titled “The Commons,” comes before the module and includes slides directly introducing BASICS and the Mississippi River module. The second lecture, titled “Stakeholders,” introduces the concept of stakeholders, assists with conducting Part 1, and introduces instructions and role-play groups for Part 2. The third lecture, titled “Externalities,” takes place between Parts 1 and 2 and introduces externalities and Pigouvian taxes in supply/demand graphs. The fourth lecture, titled “Town Hall,” gives students wrap-up time prior to their presentation, gives discussion questions following the town hall role-play activity, presents the issue of property rights and the Coase Theorem, and then describes the “Lake Erie Bill of Rights,” a Lucas County, Ohio, ballot initiative from 2019. The final lecture, titled “Asymmetric Info,” conducts Part 3 of the common exercise, compares the Part 1 maps to the Part 3 class map, presents discussion questions, and then covers asymmetric information including adverse selection and moral hazard in various environmental contexts. The instructor’s slides are available at [https://serc.carleton.edu/basics/teaching\\_materials/mississippi/exercises/249688.html](https://serc.carleton.edu/basics/teaching_materials/mississippi/exercises/249688.html) and can be adapted to fit the instructor’s needs and level of the course.

inherently complex, locally specific, and require understanding of multiple disciplines and institutional contexts (Zetland 2023). The PIs ultimately assisted the team in narrowing the focus to downstream pollution in the Mississippi River Watershed and, using the ideas and feedback from the cohort of instructors from varied disciplines, assembled the common exercise for the curriculum module. Lenhart and Bouwma-Gearhart (2022) describes the process of module creation with respect to the faculty cohort to engaging in transdisciplinary work. The first iteration of the module focused on nitrogen pollution specifically, while subsequent iterations created materials for antibiotics and mercury as well. In this article, we focus on the nitrogen module.

One author implemented the module in her Honors Principles of Microeconomics course, which regularly seats 20–25 students enrolled in a business-oriented private institution. The module was included in both hybrid (Fall 2020) and in-person (2022–2023) modalities. The course is 14 weeks long, and the module was implemented in weeks 8 and 9. In preparation for the module, students were introduced to topics of supply and demand, market equilibrium, government policy interventions, welfare analysis (consumer and producer surplus, deadweight loss), market failure, and externalities. The students became familiar with the UN SDGs at the beginning of the course, allowing for an easier incorporation of the BASICS module. Almost all course applications were structured around the idea of wicked problems and how to use economics to address issues such as gender inequality, poverty, economic growth, etc.

The other author implemented the module in her Introduction to Environmental Economics course at a public university with high research activity. The exercise was first implemented virtually in Spring 2021, taught again in a hybrid course in Fall 2021, and in person Spring 2024. The course is 15 weeks long and divided into six units: Basics of Economics, Free Markets, Environmental Market Failures, Environmental Preferences, Valuation (Micro Level), and Valuation (Macro Level). The module falls into the unit on market failures, right before the halfway point in the course. Students are exposed to similar topics as in the other author’s course, excepting the UN SDGs, which are presented as part of the module specifically.

Other economics and business-oriented courses that incorporated the module include accounting, entrepreneurship, and information design. The module has also been taught in noneconomics classes such as microbiology, water quality, anthropology, pharmacology, and a general education course on sustainability. The curriculum’s “common module” portion is the same across courses and was thus designed with broad applicability. Instructors also design and implement a “course-specific exercise” that applies the material to their discipline. Instructions and rubrics for the common module and the authors’ course-specific exercises are included in this article; additional instructors’ implementation materials and stories are available online in the project’s SERC repository.<sup>5</sup> The remainder of this article describes the BASICS common module, the course-specific exercises the authors designed, and lessons from implementation in the authors’ economics courses.

## 2 Common Module

The common module is designed to take approximately 1 or 2 weeks of a course and includes preparatory material which introduces the BASICS project, the concept of wicked problems, and the issue of nitrogen pollution in the Mississippi Watershed. The student learning objectives (LOs) for the common module are to have students be able to

- (1) locate and describe interactions between human and natural systems.

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<sup>5</sup> The BASICS homepage is available at <https://serc.carleton.edu/basics/index.html>. Table B1 in Appendix B presents a directory of specific links for all teaching materials, instructor guides, and assessment resources referenced in this paper.

- (2) diagram key components of a complex system focused on water quality and identify different stakeholder perspectives or interests associated with water use.
- (3) explain how differing power dynamics among stakeholders creates conflict and the potential for social/environmental injustice.<sup>6</sup>

In addition to these broad LOs, the economics-specific exercises focus on graphing the supply and demand for water and related markets and understanding externalities as a potential source of conflict within a complex system. Table A1 in Appendix A summarizes all the learning objectives addressed by the BASICS module, distinguishing between those designed specifically for the common module, the course-specific exercises, and the economics-specific objectives (Allgood and Bayer 2017) that emerged during implementation.

The common module consists of three exercises: a stakeholder mapping exercise conducted individually or in small teams, a Town Hall role-playing exercise, and a repetition of the stakeholder exercise with the entire class. Because stakeholder mapping is an exercise many disciplines do not use, students are introduced to the process of stakeholder mapping via definitions of “stakeholder,” connections to mind mapping and diagrammatic depictions of the water cycle, and examples of such maps in entrepreneurial settings. Instructors are provided with materials, including instructor and student guides and PowerPoint presentations. Depending on their lecture style, instructors can adapt these resources to align with their pedagogical techniques. Table A2 in Appendix A provides a roadmap for module implementation, including a breakdown of the common exercise components, expected duration, and guidance on format, group work, and preparation required; these details and our own lessons from implementation are also more fully explored in the next sections.

## 2.1 Individual or Team Stakeholder Board

The first assignment in the common module is for students to consider the presented information, including maps of the Mississippi Watershed and diagrams of the water cycle, and construct a stakeholder map. In addition to an introductory lecture, students receive a student guide (see Appendix C, supplementary material; Mississippi Watershed Nitrogen Student Guide); the Part 1 instructions are as follows:

It should be apparent now why so many people in the Mississippi River Watershed are connected in some way with nitrogen. In the next part of this exercise,<sup>7</sup> we’re going to define how these interests are related, that is, how they overlap and how they may conflict based on the perspective of the *stakeholder*. A stakeholder is any individual or group that has an impact on or is affected by the system of interest. They are components in a system.

Goal: Recall or review the introductory materials, and map the stakeholders involved in the nitrogen pollution in the Mississippi River Watershed, and the relationships among those components/stakeholders. (Mississippi Watershed Nitrogen Student Guide, p. 4)

This directly begins to address the first and second learning objectives of locate, describe, and diagram. Students are asked to write or use online mapping software to add items representing key

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<sup>6</sup> These are the *revised* learning objectives following the first year of implementation. In the original learning objectives from the summer 2020 cohort, the second objective was broader (“Diagram the key components of a complex system and identify relationships among them”) while the third objective concerned water specifically (“Describe the perspectives and interests of a stakeholder with respect to water and explain how differing perspectives create conflict among stakeholders). A fourth objective called upon students to be able to “Describe an example of environmental injustice as it relates to the wicked problem of water quality in rivers.” In the summer 2021 revision process, faculty noted difficulty with the environmental justice objective as originally written, so the PIs streamlined and clarified the objectives into those above.

<sup>7</sup> The “first part” being the introductory lecture/reading, and the “next part” being the stakeholder exercise.

components of the complex system as described in lecture and the reading guide. Students are also tasked with indicating relationships between items with arrows and descriptors. These initial maps are generally done in class in teams, but this is not required; some instructors have done the maps individually or outside of class as homework. One of the authors used the online mapping platform Lucidspark, once in an online synchronous class and multiple times in person. Students completed the maps with their preassigned teams either in Zoom rooms or in class looking at one laptop (see Figure 1 for illustration of such a map). The other author used Mural (a program very similar to Lucidspark)<sup>8</sup> the first year in hybrid mode and had teams complete the maps on article by hand outside of class time the following years.<sup>9</sup> Each team's or individual's stakeholder map is graded according to the rubric presented in Table A3 in Appendix A, which rewards higher points values for larger numbers of correct natural system components, human stakeholders, and interconnections.

## 2.2 Town Hall Role-Play

The second common exercise assignment is a Town Hall role-playing exercise in which students explore specific issues related to nitrogen in the Mississippi River Watershed. The class takes on the location of Misiziibi (the Ojibwe Native American name for the Mississippi, meaning "Great River"), a fictional town along the Mississippi River. Prior to the exercise, students are assigned to one of six stakeholder groups; for the nitrogen-focused module, these groups were (1) Upper Midwest family farms, (2) the Gulf fisheries industry, (3) the Misiziibi municipality water treatment plant, (4) concerned citizens of Misiziibi, (5) a small brewery expanding operations, and (6) a local non-governmental organization (NGO) protecting habitat. Students can be assigned to the same teams as in Part 1 of the exercise (for ease and continued socialization) or to new teams, according to the instructor's preference. The student guide describes the motivations of all six groups and provides additional resources for each. Students are tasked with creating a presentation that represents their team's stakeholder perspective to the "Mayor" and making a case for water decisions that would assist their team. Teams are also asked to make note of the interests of other stakeholders and note how their requests may worsen or ameliorate environmental injustice:

Goal: Make a case for water decisions that reflect your stakeholder perspective. Note that you will also need to take notes on the interests of other stakeholders, so that you understand how interests of some stakeholders may result in vulnerability, or challenges of environmental injustice for other stakeholders or community members not present (i.e., when poor communities, communities of color, or other marginalized groups are disproportionately impacted). Each group should appoint an "advocate" that keeps the group cognizant of power dynamics among the stakeholder groups that can lead to various forms of social or environmental injustice.

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<sup>8</sup> Lucidspark requires all users to have an account in order to view/add to the board; additionally, the free version will limit the number of collaborators that can be added at a time. Mural allows visitors to view the board without an account, but students must create an account to participate. Free accounts for both allow for up to three boards on one's own account, but unlimited participation. Best practice for using either one of these options is to have students register for accounts in advance and for the instructor to at least temporarily upgrade their account. Both platforms have similar controls; allowing students time to familiarize themselves with the program for Part 1 individually or in teams allows for the class map in Part 3 to go more smoothly. Appendix D (supplementary document) appends additional instructions on registering for and using Lucidspark to the original Part 1 student guide.

<sup>9</sup> Miro is another program very similar to Lucidspark and Mural; visitors may view boards, but a free account is required to edit. Canva and Adobe Express are also both collaborative document options, and some universities have acquired campus licenses; though these are not whiteboard-focused programs, Canva does have a whiteboard mode.



person; with six presentations of five minutes each, the town hall takes about 35-45 minutes of class time when accounting for questions and transitions.

The presentations are graded according to the rubric in Table A4 in Appendix A. The instructors of Cohort 1, including both authors, found that teams in the inaugural year did not really include the points of view of other stakeholders. In Summer 2021, Cohort 1 met virtually to discuss and revise the common module; instructions were adjusted to highlight social justice and inclusion of non-present stakeholders. Both authors found the revision to be successful in this regard, as the following semester town halls were more deliberate in their inclusion of other stakeholder positions.

Students also engage in a group assessment and self-reflection exercise following the Town Hall. For the group assessment, students individually rate themselves and each of their group members on group engagement:

Rate ***yourself*** and ***each of your group members*** on a scale of 0 (low) to 5 (high) on the following:

- Asking if and/or making sure everybody in group understands what is going on
- Asking others in the group for their ideas
- Offering ideas
- Staying on-task and/or suggestions
- Staying focused
- Putting in effort
- Completely [*sic*] assigned work outside of class” (Role-play Group Assessment and Self-Reflection, p. 2)

Students also summarize what each group member contributed to the team. As part of the self-reflection, students score themselves from 0–5 and provide additional comments on the following criteria:

- “Using knowledge or ideas I have from my other coursework (in this course or other subjects).”
- “Asking others what knowledge or ideas they have from their coursework (in this course or other subjects).”
- “Using knowledge or experience I have from other aspects of my civic life or culture.”
- “Seeking others’ knowledge or experience based on the communities or cultures to which they belong.”

Both instructors asked students to complete this exercise outside of class, with one asking students to complete this on paper and the other building an assignment in the course learning management system. Based on experience, one instructor later shifted to having the evaluation completed on paper in class to ensure students had the experience fresh in their minds and considered their teammates thoughtfully.

The town hall works best when students embrace the stakeholder roles; the instructor can set an example by having some theatricality when taking on the role of mayor by using a prop (gavel, special hat, etc.) and using a more official tone. The trade-offs between stakeholders are more visible when at least some students “embody” the role. For example, we have seen the farmer team truly pretend they are related and invent a relevant family history; this encourages other students to see the upstream run-off not as villainy but as the result of incentives and economic action. Some students on the concerned citizens or local NGO teams take on the role of activists and demonstrate how facts can support passionate oration. In our opinion, the exercise loses some efficacy in having students identify complexity

and explain power dynamics between stakeholders when groups give staid presentations that rehash the same general information. By establishing clear expectations through the rubric and emphasizing role authenticity in the initial instructions, instructors can foster the kind of engaged participation that leads to deeper understanding of stakeholder complexity.

### 2.3 Whole-Class Stakeholder Board

The final common module assignment involves a reexamination of the stakeholder mapping exercise, performed collectively by the entire class:

Goal: Create a single map with your entire class that reflects your collective and revised understanding of the wicked problem based on the role-playing activity in Part 2 (Mississippi Watershed Nitrogen Student Guide, p. 8).

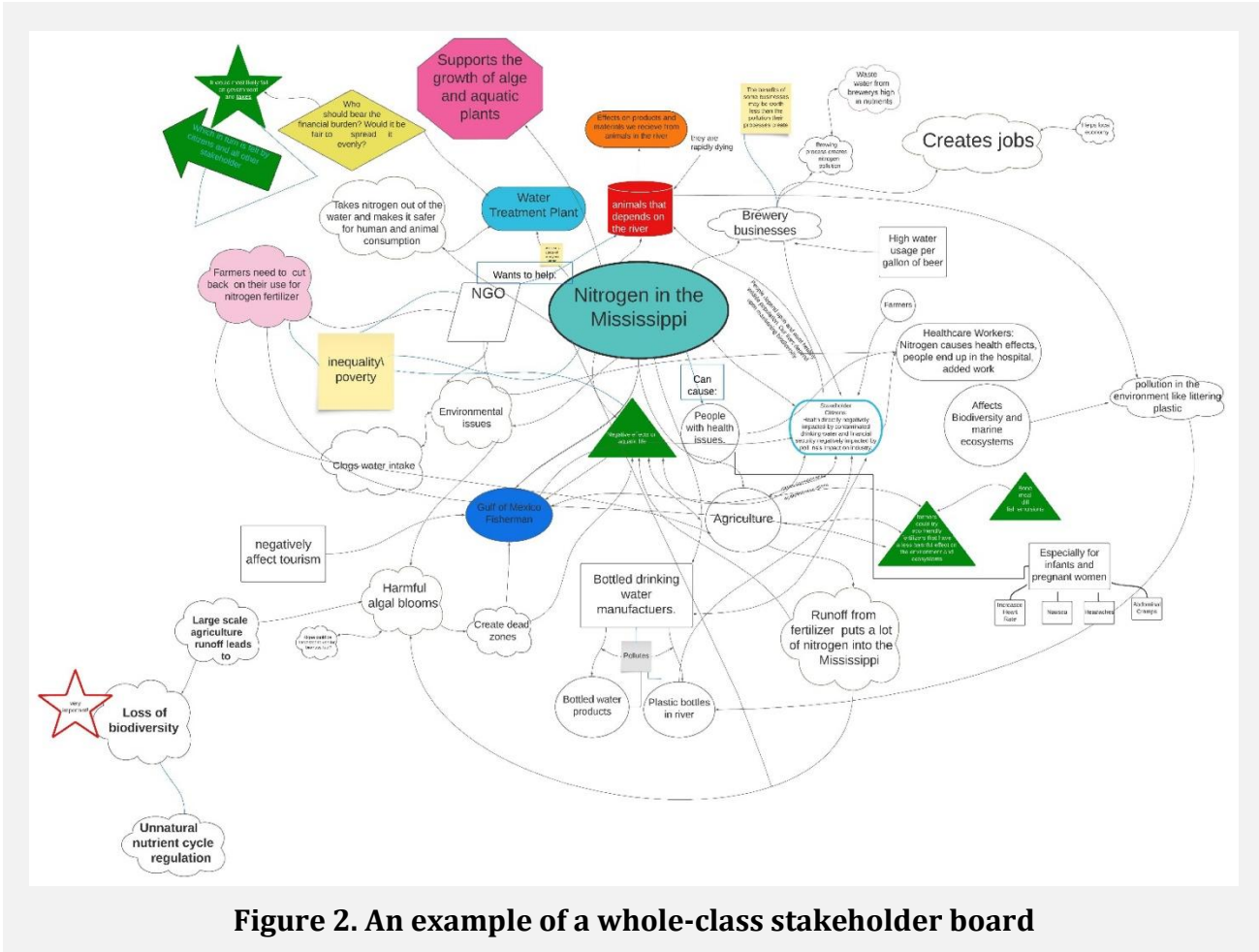
Students are asked to add at least one stakeholder or connection to the map with shapes and arrows to count for their individual participation in the class assignment; students are also encouraged to step back, observe commonalities happening on different parts of the board, and organize groupings and intersections of existing shapes. Both instructors used digital whiteboard software, such as Lucidspark, Google Jamboard, Miro, or Mural (see Figure 2 for an example of the class map). One instructor found this worked very well when the students were on Zoom during distanced learning; additionally, if the course is in a computer lab or as long as students are reminded to bring a laptop or other larger device, and the concept map is displayed at the front of the room, the digital approach can still work in person. Students without a device can then borrow access from another student or use the classroom computer. A low-tech approach using sticky notes and whiteboards would also work. Ideally, this final portion of the module uses 10–15 minutes of class time immediately following the presentations.

The class map is graded using the same rubric as the team map exercise, with all students receiving the same grade provided their presence and contribution to the map. Anecdotally, instructors have found increased complexity in the class maps after engaging with the module and role-playing activity compared with those drafted by teams in the first portion of the exercise.

### 2.4 Economics Through the Case-Based Common Module

The three parts of the common module were specifically designed to apply generally and fit into classes in multiple disciplines. While stakeholder mapping is a technique most commonly used in systems and business-oriented fields, concept maps more generally are applicable to any field (Davies 2011). Role-playing is another foundational learning technique (Rao and Stupans 2012). The common exercise does address a few economics-specific LOs that both authors realized after implementation, including LOs 2 and 5 from Allgood and Bayer (2017). In their framework, LO 2 is for students to be able to “Choose and use appropriate concepts and models to analyze and evaluate choices, outcomes, and policies in diverse settings,” which is addressed by role-playing in the town hall, while LO 5 from Allgood and Bayer (2017) is for students to “Discuss economic issues in ways that promote mutual understanding and inquiry, demonstrate fluency in basic economic terminology and tools, and explain economic reasoning to and incorporate insights from non-economists” (p. 662).

The common exercise also allows students in noneconomics courses to gain exposure to core economic concepts. At its foundation, the exercise invites students to identify the relationships among numerous stakeholders, considering the interaction of natural and human systems in market and non-market settings. The role-playing component then requires students to characterize how the incentive structure for each group affects their behavior as well as the impact on other stakeholders. Students must acknowledge the presence of externalities when exploring the downstream effects of certain industries and the reliance of specific markets on the outcomes of other markets, government policies, and household behavior.



### 3 Course Component

Successful implementation of the Business and Science: Integrated Curriculum for Sustainability (BASICS) module goes beyond inclusion of the common component; Cohort 1 instructors also developed course-specific components to tie the module to disciplinary skills and integrate the case-based lesson into their classes. The BASICS repository provides “instructor stories” from several other noneconomic fields; the two economics course integrations are described in this section.

#### 3.1 Principles of Microeconomics

For the course component of the BASICS module in the Honors Principles of Microeconomics course, one author created an assignment where each team is given a product market related to the wicked problem of nitrogen in the Mississippi River and its stakeholders; four specific industries used were agricultural/corn, fishing, breweries/beer, and drinking water. The exercise aims to achieve the following *course-specific* learning objectives:

- **Design** a policy for government intervention in the market for using water in a community.
- **Predict** and **explain** how stakeholders may change their behavior in response to the policy: firms, households, schools, etc.
- Students are asked to model the market by defining who is on each side of the market and assessing the private market equilibrium with the following instructions:
  - For your assigned industry, define the equilibrium in the private market outcome
  - Draw the supply and demand diagram for the good/service in question. Label the quantity axis as you see fit. Define the price-per-unit as appropriate.
  - Define who makes up the “supply” side and who makes up the “demand” side of the market.
  - Label the equilibrium price and quantity.
  - Label the consumer and producer surplus.
  - Assess the allocation of the total surplus among stakeholders in question.

Teams then analyze shifts in a supply/demand graph expected from a change in nitrogen pollution. Using their graph, students are asked to identify consumer and producer surplus, identify externalities present in the market, and assess welfare by finding the triangle of deadweight loss:

- Consider the social costs and benefits of this industry.
- Brainstorm potential externalities that exist in the market.
- How can you classify the good/service in question (i.e. common resource, public good, private good, etc.)?
- Which side of the market likely experiences the externality and how is this internalized by the market?
- How does the private outcome compare with the socially optimal outcome?

After identifying the existence of externalities, students consider the true social costs and benefits of their industries. Finally, students are asked to design a policy intervention that improves welfare:

- Design an appropriate government intervention.

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Mississippi Watershed module, there were statistically significant increases in their assessment of the importance of fields including humanities, business, and social science.

- How can the government use policies to achieve an improvement in overall social welfare?
- How are surpluses affected or reallocated? Consider the elasticity of each side of the market.
- Do you think these policies are feasible?

In many of these markets, students suggest a Pigouvian tax on nitrogen fertilizer, but they sometimes suggest other policies like subsidizing bottled water for low-income families. Curve-shifting analysis is common throughout early microeconomics courses, but connecting the exercise to the specific case of nitrogen pollution in the Mississippi River reinforces the real-world situational complexity and the applicability of economic modeling to gain understanding.

### 3.2 Introduction to Environmental Economics

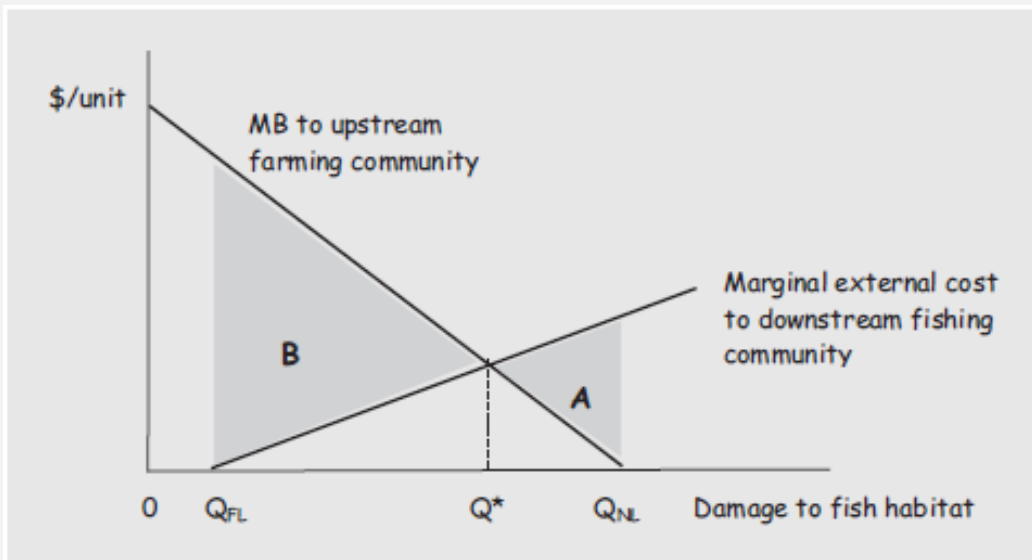
For the course component in Introduction to Environmental Economics, the other author chose to focus on integration of the BASICS module into lecture. The elements of the common module were spaced out over the course of 3 weeks, with lectures introducing the module and team work time alternating with a lecture on one-sided externalities as covered in Jaeger (2005) and a lecture on property rights with the example of the Lake Erie Bill of Rights (Ma 2019). The BASICS module thus serves as the backbone of the course unit on market failures in the environment. For example, the Spring 2024 meeting dates and activities are shown in Table A6 in Appendix A; the unit including BASICS began with a Team-Based Learning Readiness Assessment Quiz (Michaelsen et al. 2004) on the relevant textbook chapters covering property rights and regulation failures, thus preparing students for a deeper economic application of the material.

Following the BASICS introductory lecture and first stakeholder map is a lecture on unilateral externalities which integrates material from the textbook; Figure 3, which shows how the property rights schemes between an upstream farming community and a downstream fishing community are affected by the size of the externality, is incorporated from the students' reading into lecture and serves as a natural introduction of the Town Hall exercise. The next lecture presents Pigouvian taxes and provides students with time to work on the role-play presentation. The unit and module are capped off with the role-play exercise and discussion, second stakeholder map, and the Lake Erie example of an attempt to change property rights.

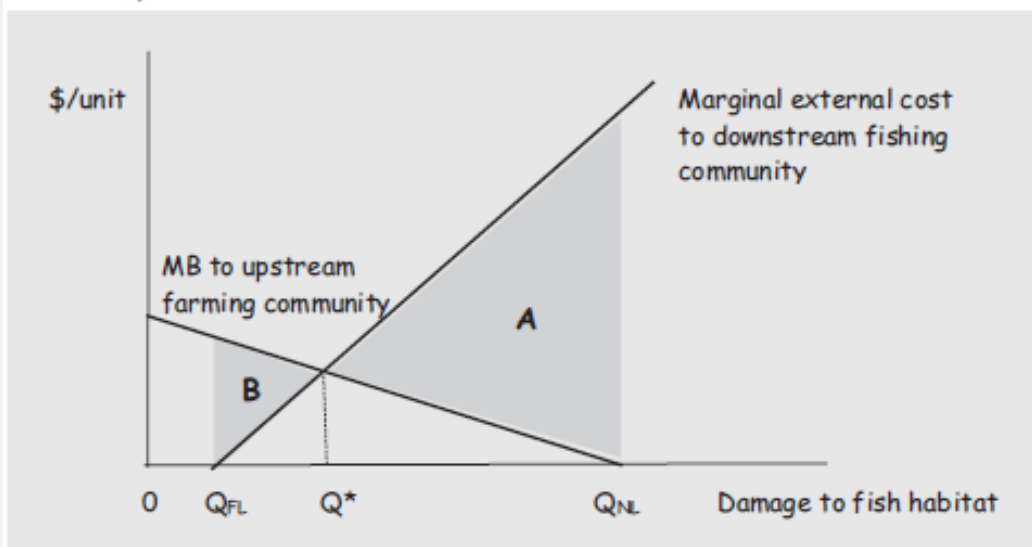
The Spring 2024 semester additionally presented serendipitous timing with another activity the instructor uses in this course. Prior to inclusion of the BASICS module, the course already included a field trip to a local distillery attached to a corn farming operation. The distillery incorporates numerous sustainability measures such as a closed-water cooling loop for the fermentation process, a small solar field to provide the energy required for cooling and all other operations, and large "thermos" which keeps warm for the following day the water that cooled the mash ton by absorbing its heat. The owner provides a tour of the facility for the students, describing these sustainability measures and his decision-making as a small business owner in two different markets. This field trip normally takes place earlier in the semester but fit especially well during the BASICS module because of the focus on water and the inclusion of a brewery as one of the town hall roles. Following the trip, students are asked to reflect upon the tour and the perspectives and actions of the real-life counterpart to one of the case's stakeholders.

### 3.3 Economics, Business, and Science Through the Case-Based Course Module

In addition to the three common module LOs, both authors identified economics-specific LOs 1, 3, and 4 from Allgood and Bayer (2017) as the main targets of their course component. LO 1 is for students to be able to "explain how economists use the scientific process to expand understanding of individual decision-making, market outcomes, and government policies, and apply the process by practicing curiosity and hypothesis testing." LO 3 is to have students "develop quantitative reasoning skills by



**FIGURE 9.1** An externality between a farming community and a fishing community



**FIGURE 9.2** An externality between a farming community and a fishing community

**Figure 3. Supply/demand graphs of a unilateral externality between an upstream farming community and a downstream fishing community**

Source: Source: Jaeger (2005, pp. 135, 137).

working with equations and graphs and by explaining the need for empirical methods that distinguish causation from correlation.” LO 4 asks students to “identify the assumptions underlying models, and connect the assumptions to particular theoretical results and/or observed conditions” (p. 662). The use of supply/demand graphs in both course components directly addresses each of these. For the Honors Principles of Microeconomics course, students describe the assumptions they made when modeling their assigned market and use the graph(s) they drew to suggest policy changes. For the Introduction to Environmental Economics course, students see and discuss the graphs of the same situation with two

different cost and benefit structures, thus realizing the importance of identification and estimation of the situation's true parameters. Finally, by embedding these course activities inside the BASICS module, students also connect the importance of other disciplines—chemistry, hydrogeology, horticulture, biology, communications, political science, among others—to the crafting of good economic policy and the resolution of wicked problems.

## 4 Lessons from Implementation

Anecdotally, both instructors found that the assignment resonated with students: For one instructor, the module was mentioned on the course discussion platform multiple times for weeks after the event, and both instructors' course evaluations at the end of the semester mentioned the module positively as well. The stakeholder maps appear to show an increase in complexity, intimating that students gain deeper insight into the “thorniness” of the wicked problem. Figures 2 and 3 present a team stakeholder board and the class-wide collaborative board from the same semester of the same course which are suggestive of this increase in complexity; further analysis of network complexity could be conducted. Preliminary results from pre-post assessments demonstrate an increased awareness of the transdisciplinary nature of wicked problems (Bender-Awalt et al. 2021; Iverson et al. 2024; Szymanski et al. 2023), but here we present a few of our own lessons from implementation.

First and foremost, because this module was adopted by multiple instructors at the same university, some students saw the common module two or even three times in the same or immediately subsequent semester.<sup>12</sup> Twice appears not to be an issue, provided the student is assigned to a different stakeholder group for the role-playing exercise, as the repetition appears to cement the material while the varied course components provide for disciplinary application. Three times, however, proves too repetitive and potentially boring for the student. This concern is alleviated, however, in adoption by instructors beyond the initial three universities.

A second issue regards students needing to meet in groups outside of class. For business instructors, the team portion of the exercise may not pose any issue, as students are accustomed to group projects. For team-based learning (TBL) courses, the use of teams is expected, but the creation of a role-play presentation does not meet the typical TBL team exercise parameters of same problem, specific choice, and simultaneous report (Michaelsen et al. 2004, p. 62). The exercise should therefore be emphasized as an addition outside of the norm in TBL courses. Instructors can alleviate the difficulties of group coordination outside of class by providing time in class to work on the presentation. Students choose a presentation software with which they are comfortable—such as Google Slides, Microsoft PowerPoint online, Canva, or Prezi—and then commonly break down the assignment into slides and assign each team member at least one slide. Even providing two half-hour sessions and then a shorter check-in prior to the town hall can allow students adequate time to complete the presentation without having to meet outside of class.

Third, we highlight some considerations regarding constructing teams for the role-playing exercise and the discussion following the town hall. With a hybrid course, there is the typical consideration of constructing teams of students who are physically in the classroom versus those tuning in online. This creates an obvious selection bias and means the in-person teams might have an easier time meeting and working together. Additionally, when implementing the activity in TBL, students did not like being assigned to a new role-play team constructed through a “jigsaw” process (one person from each permanent TBL team assigned to a role-play team). Despite the more creative nature of the work,

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<sup>12</sup> Unfortunately, the pre- and post-surveys were not able to control for this aspect, as student identifiers were only collected to match pre-/post- responses and were deleted after to maintain student anonymity as required by the IRB approval. The number of students seeing the module more than once was very small and generally limited to students in the environmental studies major at one of the universities.

students were more excited to complete the role-play assignment in their original team; in Spring 2024, the jigsaw process was saved for the discussion after the town hall, to greater success.

Finally, to no surprise, we note that the experience improves with practice. Each author found implementation of the common module and class component much easier in subsequent semesters, incorporating the feedback of students. The BASICS team incorporated such lessons as well, adjusting the Mississippi River module to accommodate antibiotics and mercury in addition to nitrates to allow for greater applicability in varied courses. In fact, one author found that the module stuck out so obviously the first time she taught it that she redesigned her entire course to better integrate the lessons of wicked problems. The same textbook is used, as is the ordering of topics, but the concept of wicked problems and the Sustainable Development Goals (SDGs) are introduced the first day of class, and then almost every chapter includes a hands-on application with a wicked problem or SDG one could address using the economic way of thinking. For example, the class tours a LEED-certified<sup>13</sup> building on campus and learns about efforts to preserve the environment around the building, as well as how operations of the building fit into the university's overall climate goals. Students analyze the opportunity costs of sustainability initiatives and engage in a critical discussion of what citizens can or cannot achieve in terms of progress toward sustainability, given scarce resources and trade-offs. Another activity examines the minimum wage in the context of price controls and average income data from the Federal Reserve Economic Data system. Using wicked problems as inspiration is similar to problem-based learning, Bayer et al. (2020) demonstrated how a problem-based data course can improve student relevance and gender balance in economics.

In an interesting contrast, Ault and Rutman (1978) found higher performance in intermediate microeconomics (intermediate price theory) for economic students in a lecture-based class than for business students in a problem-based class, but that

the problem-solving laboratory does have one advantage. It is a simple and effective means of getting faculty from different disciplines to interact. The use of a complex problem forces the instructors teaching their disciplines in an interdisciplinary format to think of the problem in broader terms in order to see how their disciplines integrate with the others in the analysis of a complex problem. (p. 100)

The BASICS curriculum has allowed multiple cohorts of faculty to work together to create a transdisciplinary module that incorporates economic and scientific principles into any college classroom that adopts it and is easily adapted to fit into the economics classroom to illustrate the concept of externalities.

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## Appendix A

**Table A1. Learning objectives addressed by the BASICS common module and course-specific components**

Source	Learning Objectives
Common module (drafted by PIs), as of 2021 revision	Locate and describe interactions between human and natural systems Diagram key components of a complex system focused on water quality and identify different stakeholder perspectives or interests associated with water use Explain how differing power dynamics among stakeholders creates conflict and the potential for social/environmental injustice
Course-specific module for Principles of Microeconomics	Design a policy for government intervention in the market for using water in a community Predict and explain how stakeholders may change their behavior in response to the policy: firms, households, schools, etc.
Allgood and Bayer (2017, p. 662)	Addressed by Common Module Choose and use appropriate concepts and models to analyze and evaluate choices, outcomes, and policies in diverse settings Discuss economic issues in ways that promote mutual understanding and inquiry, demonstrate fluency in basic economic terminology and tools, and explain economic reasoning to and incorporate insights from non-economists  Addressed by Course-specific Modules Explain how economists use the scientific process to expand understanding of individual decision-making, market outcomes, and government policies, and apply the process by practicing curiosity and hypothesis testing Develop quantitative reasoning skills by working with equations and graphs and by explaining the need for empirical methods that distinguish causation from correlation Identify the assumptions underlying models, and connect the assumptions to particular theoretical results and/or observed conditions

**Table A2. Module implementation roadmap showing timing, format, and preparation requirements**

<b>Component</b>	<b>Duration</b>	<b>Format</b>	<b>Group Work</b>	<b>Preparation Required</b>
Introduction (overview, wicked problems, nitrogen in the Mississippi)	Flexible, up to 15 minutes	In class lecture or reading prior to class	No	Instructor slides and student reading guide available
Part 1: Stakeholder Mapping	30 minutes	Individual or teams, in class or outside	Optional	Exercise instructions in student guide; lecture with examples of stakeholder maps (optional)
Part 2: Town Hall role-play	35-50 minutes; up to 30 minutes of in-class work (optional)	6 defined teams of 3-8 students	Yes	Exercise instructions and suggested references in student guide; presentation prep in class or outside
Part 3: Class stakeholder map	10-15 minutes	Whole class	Yes	None
Course-specific exercises	1-2 additional 50-minute periods	Varies by implementation	Varies	Course-specific prerequisite knowledge needed

**Table A3. Assessment rubric for the stakeholder exercise (team and class)**

	<b>Developing (0 pt)</b>	<b>Meets (1 pt)</b>	<b>Masters (2 pt)</b>
Natural components of system	Student correctly identifies fewer than five (5) natural system components	Student correctly identifies at least five (5) natural system components	Student correctly identifies at least ten (10) natural system components
Stakeholders in system (individuals or groups with an interest in or impacted by this issue)	Student correctly identifies fewer than five (5) stakeholders	Student correctly identifies at least five (5) stakeholders	Student correctly identifies at least ten (10) stakeholders
Interactions between components	Very few of the interactions between the components are correct	The majority of the interactions between the components are correct	All or nearly all interactions between the components are correct

**Table A4. Assessment rubric for the town hall role-play**

	<b>Unacceptable (0 pt)</b>	<b>Needs Improvement (1 pt)</b>	<b>Meets Expectations (2 pt)</b>	<b>Exceeds Expectations (3 pt)</b>
Introduction/ background	No understanding of the background associated with the group. Not a compelling case.	Introduction and background are not well researched. Not a compelling case.	Introduction and background are adequate for the case. Compelling case.	Clear introduction and background to stakeholder’s position. Compelling case.
Organization	Ideas not in proper order. Lacking major transitions. Lacking major ideas. Unclear.	Some ideas are not in logical order. Needs better transitions. Some parts are unclear or wordy.	Most ideas are logical and with effective transitions between major points. Generally clear and concise.	Ideas in logical order with effective transitions between major points. Clear and concise.
Information and articulation of position	Position stated but is simplistic and uses less than 1 piece of provided information.	Position stated, acknowledges there are different sides of the issue, uses less than 2 pieces of provided information.	Position takes into account complexities of the issue with either different sides or multiple ways of understanding from different professional fields and uses 2-3 pieces of provided evidence. May use additional resources.	Position is creative and clearly acknowledges the complexity of the issue with multiple perspectives and ways of understanding from different professional fields and uses 3 pieces of provided evidence and uses additional resources.
Consideration of alternative viewpoints and justice implications	Considers only primary (assigned) stakeholder interest.	Alludes to other stakeholders and/or disproportionate effects.	Articulates positions of 1 or 2 other stakeholders.	Articulates positions of at least 3 other stakeholders and highlights issues of injustice
Reflection on environmental injustice	Considers only the interests of primary (assigned) stakeholder.	Is able to describe the interests of at least one other stakeholder but fails to correctly provide evidence and fails to evaluate not possible conflicts or vulnerabilities.	Is able to describe the interests of at least one other stakeholder with some use of evidence and evaluates how power dynamics might result in an injustice to a vulnerable stakeholder or group not present.	Is able to use evidence from at least 2 stakeholders to discuss and evaluate specific issues of injustice that might arise.
Delivery	Under 3 minutes. Unprofessional appearance. Poor pace. Difficult to hear.	Over 5 minutes or under 3 minutes. Unprofessional appearance. Low volume. Seems rushed or too slow.	Remains within 5 minutes. Professional appearance. Good pace. Adequate volume.	Remains within 5 minutes. Professional and speaks clearly. Engages the audience. Good volume.
Questions and answers	Not prepared to answer any questions.	Answers not directly related to questions and not well thought out.	Answers to questions are answered by only one person but well thought out.	Answers to questions are handled by the whole group and well thought out.

**Table A5, Increased importance of disciplines indicated in the Mississippi watershed exercise, academic years 2020–2024**

<b>Field</b>	<b>Total Number of Paired Pre-Post Responses (N)</b>	<b>Ceiling (responses with pre = post = 5)</b>	<b>Importance Increase (responses with pre &lt; post)</b>	<b>Percentage Indicating Importance Increase</b>
Accountancy	958	42	441	48.14%
Business	1,292	12	658	51.41%
Entrepreneurship	948	51	477	53.18%
Finance	962	63	468	52.06%
Hospitality & Tourism	964	71	475	53.19%
Marketing & Sales	960	41	508	55.28%
Anthropology	930	84	392	46.34%
Agronomy	846	222	272	43.59%
Economics	960	116	445	52.73%
Geography	957	333	263	42.15%
Health Studies	953	330	356	57.14%
Psychology	950	35	479	52.35%
Public Policy	951	279	342	50.89%

**Table A6. Calendar of one author’s spring 2024 class (two 75-minute meetings per week) and BASICS activities as example of integration of lecture and common module**

<b>Date</b>	<b>Topics Covered</b>	<b>BASICS Activities</b>
Feb. 22	The Commons as rival and nonexcludable The Mississippi River as a commons Stakeholders and stakeholder maps	Lecture introducing BASICS, systems thinking, and wicked problems Common Module Part 1: Team Stakeholder Map
Feb. 27	Field Trip to whiskey distillery	
Feb. 29	Unilateral Externalities S/D Graphs Shareholders vs. Stakeholders	Introduction of Common Module Part 2: Town Hall Meeting and in-class work time
Mar. 5	Team-based Learning Peer Evaluation Pigouvian Taxes in S/D Graphs	In-class work time for Common Module Part 2
Mar. 7	Property Rights 2019 Lake Erie Bill of Rights, Election Results, and Legal Battles	Common Module Part 2: Town Hall Meeting Post-Role Play “Jigsaw” Discussion Common Module Part 3: Class Stakeholder Map

## Appendix B SERC Repository Hyperlinks

**Table B1. Resource links for the Mississippi River Watershed module**

Resource Type	Description	URL
Project overview	BASICS homepage with project overview, video introduction, and links to teaching materials, faculty perspectives, and contact information.	<a href="https://serc.carleton.edu/basics/index.html">https://serc.carleton.edu/basics/index.html</a>
Mississippi module homepage	Module description, goals, and material links for “The Wicked Problem of Water Quality in the Mississippi River Watershed”	<a href="https://serc.carleton.edu/basics/teaching_materials/mississippi/index.html">https://serc.carleton.edu/basics/teaching_materials/mississippi/index.html</a>
Common module materials	Module overview for instructors, including goals, timing, component descriptions, and instructor guide download.	<a href="https://serc.carleton.edu/basics/teaching_materials/mississippi/overview.html">https://serc.carleton.edu/basics/teaching_materials/mississippi/overview.html</a>
	Instructor guide for “Part 1: Drafting a Stakeholder Map for Downstream Pollution in the Water Cycle”	<a href="https://serc.carleton.edu/basics/teaching_materials/mississippi/part_1.html">https://serc.carleton.edu/basics/teaching_materials/mississippi/part_1.html</a>
	Instructor guide for “Part 2: A Town Meeting on Pollution in Mississippi River Watershed”	<a href="https://serc.carleton.edu/basics/teaching_materials/mississippi/part_2.html">https://serc.carleton.edu/basics/teaching_materials/mississippi/part_2.html</a>
	Instructor guide for “Part 3: Creating a Revised Stakeholder Map for Downstream Pollution in the Water Cycle”	<a href="https://serc.carleton.edu/basics/teaching_materials/mississippi/part_3.html">https://serc.carleton.edu/basics/teaching_materials/mississippi/part_3.html</a>
	Module introduction for students, including background information, relevant links, and videos, and instructions for all three parts.	<a href="https://serc.carleton.edu/basics/teaching_materials/mississippi/student_guide.html">https://serc.carleton.edu/basics/teaching_materials/mississippi/student_guide.html</a>
Course-specific: microeconomics	Materials for Principles of Microeconomics implementation, including lecture slides and exercise instructions	<a href="https://serc.carleton.edu/basics/teaching_materials/mississippi/exercises/249687.html">https://serc.carleton.edu/basics/teaching_materials/mississippi/exercises/249687.html</a>
Course-specific: environmental economics	Materials for Introduction to Environmental Economics implementation, including lecture slides	<a href="https://serc.carleton.edu/basics/teaching_materials/mississippi/exercises/249688.html">https://serc.carleton.edu/basics/teaching_materials/mississippi/exercises/249688.html</a>
Instructor stories	Implementation experiences across multiple disciplines	<a href="https://serc.carleton.edu/basics/teaching_materials/mississippi/instructor_stories.html">https://serc.carleton.edu/basics/teaching_materials/mississippi/instructor_stories.html</a>

*Notes:* All materials are freely available through the BASICS repository with the Science Education Resource Center (SERC) at Carleton College. The module homepage provides access to student guides, PowerPoint presentations, and assessment rubrics referenced throughout this article.

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