Exploring Indigenous Viewpoints in the Undergraduate Biology Classroom: An Environmental Case Study Incorporating Hawaiian Traditional Ecological Knowledge

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Abstract
Changing science education to foster greater equity and inclusion for Indigenous students will require effort from instructors and institutions. Instructors can help by including Traditional Ecological Knowledge (TEK) in their science classrooms. TEK refers to the many diverse knowledges, practices, and values regarding the environment that Indigenous peoples have acquired and passed down over many generations of living closely with the earth. TEK is practical and still in use today; in 2021, the White House Office of Science and Technology Policy and the Council on Environmental Quality released federal guidance that TEK is to be considered alongside Western science when making federal policy decisions. Many have called for the inclusion of TEK in science classes and have provided guidance on how to do so thoughtfully. This lesson takes those suggestions into account and was developed and taught at an institution in Hawai‘i. During the lesson, students work to address an environmental phenomenon, in this case the degradation of water quality in Hawaiian fishponds, or loko i’a. Students are required to review resources from four interest groups and knowledge systems (TEK, Western science, consumers, and the government) to create plans to address this problem. We found that this lesson helped students understand what TEK is, view TEK as a valuable and irreplaceable knowledge system, and view TEK and science as compatible ways of knowing. We also found that non-Indigenous and Indigenous students alike enjoyed and appreciated the inclusion of TEK in the class, and many of them asked for more TEK to be included in the future. This lesson is an important step for educators as we strive to repair misconceptions that science is exclusively for certain stereotypical groups. It opens the door to meaningful discussions on the relationship between various ways of knowing while exposing students to knowledge frameworks they may be unfamiliar with. Finally, it teaches students important systems thinking, communication, and collaboration skills while demonstrating that Western science is not the only way that humans learn about the earth.

Learning Goals
Students will:
- describe the impact of excluding certain groups from science.
- create a plan to address an environmental problem that considers the perspectives of multiple interest groups and knowledge systems.
- determine what kinds of data/knowledge/information various groups can provide (e.g., Indigenous experts, government officials, consumers, and scientists).
- describe the contributions of Indigenous peoples to science and explain how Indigenous knowledge (such as TEK) can be complementary to science.
- create and present a collaborative team plan.

Learning Objectives
Students will be able to:
- formulate questions to investigate an environmental phenomenon.
- evaluate data and resources to answer questions about an environmental problem.
- discuss the needs, roles, and perspectives of various interest groups and knowledge systems.
- determine what kinds of data/knowledge/information various groups can provide (e.g., Indigenous experts, government officials, consumers, and scientists).
- describe the contributions of Indigenous peoples to science and explain how Indigenous knowledge (such as TEK) can be complementary to science.
- create and present a collaborative team plan.


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Learning Goals
From the Science Process Skills Learning Framework:
Students will:
◊ share ideas, data, and findings with others clearly and accurately.
◊ work productively in teams with people who have diverse backgrounds, skill sets, and perspectives.

Learning Objectives
Students will be able to:
◊ compare and contrast Indigenous environmental knowledge, government officials, consumers, and Western science. How are they unique from each other? How are they similar to each other? What are they able to contribute to solving an environmental problem?

INTRODUCTION

Science classes are typically taught from a Western perspective that can decontextualize knowledge, which differs from Indigenous Science perspectives that are holistic and multidimensional, such as direct experience and interaction with nature, morality, and spirituality (1). This contrast in knowledge systems can drive a divide between Indigenous students and Western science, resulting in exclusion and underrepresentation (2). In response to science education typically only teaching Western science, both Indigenous and non-Indigenous scholars have called for Traditionally Ecological Knowledge (TEK) to be included in science classes alongside Western science (3–17). TEK refers to the diverse knowledges, values, practices, and beliefs of Indigenous peoples concerning their local environments that are acquired over generations of living closely with the earth (4, 18–23). TEK often involves a view of nature as a web of interrelated elements that are bound together in reciprocity and relationship (18, 24, 25). Teaching TEK in the classroom can help students engage in Two-Eyed Seeing, a concept presented by Mi’kmaq Elders Albert and Murdena Marshall, which they describe as simultaneously seeing from one eye with the strengths of Indigenous knowledge systems and from the other eye with the strengths of Western knowledge systems to benefit the world (26). Additionally, efforts to bring TEK into the classroom, while not making direct reparations to Indigenous peoples, help to disrupt the status quo of science put in place by colonizers (27).

In addition to combating a limited, colonized portrayal of science and encouraging Two-Eyed Seeing, including TEK in science classes positively affects students. It can help dismantle the stereotype of scientists being primarily white heterosexual men, which benefits diverse students from every background while validating and encouraging the inclusion of Indigenous students (4). Science education involving Native epistemologies and practices also helps students “see science as a set of practices rather than a body of facts,” which helps students understand how knowledge is created in science (28). Including aspects of TEK that perpetuate the important role humans play in ecosystems is also congruent with the core concept of systems thinking from the Vision and Change report (29). TEK emphasizes that humans are connected to, and not above, nature; this emphasis can help address misconceptions caused by belief in human exceptionalism, which is often characteristic of mainstream anthropocentric thinking and culture (30–33). Science education that includes Native epistemologies and practices may additionally help increase students’ relational and systems-level reasoning (28). Additionally, including TEK in science education has the potential to boost belonging for Indigenous students (30, 34, 35).

Furthermore, Indigenous Knowledge is invaluable in practically responding to current environmental crises, and is being increasingly recognized as such; including TEK in science education can teach students to value the input of Indigenous peoples and effectively consider and incorporate their perspectives when environmental management decisions are made (4, 23). The development and practice of TEK often leads to ecological wellbeing and biodiversity preservation, as demonstrated by the pattern of Indigenous lands holding some of the highest remaining biodiversity on the planet (4, 18, 36–39). In fact, 80% of the world’s remaining forest biodiversity is located on Indigenous homelands and over 24% of our above-ground carbon stored in tropical forests is in lands managed by Indigenous peoples (18, 40, 41). Additionally, deforestation rates are lower in lands managed by Indigenous communities, and they subsequently emit 73% less carbon than lands managed by other groups (40, 41).

The trend of biodiversity thriving in the care of Indigenous communities has not gone unnoticed, and in November 2021, TEK was formally recognized by the United States government as an important knowledgebase that contributes to scientific, technical, social, and economic advancements and to our understanding of the natural world (41, 42). The White House Council on Environmental Quality and the White House Office of Science and Technology Policy released a joint, government-wide implementation memorandum for all Federal Agencies to recognize and include Indigenous knowledge in their research, policy, and decision making alongside Western science (42). As global biodiversity is declining faster than at any other time in human history (43), academics, scientists, governments, and policy makers are increasingly looking to Indigenous peoples and seeking direction from their TEK (4, 6, 17, 18, 44–46). Instructors should prepare students—the next generation of government officials and scientists—to do so effectively and use conservation methods that are people-friendly, participatory, inclusive of local knowledge holders, and not marginalizing or disregarding to Indigenous peoples (47).

While there have been many calls to include TEK in science education (as reviewed in 30), efforts to include TEK in science are often large-scale and involve entire courses or after school programs devoted to TEK (12, 13, 48–50), and while greatly beneficial, these are not always feasible for instructors or institutions to implement. Fortunately, more and more small-scale, peer-reviewed lesson plans have been published in recent years to help teachers more easily incorporate TEK into their existing biology courses. Some only reference TEK and focus mainly on Western science, such as a lesson wherein students learn about the Indigenous planting practice of the Three Sisters (beans, corn, and squash) and the Western scientific explanation of the symbiotic nitrogen fixation.
between these three plants (51). Other lessons go more into depth for students to understand the TEK, such as a place-based lesson about global climate change through the lens of modern technology and Indigenous knowledge (52), a lesson introducing TEK and how Indigenous people use their knowledge for environmental conservation via examples (53), and a lesson teaching students about bowhead whales using Indigenous Knowledge from the Inuinniat community of Alaska and Canada alongside Western science (54). Such lesson plans are useful for instructors who aim to include TEK in their curricula, and we aim to add to these resources by providing another lesson instructors can feasibly and meaningfully use that includes TEK and highlights Indigenous voices in undergraduate biology classes.

This intervention was conducted at a university in Hawai‘i and incorporates Hawaiian examples of TEK, but instructors in other regions could adapt it to highlight localized Indigenous knowledge. The intervention consisted of a three-day environmental case study that included knowledge and viewpoints from four knowledge systems and interest groups: Western science, TEK, government, and consumers. During the case study, students worked in teams to learn about the perspectives of these interest groups and knowledge systems and were tasked to create and present a plan to their peers utilizing these perspectives to solve an environmental issue.

Positionality Statement

The authors include two White women (RFG, EGB) and one White man (SLJ) with PhDs in biological science fields, one White woman who is currently an undergraduate student (GK), and one Hawaiian man with a master’s in biology (LKE). Author RFG primarily created this lesson under the advisement of EGB and SLJ. None of these three are Hawaiian, but all have lived (or currently live) in Hawai‘i while teaching at a university in Hawai‘i. This connection enhances our appreciation of Native Hawaiian and other Pacific Islander (NHPI) cultures and gives us a particular investment in the success of NHPI students. Because this familiarity and appreciation does not give us understanding or ownership of Hawaiian traditional knowledge, we always utilize words and videos of Indigenous people when defining TEK or presenting TEK resources. Author GK assisted with writing the lesson plan for this publication. She is not Indigenous either, but her experiences living abroad in multiple countries have given her a unique appreciation for different cultures and knowledge types. Author LKE gathered and provided scientific data that was used in the case study. Although his role in the case study was that of a scientist, he was presented to the students as a Hawaiian scientist to show that Indigenous peoples can and are engaged in multiple ways of knowing. He also reviewed all materials and the manuscript for this lesson plan.

Intended Audience

Author RFG taught our lesson at a small, private university in Hawai‘i during the second half of a two-semester introductory biology series for science majors. The class was focused on evolution, diversity of life, ecology, environmental issues, and conservation. Students were predominantly first-year students, but there were upper-level students who were also enrolled. This lesson could be taught in any biology course that has a focus on environmental knowledge—not just an introductory class—as it focuses on practicing communication, research, data interpretation, and collaboration skills, making it a valuable activity for students of all levels. If an instructor feels that their students require more rigor and can complete the lesson in fewer than the three class periods outlined in this lesson plan or wish to assign the group work outside of class, they may do so. Another way to increase the rigor of this lesson is to have all students research all knowledge systems/interest groups (instead of just one of four) before working together to come to a solution. Instructors could also have students research an environmental phenomenon and find resources for each knowledge system/interest group on their own.

Required Learning Time

This lesson took place over three 50-minute class periods but could be adjusted to fit other timeframes. Students who did not complete each day’s packet (Supporting File S1) during class spent an hour or less completing it as homework. Students had time to prepare their class presentations during the lesson, but they could also spend time polishing their presentations outside of class if desired.

Prerequisite Student Knowledge

There are many adaptations that could be made to this lesson, including when in the semester it is being taught. It is not essential for students to have taken an entire course on conservation biology or on environmental issues to complete this case study. For this lesson to be successful, students should at the very least understand basic ecological concepts (e.g., that organisms and abiotic factors in an ecosystem affect each other and changes in these interactions can affect survival), understand how humans impact ecosystems, and be aware of TEK, know what it is, and how TEK is similar to and different from Western science. Students may also benefit from discussions about injustices and exploitation of Indigenous peoples in the field of science historically and presently (see this CourseSource article for an example of such a discussion). Lastly, students should know how to work effectively in and present with teams. This can be done in a variety of ways, but our students were prepared to do this by frequently working in small teams throughout the semester during active-learning activities, which developed students’ coordination, communication, problem-solving, organization, and presentation skills.

This lesson was taught near the end of the semester, so students had already covered diversity of life, ecology, climate change, environmental science, and conservation. They were prepared for this lesson by learning about different important conservation issues that we face due to climate change and other human-driven factors, such as pollution, desertification, deforestation, sea-level acidification and rise, ocean warming, and overexploitation of resources. These topics were not covered extensively, but students were aware of each and had a basic understanding of the impacts these factors have on ecosystems. Students had also learned how to predict the impact of human activities on other organisms in the ecosystem, and they had practiced including humans in their systems thinking throughout the semester.
Additionally, students in our classes were aware of Traditional Ecological Knowledge and had a lesson on “other ways of knowing” earlier in the semester (see Supporting File S2 for example slides). This activity set students up to understand the value of knowing that exist outside of Western science. Ways of knowing answer the question “how do we know what we know?” and include areas such as science, TEK, religion/spirituality, experiences, language, senses, emotion, reason, imagination, and intuition, amongst others. Students should at least be aware that there are other valuable and valid ways of knowing what we know that do not exist in Western science before they are presented with this lesson. Adding in a short discussion on ways of knowing could work well when discussing the nature of science, for example. Students had also been given local examples of Hawaiian TEK periodically throughout the semester and had been primed to discuss TEK as an equally valid way of knowing compared to Western science. They did not learn extensively about TEK, but it was mentioned prior to this lesson. For example, when learning about trophic cascades, they manipulated a food web that incorporated species endemic to Hawai‘i (and their Hawaiian names).

**Prerequisite Teacher Knowledge**
Teachers should familiarize themselves with all resources provided to students in Supporting Files S3–S6. Additionally, instructors should review the following materials to prepare to teach the lesson:

**TEK Background**
Students will mainly learn about TEK from Indigenous people themselves as included in the resources. However, it is important to be familiar with the TEK included in this lesson as you will give an overview when introducing the activity. If you are teaching this lesson as it is written, you should be familiar with Hawaiian fishponds, which are advanced aquaculture systems created by ancient Hawaiians to essentially “farm” fish from the ocean. The following resources could be helpful:

- National Oceanic and Atmospheric Administration’s (NOAA’s) [page](https://www.noaa.gov) on Hawaiian fishponds
- [Fishpond Basics](https://www.fishponds.org)
- The Return of Kū‘ula
- Paepae o He‘eia-The Fishpond

You should also know what an ahupua’a system is, or Hawai‘i’s land and socioeconomic division system. These resources provide good background information:

- Ahupua’a System
- Ancient Moku and Ahupua’a
- [Hawai‘i’s ancient land management system](https://www.hawaii.gov)
- Hawai‘i Education Series: Ahupua’a [video](https://www.youtube.com)
- Ahupua’a: From Mauka (Mountains) to Makai (Ocean) [video](https://www.youtube.com)

Additionally, learn about the concept of “aloha ‘āina,” or the Hawaiian value and belief that if you take care of the land and sea, they will take care of you in return. These resources provide a good introduction to this concept:

- [Aloha ‘Āina: Concept](https://www.alohaaina.org)
- [Aloha ‘Āina - Indigenous Life in Hawai‘i](https://www.indigenouslifehawaii.com)

If you are adapting this lesson to incorporate sources of TEK other than the Hawaiian examples used here, you should be familiar with local Indigenous peoples and TEK that is relevant to the environmental issue you describe. Including Indigenous experts is especially beneficial for students, so reaching out to local tribes or Native groups is a great place to start. There are also many resources available online and in libraries, museums, state parks, or other areas that highlight TEK and Indigenous groups of the area, and using pre-published materials puts less demand on Indigenous individuals’ time and resources. Doing an online search on your topic and related TEK will often turn up fruitful results. Whenever possible, use existing sources that come directly from Indigenous people so your students learn about TEK from them rather than from you. During initial planning stages of our lesson, author RFG consulted with two Indigenous experts (Mark Ellis of Kamehameha Schools and Robin Wall Kimmerer during a seminar visit to our campus) to brainstorm broad ideas. A research group from our university then met extensively with Walter Ritte (an Indigenous expert on Hawaiian fishponds and environmental activist) of ‘Āina Momona to learn from his expertise. He gave us permission to use video footage from these discussions in our lesson.

**Consumer Background**
Regarding the consumer interest group, you should also be aware of food sovereignty and the food crisis in Hawai‘i, since between 85 and 90% of Hawai‘i’s food is imported. These resources could be helpful:

- Increased Food Security and Food Self-Sufficiency Strategy from State of Hawai‘i
- Civil Beat: How Hawai‘i squandered its food security
- The Guardian: Hawaiian traditional farming methods
- Harvard University: Food sovereignty and traditional Hawaiian agriculture

If you are adapting this lesson to a different area’s TEK or another environmental issue, you should find out how the issue relates to the economy and consumers. While you may not find extensive information connecting to your specific environmental problem (e.g., “fishponds”), branching out to some general environmental issues (e.g., “food supply,” “pollution,” and “global warming”) and their relation to the economy/consumers in the region you are investigating may yield better search results. Resources you provide to students may include news articles, government reports, and videos, as well as relevant environmental policies of corporations.

**Science Background**
The science portion of the activity (Supporting File S6) is structured differently from the portions on government, TEK, and consumers, which are collections of quotes. The science section is deliberately designed so that students can look at and draw their own conclusions from real, collected data. This also means that there is no clear answer for restoring the fishponds that comes from using the science resources alone. Thus, you do not need to be an expert on the science that is presented in the packet. You should, however, have a basic understanding
of remote sensing, as it is the technique used to gather some of the data in this activity. Here are some resources that could provide helpful background:

- USGS
- NOAA
- GISGeography

As an instructor, you should have a basic understanding of environmental issues and be familiar with human impacts on ecosystems. You should understand the ecological concepts of connected systems and be familiar with the impacts of erosion and land runoff. These concepts are discussed in these resources:

- Impacts on water quality
- Subsequent impacts on fish populations

If you are using a different environmental issue for your lesson, choose different resources that will provide students scientific data, without giving a clear answer on what to do to solve the issue. This may be giving students a research study on the issue (or simplified studies, depending on grade level) without the calls to action or implications sections. Be familiar enough with the methodology in the studies to help students understand it, and provide simple resources or explanations for necessary ecological concepts you have not already covered in class (e.g., carbon cycle for wildfires).

**Government Background**

For the government section, the following resources could give you good background information:

- What is an Environmental Impact Statement (EIS)?
- How does the Environmental Protection Agency review an EIS?
- Restoring a Part of Hawai’i’s Past: Kaloko Fishpond Restoration

When adapting the lesson to a different environmental issue, you may look at procedures for change to be implemented by the government and laws affecting how corporations treat the environment. You may also decide that the government is not clearly involved in your issue and therefore choose a different interest group, such as children and youth or a non-governmental organization.

The environmental issues outlined in your adapted case study do not necessarily need to be completely accurate but could be exaggerated or invented to help students learn the complexity of environmental issues. Ultimately, this case study has no one “correct” answer, as the objective is not to teach students to arrive at and regurgitate a solution to one problem. Rather, this activity aims to teach students the important skills of weighing multiple interested groups when solving environmental problems and including TEK alongside science. Thus, it is not critical to know what the solution to the environmental problem would be, as there is not one correct solution. We believe that letting students be creative and come up with their own ideas can produce richer, more interesting solutions and also more closely mimics real-life scenarios where there is not always one correct solution to an issue.

**Scientific Teaching Themes**

**Active Learning**

This lesson is designed to use active learning throughout, with frequent small-group discussion, small-group collaborative work, and think-pair-share exercises (55–59). Students also work together to research and explore different resources to create a plan, which they then present to peers (55, 60). This lesson could easily be adapted to be a jigsaw (61) as well, wherein teammates are each assigned a topic. After doing research with a separate team of classmates who have the same topic, they go back to their original team and teach about their assigned topic.

**Assessment**

The questions students complete throughout this lesson in their student packet (Supporting File S1) act as a formative assessment (62, 63). Students are graded on completion for the packet and can adjust their answers after discussion with their peers or the full class. The questions in the packet help guide the students’ learning and ensure that they are thinking critically about and engaging with the lesson material (64). The team presentation (see instructions in Supporting File S11, slide 2), which students turn in before presenting to their classmates, serves as a summative assessment (65, 66). The presentations demonstrate to instructors and students whether the students have achieved the learning objectives and are a summation of the entire lesson. Finally, students complete reflection questions in their student packet after the presentations, which also assess their learning.

**Inclusive Teaching**

The purpose of this lesson is to foster inclusivity in science. With a focus on other ways of knowing and an emphasis on TEK and Indigenous knowledge, the lesson demonstrates the value of including diverse ways of knowing in science. Indigenous voices and knowledge holders are highlighted in this lesson, demonstrating to students the importance of considering diversity in science. This is beneficial for students of all excluded and underrepresented backgrounds, as it helps break down the stereotype that science is an exclusive field.

The inclusion of examples of NHPI scientists in the science resources also presents students with examples of scientists from diverse backgrounds, which has been shown to be beneficial to students, as in “scientist spotlight” interventions (67, 68). Additionally, active learning has been shown to narrow achievement gaps for marginalized students in STEM, and this lesson utilizes multiple forms of active learning (69).

This lesson could also be easily adapted for a remote or hybrid course. Due to the collaborative requirements of the group presentation, students would need to communicate with and/or meet with peers electronically or in person outside of class. They would need to record their presentation as a team, but this could be done remotely using technology. If done in a synchronous online class, students could present to their peers online during class time utilizing breakout rooms. If done in an asynchronous class, students could upload their recorded presentations to a learning management software and could be assigned to watch and respond to other classmates’ presentations.
This lesson also considers students from diverse socioeconomic backgrounds, as there are no required materials that students would need to purchase (e.g., a textbook). Everything necessary to complete this lesson is provided to students. Since only one computer or tablet is necessary per team, not every student needs to have access to one to present successfully. However, if students do not have access to computers or tablets, this lesson could be adapted. Instructors could print out all necessary supporting materials, then give students posters to create their presentations on. Thus, access to computers is not critical for this lesson to be successful.

**LESSON PLAN**

**Preparation**

Students should be made aware of Traditional Ecological Knowledge (TEK) before this activity. We included a lesson towards the beginning of the semester that discussed “other ways of knowing” outside of Western science, and TEK was brought up as a way of knowing (see Supporting File S2 for an example). Differences and similarities between TEK and science were discussed. The complexity around the term “TEK” was also discussed and Indigenous authors who were both for and against including TEK in Western science were cited and discussed.

Have “Environmental Case Study Student Packet” (Supporting File S1) available for all students electronically or printed. Compile all resources (Supporting Files S3–S9) to share with students (e.g., in a shared Google Drive folder or posted on your classroom management software).

Note: Before using any of the supporting materials available with this lesson, please go through and insert images where noted (examples are given) and change red text to be applicable to your class.

**Day 1: In Class**

**Part 1 of Student Packet**

Pass out or have students pull up electronic copies of “Environmental Case Study Student Packet” (Supporting File S1).

Introduce class activity to students using the Day 1 Slides (Supporting File S10). Briefly describe a “loko i’a,” or Hawaiian fishpond. Have students familiar with fishponds share any knowledge they have with the class. Use this as scaffolding for the rest of the lesson. Table 1 contains suggested times for each part of the lesson, though these can be adjusted to fit your needs.

Discuss how fishponds were used anciently by Hawaiians to essentially farm fish. Explain how fishponds were built and how they worked. Bring up that there were around 488 fishponds across the Hawaiian Islands prior to Western contact, then discuss how many of the fishponds fell into disrepair or were destroyed during the 19th century.

Explain that today there are around 40 active fishponds across Hawai’i that are in different stages of restoration.

Then, share the following with the class (found on slide 4 and in Part 1 of the student packet):

Some fishponds around Hawai’i are classified as having “impaired waters”, wherein their water quality is not meeting Department of Health standards. This water quality degradation has led to a decrease in the productivity (or number of fish able to be harvested) in the fishponds.

Organize students into teams of four. We allowed students to select their own team; however, you may divide students yourself if you prefer. If your class is not a multiple of four, you could adapt and have students in a team smaller than four do more than one interest group or knowledge system (discussed later), or students in a team larger than 4 could double up to research an interest group/knowledge system. We would recommend having the teams be four or smaller so that students all are able to contribute.

Instruct them to complete **Part 1 Question 1** in their student packet, and tell them you will bring the class back together to discuss. Give them approximately 5 minutes to work as a team on the question.

As students are working, walk around and talk to teams and see if students are on track or have questions. Students might need direction or additional instructions to get started or to stay on track. You could ask probing questions to students who seem stuck. These could include questions such as “Why is this happening? What exactly is happening? How do we know this is happening? What can we do about it? What could have caused this?” If you start asking questions, students should be able to come up with their own additional questions as well. Let them know that any question they come up with is good, and not to worry about getting the “right” answer.

After 5 minutes, call the class back together and discuss the different questions students thought of when they were in their teams. List the questions students share on the board. You could use this as an opportunity to differentiate between different types of questions (i.e., causal and observational).

Here are some types of questions that they might come up with:

- Causal questions:
  - Why is this happening?
  - Where is the pollution coming from?
  - How is the degradation of fishponds impacting fish?
  - What about other species? How about humans?
- Observational questions (that are helpful to ask because they’ll give you hypotheses for your causal questions):
  - How long has this been happening?
  - Are all fishponds being impacted or just some?
  - Is this bad?
  - What happens if it gets worse?

After discussing these questions as a class, tell students to complete Questions 2 and 3 in their student packet with their teams. Give them another 5 or so minutes to work as you walk around and observe/help students.

Reconvene as a class and ask:

- What information would you want to gather to answer these questions (i.e., Questions 2 and 3 in
For the last question above, have an open discussion and write on the board students’ responses.

Here are some examples of what they might come up with:

- Local experts or elders (kupuna)
- Scientists
- Government officials
- Business people
- Fishermen
- Tourists
- Conservationists
- Activists

Go over students’ answers briefly, then as a class, group similar responses. If students aren’t coming up with Indigenous people or government, for example, ask probing questions such as “Is there anyone else we could consider? What about local peoples?” and see if they get there themselves. Then, consolidate into four main categories of interest:

1. Science
2. TEK
3. Government
4. Consumers

Note: Students may come up with valuable interest groups or knowledge sources that are not included in these four. Acknowledge that these are great to consider, but explain that for the sake of this activity, you will be focusing on the four categories presented.

Then, present the table slide (Supporting File S10, slide 6) and direct students to work with their teams for about 10 minutes to fill out the table in their student packet (Question 4).

Note: Students will fill in the top row of the table themselves, so their orders may not match what is on the slide.

After students have worked in their teams for around 10 minutes to complete the table under Part 1 Question 4, reconvene as a class and spend a couple of minutes having students share what they put. You could ask for an example for each interest group/knowledge system for one of the two questions.

Part 2 of Student Packet

Introduce Part 2 to students (Supporting Materials S10, slide 7). Show them how to access the resources* they will need to complete the table found in Part 2. Give students the rest of the class period to work on Part 2, invite them to start exploring the resources and decide who will be responsible for researching each interest group/knowledge system for one of the two questions.

Note: You could adapt this by having these pre-assigned or give students their top two choices after taking a poll.

*Resources are available as supporting files S3–S9. You can add more resources for students if desired. For example, links to YouTube videos or other relevant articles can help students practice investigating materials. If you are choosing to adapt this lesson, you will need to update these resources before giving them to students so that they are relevant to your environmental problem.

Note: We had the resources available and organized inside a shared Google Drive folder. Students were given access to the folder through the shared link and could click on a subfolder with the resources that correspond to that group organized within. Thus, there were four subfolders labeled “Science,” “TEK,” “Government,” and “Consumer.”

As students are working, walk around the classroom and assist students as needed. If teams are struggling, spend extra time with them and ask them questions to help them get started. You could also ask students what they are putting or ask them to explain something interesting they have read to make sure they are on track.

When there are a few minutes of class time remaining, instruct students about the homework for the activity (Supporting File S10, slide 8). Remind students to bring their packet and a computer or tablet to the next class period (so they can access the resources in Google Drive, if that is your method of sharing them with students). Ensure they get the contact information of their other teammates.

Day 1: After Class (Homework)

Part 3 of Student Packet

Students should complete whatever they didn’t finish of Day 1’s packet (Parts 1–3) for homework. Tell them to share the sections they researched to fill out Table 2 with the rest of their team (via email or text) so that each student arrives at the next class period with their tables completely filled out.

Note: They can copy/paste what their other team members put, but they should read through the entire table before coming to the next class.

Day 2: In Class

Have the Day 2 slideshow opened at the start of class (Supporting File S11, slide 1). Instruct students to sit with their teams from last class and ask them to get out their “Environmental Case Study” student packet.

Part 4 of Student Packet

Explain that students will work with their teams to create a plan to address the reduced water quality in the fishponds. They will create slideshow presentations to present their plan to their classmates during the next class period. Give them the instructions found under Part 4 in their student packets and the Day 2 slides (Supporting File S11, slide 2).

Give students the entire class period to work with their teams. Be available to help students with questions and give support when needed.

Day 2: After Class (Optional Homework)

Students can continue working on their presentations with their teams if they would like to. They should give it to you before the next class period however, so you can assign the teams that will be presenting to each other.
Note: We had students email their slideshow presentations to the instructor and include each team member’s name in one email. This allowed us to preview presentations beforehand and match teams together with different plans to present to each other.

Day 3: In Class
Have the Day 3 slideshow opened at the start of class (Supporting File S12, slide 1). Instruct students to sit with their teams and get ready to present as they are arriving in class. Remind students to turn in their completed student packets by the due date and tell them about the reflection questions that follow the presentations and the accompanying homework assignment (Supporting File S12, slide 2).

Part 5 of Student Packet
Remind students of how the presentations will work (Supporting File S12, slide 3). One team presents to one or two other teams, so if you had eight teams total, for example, you would only have four teams presenting at once. It may be helpful to allow students to spread out to different corners of the classroom or outside if you are able to. Since not every team presents at once, it shouldn’t get too noisy. Have teams sit close together in a circle and use one students’ laptop or tablet to present to their classmates.

Separate the students into teams (depending on your class size). We had each team in the class present to two other teams. This allowed for 18 minutes (+2 buffer minutes) of teams presenting.

Instruct the first team to begin their presentations and start a six-minute timer. Since all teams have already studied about each of the four focus perspectives (TEK, Science, Government, and Consumers), this presentation is meant to be an overview of what they found and an explanation of their solution that takes the interest groups and knowledge systems into account, not an in-depth retelling of information in their packets. To keep students focused on this objective of the presentation, remind them not to exceed the time limit. Walk around and watch different teams presenting. Once five minutes have passed, give a one-minute warning so they can wrap up. After six minutes, tell the first teams to stop their presentations. Give a 30 second/1 minute buffer, then have the second teams begin their presentation once you re-start the six-minute timer. Repeat this until all teams have presented. Once all the teams have presented, instruct students to complete Questions 1–4 in their student packets under “Day 3.”

Give students around 5 minutes to complete the questions individually, then have the class come back together.

For the remainder of the class period, have a class discussion on the questions they answered. To facilitate the discussion, you can consider asking students the following:

- What did you learn from this activity?
- What is the value of incorporating more perspectives in addition to Western science when making management decisions?
- What are the challenges to including Indigenous voices and knowledge in science? What are the benefits?
- What are ways TEK can be included in Western science?
- You could also discuss the importance of weighing different interest groups and knowledge systems and discuss contributions each can make. Finally, you can discuss how we can include more diverse voices in science and what the benefits are of including these voices. You could also ask students “what are potential risks to including TEK in Western science? What are the benefits?” to generate discussion.

Remind students that their completed packets will need to be turned in. Tell them there are some reflection questions (found under Part 6) to complete before turning in their packet.

Day 3: After Class (Homework)
Part 6 of Student Packet
Students should complete the reflection questions in their student packet (found under Part 6) before turning in the completed packet.

TEACHING DISCUSSION
This lesson is a useful way to expose all students to the value of TEK and open their minds to ways of knowing that exist outside of Western science. We collected qualitative data on student experiences with this lesson. IRB approval was obtained from the monitoring institution (IRB#: IRB2021-335) and from the institution where the lesson was implemented (IRB#: 20-64). Of the 64 students in the classes, 61 completed both a pre- and post-survey that asked them “What do you think of when you hear ‘other ways of knowing?’ What do these ways of knowing include?” On the pre-survey, there were only two students who mentioned “TEK” or “Traditional Ecological Knowledge” as a way of knowing. The rest of the students listed things such as science, religion, experience, and activities related to scientific study (e.g., research, collecting data, reading scientific papers). On the post-survey, however, 35 students listed “TEK” or a variation of “TEK” (i.e., Indigenous knowledge, Native knowledge, or knowledge from local people) as a way of knowing. This demonstrated to us that students became more aware of TEK’s existence after the intervention and came to recognize it as a way of knowing. Additionally, students were asked if they felt TEK and Western science are compatible. Of the 60 students who responded to that question, 51 marked “yes, they are compatible,” eight students marked “it depends,” and one student marked “no” (though when answering the follow-up question to explain their answer, the student wrote “it depends”). This shows that most of the students felt like Western science and TEK are compatible knowledge systems, which was a learning goal of the lesson.

When asked what students thought about the class activities that incorporated TEK, students were generally extremely positive about their experience with TEK in the class and indicated that they were meaningful and useful activities for them. This was the case for both NHPI and non-NHPI students; one NHPI student said, “I thought it was a GREAT activity!!! Very meaningful for the class.” Another NHPI student said:

“I found the [TEK activities] very meaningful and I was very interested in learning about TEK. I was not expecting the incorporation of TEK but it was a pleasant surprise. I feel like I have learned a lot and I am hoping my peers who have had less experience with TEK did as well.”
Non-Native students also reacted positively to the activity. Many expressed how “eye-opening” learning about TEK was. For example, one student said, “I really enjoyed learning about TEK because it really opened my eyes about what Indigenous people already knew.” Many non-NHPI students also expressed that they were previously unaware of TEK and were therefore appreciative of its inclusion in the class. One non-NHPI student explained:

“I enjoyed the [TEK activities] and thought they were meaningful because we need to learn to be educated and respect the Native people. I think these are important things to talk about and I myself had never had these conversations before but I believe TEK should be incorporated [in science].”

Students were overwhelmingly in favor of including TEK in the class. When asked what they would change about the way TEK was incorporated into the course, many students indicated that they would prefer more TEK to be included throughout the semester. Second, several students indicated that they would like a local expert to come and talk about or introduce TEK to the class. (Videos in a follow-up assignment showed local Indigenous experts discussing the TEK relevant to the fishpond activity; many students referenced these videos and said they appreciated their inclusion.) If we were teaching this lesson again, we would invite local Indigenous experts to introduce the fishpond activity and give an overview of the associated TEK if possible. However, since this is not always feasible, we believe using videos online of Indigenous experts teaching/explaining the concepts (with permission) is sufficient in order to decrease demand and strain on Indigenous experts’ time and resources. Students also indicated that they thought the TEK portion of the case study should be required for all students to read. As the lesson is currently set up, not every student would have the opportunity to investigate the TEK materials that are provided. They would hopefully learn about the material from their classmate who reviewed it and reported it back to them, but perhaps they could have more exposure to the TEK materials. As some students suggested, the TEK materials could be required for everyone to read or could be given as the first assignment that everyone worked on simultaneously as a class. Once they finished completing their packet questions for the TEK group, they could split up and individually research the remaining interest groups/knowledge systems. Finally, a couple students suggested that the instructor advise the class to be respectful and open-minded towards TEK. There were also a couple of non-Native students that indicated feeling excluded because they were not part of the culture that was being discussed. Having a discussion at the beginning of this activity that advises classmates to be respectful of all ways of knowing could improve this lesson. A study providing more detail on the empirical evidence obtained from this intervention is in progress by the authors.

Extensions/Modifications

This lesson can easily be built upon or incorporated into multiple units. Students could research different types of TEK throughout the semester and complete activities that compare the TEK to science or demonstrate their compatibility/independence. A more formal presentation could be done if students were given more time to prepare, such as if this became a semester long or unit-long project/homework assignment.

This lesson could be done entirely online. Students could post their presentations to classroom management software and comment on other presentations. They could work independently if it would be difficult to coordinate teams, but we think this assignment is best done as a group assignment as it teaches important communication and collaboration skills. Larger classes could have students work on the student packet in class, but post and view presentations to classroom management software to not take class time for the presentations and to avoid chaos with everyone presenting at once. This would include creating a homework assignment for students to record their presentations outside of class with their teams and to upload it, then to watch other teams’ presentations and comment on them via a discussion board or something similar. Depending on time, there could be a follow-up classroom discussion after students completed uploading/commenting on presentations that invites students to share things they learned and highlight presentations they enjoyed or learned from.

Most significantly, this lesson could be adapted to include different Indigenous groups and TEK. Many examples of TEK connecting with science are available, but here are a few:

- Indigenous burning practices in land management (70–73)
- agricultural practices such as the “Three Sisters” (74–76)
- Indigenous management of ecosystems (e.g., salmon fisheries; 77–81)
- overlap between remote sensing and TEK in conservation efforts (82)

Additionally, many students involved in this lesson indicated they appreciated the place-based nature of this activity, as they enjoyed learning about something relevant to where they were living. This would require researching Indigenous groups near you, coming up with or finding an “environmental problem” that could be addressed using support from TEK, and modifying the supporting interest group/knowledge system materials and the student packet to reflect the updated lesson.

Thank you for using this lesson and helping make science education more inclusive and equitable for all students. Though we have a long way to go, the efforts of earnest and passionate instructors like you can and do make a difference.

SUPPORTING MATERIALS

- S1. Exploring Indigenous Viewpoints – Environmental Case Study, Student Packet
- S2. Exploring Indigenous Viewpoints – Other Ways of Knowing, Slides
- S3. Exploring Indigenous Viewpoints – TEK Resources, Activity Materials
- S5. Exploring Indigenous Viewpoints – Consumer Resources, Activity Materials
- S7. Exploring Indigenous Viewpoints – Science Resources Picture, Activity Materials
• S8. Exploring Indigenous Viewpoints – Science Resources Landcover Classification, Activity Materials
• S9. Exploring Indigenous Viewpoints – Science Resources Bare Earth, Activity Materials
• S10. Exploring Indigenous Viewpoints – Day 1 Environmental Case Study, Slides
• S11. Exploring Indigenous Viewpoints – Day 2 Environmental Case Study, Slides
• S12. Exploring Indigenous Viewpoints – Day 3 Environmental Case Study, Slides

ACKNOWLEDGMENTS

We would like to acknowledge that Brigham Young University–Hawaii is situated on the traditional homeland of the Hawaiian people. We recognize that in 1893, her majesty Queen Lili’uokalani yielded the Hawaiian Kingdom under duress and protest to the United States to avoid the bloodshed of her people. We acknowledge and give gratitude to Hawai‘i, for the gifts and nourishment she bestows upon us. We recognize and appreciate the generations of Kānaka Maoli and their knowledge systems that shaped Hawai‘i in sustainable ways, thereby allowing us to enjoy these gifts today.

This material is based upon work supported by the National Science Foundation Graduate Research Fellowship Program under grant no. R0112436. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.
Table 1. TEK activity teaching timeline. Suggested times for completing each aspect of the lesson are included.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Description</th>
<th>Estimated Time</th>
<th>Notes</th>
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</thead>
<tbody>
<tr>
<td><strong>Introductory Activity</strong></td>
<td><strong>Activity</strong> <strong>Description</strong></td>
<td></td>
<td><strong>Notes</strong></td>
</tr>
<tr>
<td>Day 1 Class Activity</td>
<td><strong>Introductory Discussion</strong></td>
<td>5 minutes</td>
<td>Have students who are knowledgeable about fishponds contribute to a class discussion. If none of your students have background knowledge on the topic, introduce it using the provided slides (Supporting File S10).</td>
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<tr>
<td></td>
<td><strong>Part 1: Question 1</strong></td>
<td>5 minutes</td>
<td>Instructions are found in the student packet (Supporting File S1). Have students work in their teams to list questions they have concerning the presented phenomenon.</td>
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<tr>
<td></td>
<td><strong>Part 1: Question 1 Discussion</strong></td>
<td>2 minutes</td>
<td>You can have students shout out the questions they came up with as you write them on the board. You should hopefully have a variety of questions if students are interested in the topic. You can help them by asking them questions to get them thinking about the phenomenon.</td>
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<td></td>
<td><strong>Part 1: Questions 2–3</strong></td>
<td>5 minutes</td>
<td>Have students answer Questions 2 and 3 in their student packet (Supporting File S1) in their teams. Walk around and discuss with teams.</td>
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<td></td>
<td><strong>Part 1: Questions 2–3 Discussion</strong></td>
<td>5 minutes</td>
<td>Have students shout out their answers and write them on the board. After you have many different types of answers, see if the students could help you group them into four main groups. Ultimately, decide on four interest groups/knowledge systems that could help address this problem, explain there could be more, but for the sake of this assignment you’ll be focusing on the following: Western science, TEK, government, and consumers.</td>
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<tr>
<td></td>
<td><strong>Part 1: Question 4</strong></td>
<td>8–10 minutes</td>
<td>Have students work in their teams to complete Question 4 (Table 1) in their student packet (Supporting File S1).</td>
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<td></td>
<td><strong>Part 1: Question 4 Discussion</strong></td>
<td>2–3 minutes</td>
<td>See if students have any questions. Maybe get an example for each interest group or knowledge system for one of the two questions.</td>
</tr>
<tr>
<td></td>
<td><strong>Introduce Part 2</strong></td>
<td>2 minutes</td>
<td>Explain the assignment to students. Have them ask questions if they have them. Tell them to coordinate with their team, exchange contact information, and be prepared to come to the next class period with Part 2 completed in their student packet.</td>
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<tr>
<td></td>
<td><strong>Work on Part 2</strong></td>
<td>Remainder of class, 10–15 minutes</td>
<td>Wander around the classroom to answer questions and make sure that students know what they are supposed to be doing. Ensure everyone knows what interest group/knowledge system they should be working on.</td>
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<tr>
<td>Activity</td>
<td>Description</td>
<td>Estimated Time</td>
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<tr>
<td><strong>Day 1 Homework</strong></td>
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<tr>
<td>Complete Part 2</td>
<td>Question 1 (Table 2), Question 2.</td>
<td>60 minutes</td>
<td>Students individually complete the section for their interest group or knowledge system. Students share their section with their team so each member has a completed table (Supporting File S1).</td>
</tr>
<tr>
<td>Part 3</td>
<td>Students work on an outline for their plan.</td>
<td>30 minutes</td>
<td>Questions are provided to help students consider what would be important to consider when creating a plan to address this problem. Students can work on this part individually or in their teams.</td>
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<tr>
<td><strong>Day 2 Class Activity</strong></td>
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<tr>
<td>Introduce Part 4</td>
<td>Introduce creating a plan and preparing to present.</td>
<td>5 minutes</td>
<td>Outline the requirements. Answer any questions. Keep this part short so students have most of the class period to work on their teams on the plan and presentation.</td>
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<tr>
<td>Part 4</td>
<td>Work in teams to complete Part 4.</td>
<td>45 minutes, or</td>
<td>Students should prepare three slides that are outlined in their student packet (Supporting File S1) and the Day 2 slides (Supporting File S11).</td>
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<tr>
<td></td>
<td>remainder of class</td>
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<tr>
<td><strong>Day 2 Homework (Optional)</strong></td>
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<tr>
<td>Finish Part 4</td>
<td>Work in teams to complete Part 4.</td>
<td>varies</td>
<td>Students can continue working with their teams to create their plan and prepare and practice their presentations if desired.</td>
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<tr>
<td><strong>Day 3 Class Activity</strong></td>
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<tr>
<td>Prepare for Presentations</td>
<td>Outline how the presentations will work.</td>
<td>5 minutes</td>
<td>Have students sit with their teams. Use day 3 slides (Supporting File S12) to go over how the presentations will work. Explain that you will set a timer to keep the presentations on time. No team can exceed 6 minutes. Divide the class so that three teams are working together. Each team presents to two other teams.</td>
</tr>
<tr>
<td>Presentation Set Up</td>
<td>Students get in teams and prepare to present.</td>
<td>5 minutes</td>
<td>Give students 5 minutes to prepare to present with their teams. Have them seated near the teams they will be presenting by.</td>
</tr>
<tr>
<td>Presentation Round 1</td>
<td>First team presents.</td>
<td>6–7 minutes</td>
<td>Give students a 1-minute warning when you are at 5 minutes. Allow for a 1-minute buffer between teams to allow the next team to set up.</td>
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<tr>
<td>Presentation Round 2</td>
<td>Second team presents.</td>
<td>6–7 minutes</td>
<td>Repeat previous step.</td>
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<tr>
<td>Presentation Round 3</td>
<td>Third team presents.</td>
<td>6–7 minutes</td>
<td>Repeat previous step.</td>
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<tr>
<td>Part 5</td>
<td>Post-presentation questions.</td>
<td>5 minutes</td>
<td>Have students complete Part 5 Questions 1–4 individually.</td>
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<tr>
<td>Discuss Part 5</td>
<td>Class discussion.</td>
<td>Remainder of</td>
<td>Have a class discussion on Questions 1–4. Ask students if there was anything they learned from this activity and discuss ways that TEK can be included in science as a class.</td>
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<td>class, around 14 minutes</td>
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<td><strong>Day 3 Homework</strong></td>
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<tr>
<td>Part 6</td>
<td>Reflection questions.</td>
<td>30–60 minutes</td>
<td>Students complete the Reflection Questions individually as homework found in their student packet under Part 6. There are 5 questions.</td>
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</table>
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Exploring Indigenous Viewpoints in the Undergraduate Biology Classroom: An Environmental Case Study Incorporating Hawaiian Traditional Ecological Knowledge

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