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Cultivating Teachers' Indigenous Knowledge through Explorations of Milkweed and Phenology

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ABSTRACT

Providing more equitable pedagogies to all students, including those who are traditionally underrepresented, is a high priority of science education. In this paper, we outline how we coupled Indigenous Ways of Knowing with investigations about plant phenology, or the timing of plant development, a trait that is expected to shift with a warming climate. We paired the investigations with lessons that allow secondary students the opportunity to explore the cultural significance of common milkweed (*Asclepias syriaca),* a host plant for the iconic and threatened monarch butterfly (*Danaus plexippus*). In our teaching, we specifically investigate the effect of milkweed phenology, or the timing of development, on species interactions. From teaching students in a variety of contexts about milkweed phenology and species interactions, we have learned that the topic is engaging and accessible to many students. We find that coupling inquiry with explorations of the cultural significance of milkweed deepens students learning and generates opportunities to compare Indigenous Ways of Knowing and Western Science and to learn how they can work together to assess the impacts of climate change.

Keywords: Indigenous ways of knowing; monarch butterfly phenology; species interactions; ecology; disciplinary literacy; jigsaw

Providing more equitable pedagogies to all students, including those who are traditionally underrepresented, is a high priority of science education (Rozowa, Brown, and Barron 2017). Indeed, the *NGSS* in Appendix D (2013), challenges educators to develop learning opportunities that allow greater access for "all standards, all students." In Minnesota, science teachers are asked to meet the benchmark of Minnesota Academic Standards in Science that seek to provide place-based evidence learning of American Indian Tribes and communities:

> Apply place-based evidence, including those from Minnesota American Indian Tribes and communities and other cultures, to construct an explanation of how a warming climate impacts the hydrosphere, geosphere, biosphere, or atmosphere. (Minnesota Department of Education 2019)

In this paper, we outline how we coupled Indigenous Ways of Knowing with investigations about plant phenology, or the timing of plant development, a trait that is expected to shift with a warming climate. We paired lessons that allow secondary students the opportunity to explore the cultural significance of common milkweed (*Asclepias syriaca),* a host plant for the iconic and threatened monarch butterfly (*Danaus plexippus*, see Figure 1), with those that prompt them to observe interactions between herbivores and plants and to inquire about the role of phenology structuring milkweed interactions with both herbivores and humans.

Background on indigenous ways of knowing

Indigenous Ways of Knowing (IWK) is a term used to try to encapsulate Indigenous knowledge of the natural world. In Native communities, knowledge of the natural world incorporates our language, history, and culture, and is passed from elders to younger generations in specific ways and with specific traditions. Indigenous scientists blend IWK with Western science in ways that prioritize traditional ecological knowledge. For example, the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) is an organization that protects the traditional hunting, fishing, and conservation rights of Tribal communities in the Midwest by infusing Ojibwe knowledge into natural resource management. Indigenous science offers different epistemologies from Western science (Bang and Medin 2010). Robin Wall Kimmerer (2022) affirms Indigenous models of knowledge as based on mutual respect and autonomy with the natural world. She posits that traditional ecological knowledge is:

> The cumulative body of knowledge, practice and belief concerning the living beings to one another and to the physical environment. [This] knowledge evolved by adaptive processes and is handed down through generations by cultural transmissions. (Kimmerer 2022)

A critical aspect of Indigenous science is that humans, as learners of the world, seek not only knowledge about the reciprocal relationships among beings, but also the responsibilities we hold to all beings (Cajete 2000).

Indigenous *relationality with* the land as well as *responsibility to* the land are key aspects of building and maintaining sustainable relationships. This isn't limited to human-land relationships, but rather includes human-human relationships, human-plant relationships, human-animal relationships, etc. (McCoy et al. 2020). All beings benefit from this approach to relationality and responsibility to the natural world. In many Indigenous communities and teachings, these responsibilities are positioned as relationships with relatives (Cajete 2000; McCoy et al. 2020). It is common for departments of natural resources to create and maintain *management* plans *for* species and ecosystems. In contrast, some Tribal entities have created *relationship* plans *with* relatives (see: The Bad River Band of Lake Superior Chippewa Relationship Plan with Ma'iingan, Fergus and Hill 2019). By maintaining reciprocal and healthy relationships among plant, animal, and human relatives, Indigenous communities contribute vital knowledge in the growing need for climate change mitigation. The GLIFWC climate change vulnerability assessment, for example, weaves the aforementioned Ojibwe science knowledge with western science natural resource planning to carefully attend to plant and animal relatives in the face of a changing climate (Panci et al. 2018).

When science learning is centered around sociopolitical consciousness, students engage with science content in more tangible and contextual ways (Mensah 2022). Furthermore, students build and refine their own critical thinking skills when they engage in sense-making around socio-ecological phenomena (Upadhyay 2009). Foundational to these statements are "nature-culture relations" – the premise that, as *part of* the natural world, humans are constantly engaging in relationships with all beings in that natural world (Warren et al. 2020). This is expressly an Indigenous science perspective, as Western ways of ecology have historically tended to place humans *apart from* the natural world. Positioning students to learn science content from a place of nature-culture relationships benefits their conceptual understanding and critical reasoning.

Importance of phenology, species interactions and culture

Students can begin to build awareness of nature-cultural relationships by learning about examples of human interactions with species in parallel to learning about species interactions. In many ecology classes, students learn about species interactions such as predation and mutualism that may provide opportunities to help students recognize the importance of human interactions with other species.

Because the decline of migrating populations of monarch butterflies has attracted international concern, and because planting milkweed to support monarch populations has recently been widely promoted, our investigations and lessons focus on the

FIGURE 1

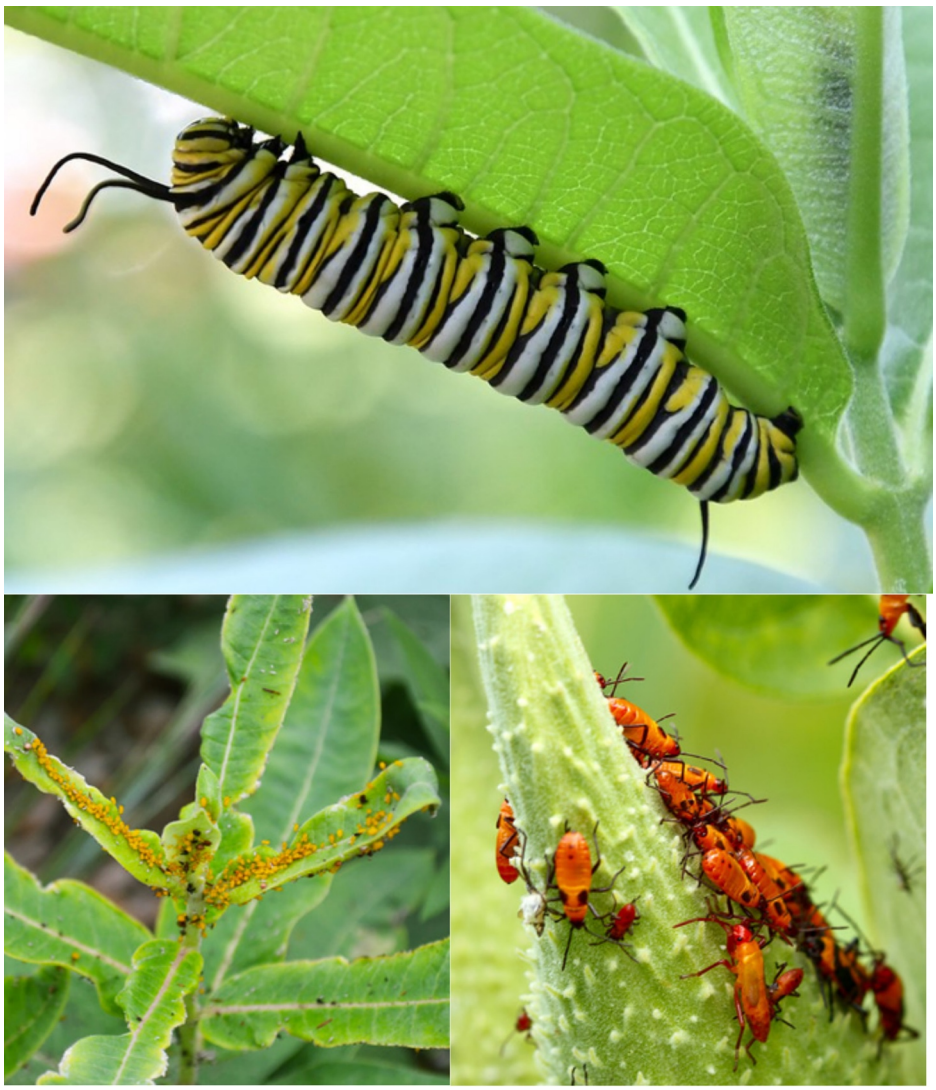
Monarch butterfly on flowering common milkweed (*Asclepias syriaca*).

interactions of milkweed, especially *Asclepias syriaca*, with a variety of animals, including monarch butterflies and humans. Humans and milkweeds have a long and varied history. Milkweed plants were a source of medicine, fiber, and food to Indigenous communities and early settlers (Gaertner 1979). Native Americans explored their use in sandals, moccasins, mats, lures, flutes and more (Campbell et al. 2016). However, as agriculture spread, milkweeds came to be viewed as a weed and their populations declined, though the exact cause is debated (Pleasants and Oberhauser 2013; Boyle, Dalgleish, and Puzey 2019). The association between monarchs and milkweed has contributed to a shift in the way many Americans value and view this species.

We specifically investigate the effect of milkweed phenology on species interactions (Figure 2). The timing of an organism's life stages, like flowering or dispersing seeds, is important for helping it survive, by avoiding dangerous conditions, and thrive, by accessing resources when they are most available. However, shifts in phenology can happen due to climate change, urban heat island effects, or light pollution, and can alter everything from allergy season to water cycles (Meng 2021). We chose to study phenology because phenology has been shown to strongly impact species interactions like pollination and herbivory in a variety of ecological systems (Kharouba et al. 2018) and because plant phenology is expected to shift in response to climate change. When interacting species experience different kinds of shifts in phenology, "phenological mismatches" can disrupt food chains or pollination (Kudo and Cooper 2019; Van Asch et al. 2007). Researchers hypothesize that monarchs time their

FIGURE 2

Monarch caterpillars (*Danaus plexippus*) (top), Aphids (Aphidoidea) (lower left), Milkweed bugs (*Oncopeltus fasciatus*) (lower right) on common milkweed (*Asclepias syriaca*).



spring migration north from Mexico to correlate with milkweed growth in the United States (Guerra and Reppert 2015), so shifts in milkweed emergence phenology could affect monarchs. Human interactions with milkweed are no different: plants must be harvested at the appropriate developmental stage to satisfy specific needs for food, medicine, and fiber, so shifts in milkweed phenology will alter the timing of human interactions with the plant. As humans continue to dramatically alter ecological communities around the globe, we think it is important for students to investigate the complex effects of these actions on communities and organisms they can observe and interact with, just as people have done for many generations.

Lesson 1: Investigating phenophases: 45–50 minutes

We begin this lesson by directing students to the Chat Stations around the classroom in groups of 4–5. Students chat about the picture and respond together to the questions on each chat poster, rotating through the stations every 2–3 minutes. Next, students return to their tables where, with a partner, they complete a word and picture sort. Pairs work together to match

milkweed phenophase words with the appropriate picture. These opening activities support differentiation through the use of pictures and words, well-documented strategies for supporting students with diverse learning needs in developing scientific language (Koomen et al. 2018) and serve as informal assessments.

The lesson continues with students exploring current common milkweed phenophases using either: (1) photographs of milkweed plants, (2) milkweed samples in the classroom or (3) a schoolyard based common milkweed plot to observe that some plants are clearly more developmentally advanced than others. Teachers taking students outdoors should consider previewing plants first in the classroom, setting behavioral expectations before going outdoors, selecting a spot to meet for instruction, and establishing parts of the garden and plants that student teams will observe.

Lesson 2: Investigating interactions across phenophases; 45–50 minutes

Phenophases are observable stages during an organism's life cycle (Figure 3) that strongly impact species interactions. For example, pollinators primarily interact with plants when they are flowering, and herbivores might prefer newly emerged plants that are not yet well-defended. We use the Phenology, Damage and Invertebrate Guide to help students identify some of the common milkweed herbivores and pollinators that interact with the milkweed phenophases. We suggest that teachers edit the Guide to reflect common invertebrates that interact with milkweed at the particular time and place of study, rather than try to teach everything in the Guide.

We engage students in thinking of species interactions by returning to the Milkweed Chat records from Lesson 1 and invite the students to talk in small groups about questions such

FIGURE 3

Common milkweed (*Asclepias syriaca*) life cycle can be divided into seven phenophases.

as: *what is happening in the picture? How are the invertebrates and plants being served or damaged? Who benefits and who does not in the interactions?*

Next, use the Guide to describe various herbivores and pollinators that interact with common milkweed. If possible, take students outdoors to observe interactions on various phenophases in a school milkweed plot. For example, ask students to observe several plants during the same class period, some of which are much further along in the seed dispersal stage than others, and to record the herbivores and damage they observe on the plants. After sharing data with the class, students can analyze the importance of these differences in phenology by studying both human and non-human interactions with milkweed plants. Even if students cannot engage in the outdoor investigations, they can study milkweed interactions with monarchs through graphs and readings available at marenweb.com in parallel with readings about cultural significance of milkweed.

Lesson 3, 4 and 5: Cultural significance of milkweed jigsaw; 45–50 minutes each

The cultural significance of milkweed activity is designed as a jigsaw with two parts. For part 1 (1–2 class sessions), students are assigned one of four readings (Table 1) about the significance and uses of milkweed in a variety of human contexts. As disciplinary literacy lessons in science, we suggest teachers use Supplemental 6, seven most important words, a research-based reading strategy that allows differentiation for all students to define key vocabulary for themselves in context (Zygouris-Coe 2015).

As students read their assigned resource, they take notes about the uses of the milkweed plant at specific phenophases (Table 2). For example, they might read about how milkweed stems can be eaten like asparagus during the early phase of vegetative growth, but medicinal uses are more common during the later phenophases when there are more toxins in the plant, and milkweed stems of a dying plant can be used for fiber. These readings complement observational field studies well. For example, students who spent time observing milkweed seeds dispersing in the wind in the fall could readily imagine school children collecting the fluff to stuff life jackets during World War II but had a harder time imagining how unripe seed pods earlier could be fried and served as a tasty appetizer. In each case, the readings extend and enrich students' understanding of the plant they are investigating, helping them make connections between human-plant interactions (McCoy et al. 2020) and nature-culture relations (Warren et al. 2020).

In part 2 (1–2 class sessions), students who have read each article collaboratively answer a set of 12 questions (Table 2) about milkweed names and uses of milkweed for food, fiber, and medicine. The structure of this activity means each student has unique contributions to make to help the group develop a complete set of answers. There is some redundancy in the readings, so students can compare and synthesize the separate readings to develop more complete answers to many of the questions. In our teaching, students used the materials and supports to successfully complete the jigsaw and contribute to a whole-class discussion, demonstrating competence in the following learning target: Students can explain, predict and provide evidence for the impact of milkweed phenology on interactions with herbivores and humans (Figure 4), aligned with the *NGSS* and Common Core Standards found in Supplemental Tables 3–8 (See Online Supplementary Materials).

In discussion, students begin to articulate connections between human interactions with milkweeds and the interactions of other milkweed consumers they observed by recognizing that phenology structures and influences all of these types of interactions, thus engendering reciprocal and recursive relations to the nature world (McCoy et al. 2020), a hallmark of IWK. For example, they hypothesize that humans prefer to eat the same stages of the plant that insects seem to prefer.

In our teaching of this jigsaw so far, students have not yet connected their knowledge about the impact of climate

TABLE 1

References for the four readings used in the *Cultural Significance of Milkweed* jigsaw activity.

1. Campbell, J., Kavasch, E.B., Kennedy, K., Kennel, E., and Seeley, G. 2016. Herbal Milkweeds: An Herb Society of America Essential Guide. Kirtland, OH: Herb Society of America. Essential Guide. *Asclepias syriaca* (pp. 29–31) and *Recipes* (pp. 37–38). https://drive.google.com/file/d/1vjbBs9-fiz7HQzqvaZqioRiCTUkqfc4Z/view.
2. Campbell, J., Kavasch, E.B., Kennedy, K., Kennel, E., and Seeley, G. 2016. Herbal Milkweeds: An Herb Society of America Essential Guide. Kirtland, OH: Herb Society of America. Essential Guide. *Introduction, Ethnobotany* (pp. 4–7). https://drive.google.com/file/d/1vjbBs9-fiz7HQzqvaZqioRiCTUkqfc4Z/view
3. Mohl, E. 2022. Compiled Indigenous Recipes and Reflections on Milkweed as Food. Author Department, Author University. https://docs.google.com/document/d/1L7k9LkeEjdueM3ewGV_hspH8i1zJuXnPaOC8npCBock/edit#heading=h.l5rjcfhc6c35.
4. Clark 2012. Milkweed fruits: Pods of plenty. Washington Post. https://www.washingtonpost.com/wp-srv/special/metro/urban-jungle/pages/120925.html.

TABLE 2

Guided questions targeted to the four readings.

Names	Food	Fiber	Medicine
What does the scientific name *Asclepias* signify?	When and how can one prepare milkweed to serve it in a similar way to asparagus?	When and how did children collect fibers from milkweed plants for the US Navy? Why?	What part of the milkweed plant has been used to treat topical concerns like bee stings, warts, or ringworm?
What is the Potawatomi name for milkweed?	When and how can one prepare milkweed to serve it in a similar way to okra?	What are some products that have been made from mature milkweed stems?	What part of the milkweed plant has been burned to treat asthma?
What is the Ho-Chunk name for milkweed?	Recent scientific research shows that cutting back milkweed can benefit monarchs. Who has practiced this habit for human benefit for many years?	Fibers from stems of dogbanes and milkweeds have been woven into nets, ropes, and other objects. What are some differences between dogbanes and milkweeds?	When and how would one harvest milkweed for medicinal purposes in comparison to food. Why?
Additional Resources: Bergo, A. 7.4.2000). Forager's Guide to Milkweed. Forager/Chef. https://foragerchef.com/guide-to-milkweed/ Berkman, B. (1949). Milkweed—a war strategic material and a potential industrial crop for sub-marginal lands in the United States. *Economic Botany*, *3*(3), 223–239. Mader, L S. (2014). Milkweed: Medicines of Monarchs and Humans. *HerbalGram, Journal of American Botanical Council, 101*, 38–47.			

change on milkweed phenology to its interactions with humans and herbivores, nor have they articulated relationships between IWK and Western Science. We suggest adding the following discussion prompts after the jigsaw to support student thinking on these topics. (1) Warmer temperatures are expected to cause milkweed plants to emerge earlier in the spring (Mohl et al. 2023). How might this change milkweed interactions with herbivores and humans? And (2) IWK view humans as part of, and in relationship with, the natural world; whereas Western Science tends to view humans as apart from, and in control of, the natural world. Where did you find evidence of these different ways of knowing in your readings about milkweed phenology? For the first question, students might predict that early emergence might mean the milkweed plants are bigger and less palatable when monarchs return from Mexico, and that humans might need to harvest milkweed earlier in the year or cut it back in order to access appropriate phenophases at a typical time of the year. For the second question, students might productively discuss the ways Indigenous recipes utilize all parts of the milkweed plant at many different phenophases and that the Potawatomi people have a practice of cutting milkweed plants to manipulate their phenology, practices that suggest a deep knowledge and relationship with the living plants. They might also notice the ways Western science has focused primarily on using the seed pod stage and engaged in widespread extraction, practices that suggest a focus on production goals rather than relationship.

Finally, we suggest that students explore the GLIFWC Climate Change Vulnerability Assessment (GLIFWC Climate Change Team 2023) as a way to synthesize their learning about how phenology can impact human-nature interactions and apply it beyond milkweed. One example student's have appreciated learning about is the science and significance of Aandeg, the crow, to the Ojibwe: "The Ojibwe follow a lunar calendar that consists of 13 moons and has connections to phenological events. Aandego-giizis (Crow Moon) is one name used for the month of March… Various elders during Traditional Ecological Knowledge interviews shared that Aandego-giizis… is the time of year when aandeg arrives and announces the news that it is time to prepare for tapping ziizibaakwadwaatigoog (sugar maples)" (GLIFWC Climate Change Team 2023, p. 176–177). As students identify additional examples of the cultural significance of phenological events, they will see how IWK and Western Scientific knowledge intersect to support predictions about how climate change is likely to impact human and non-human beings and their interactions.

FIGURE 4

Student completed responses to Table 2 (guided questions targeted to the four readings).

You will be assigned a reading. As you read, *please keep in mind that milkweeds protect themselves with toxins that affect the heart, and there are even more toxic plants that may be confused with them.* ***please do not eat or use milkweed medicinally without guidance from experts.*** Find readers of the other articles who can help you answer questions below about the cultural significance of milkweed.

1. Herbal Milkweeds—Essential Guide. *Asclepias syriaca* (pp. 29-31) and *Recipes* (pp. 37-38).
2. Herbal Milkweeds—Essential Guide. Introduction, *Ethnobotany* (pp. 4-7).
3. Compiled Indigenous Recipes and Reflections on Milkweed as Food
4. Milkweed Fruits-Pods of Plenty, The Washington Post, Sept. 25, 2012.

Names	Food	Fiber	Medicine
What does the scientific name *Asclepias* signify? Named after god Appolo because of his healing powers	When and how can one prepare milkweed to serve it in a similar way to asparagus? In first weeks of Spring you take top 2 inches and boil it.	When and how did children collect fibers from milkweed plants for the US Navy? Why? Kids grabbed pods WWII for life vests. Hollow fiber ~~was~~ are coated in wax making them waterproof and buoyant.	What part of the milkweed plant has been used to treat topical concerns like bee stings, warts, or ringworm? The milky sap
What does the name milkweed tell us about the plant? Milky juice in stem	When and how can one prepare milkweed to serve it in a similar way to broccoli? Boil and/or steam young summer buds	To design an all-natural diaper that was highly absorbent, what part of the plant should one harvest? When? Floss from seed pod can be 75x it weight absorbant	What part of the milkweed plant has been boiled to make teas that were taken for many reasons (heart problems, constipation, etc.) Roots were used for teas
What is the Potawatami name for milkweed? Nenwa'jek	When and how can one prepare milkweed to serve it in a similar way to okra? Can put in saucepan and simmer during July-August	What are some products that have been made from mature milkweed stems? Medicine pipes, instruments	What part of the milkweed plant has been burned to treat asthma? Leaves were burned and inhaled
What is the Ho-Chunk name for milkweed? Mahic	Recent scientific research shows that cutting back milkweed can benefit monarchs. Who has practiced this habit for human benefit for many years? Potawatami	Fibers from stems of dogbanes and milkweeds have been woven into nets, ropes, and other objects. What are some differences between dogbanes and milkweeds? Dogbanes are more toxic than milkweeds Dogbanes have fuzz on stems	When and how would one harvest milkweed for medicinal purposes in comparison to food. Why? Harvest food when its just beginning to bloom. Medicine when its more mature.
Additional Resources: ○Forager Chef guide to milkweed; ○ Milkweed: Medicine of Monarchs and Humans, by Lindsay Stafford Mader; ○ Berkman, B. 1949. Milkweed: A War Strategic Material ... *Economic Botany*.			

Conclusion

From teaching students in a variety of contexts about milkweed phenology and species interactions, we have learned that the topic is engaging and accessible to many students. Nearly every student is familiar with seasonal changes in plants, with many eager to search for brightly colored insects on "their" milkweeds. That said, many students do not have deep experience with the seasonal changes in milkweeds specifically, so they need training and practice learning to make specific observations, and they need help putting their learning into context. The cultural significance of milkweed activity can help students make connections about the milkweed life cycle beyond the particular stages and herbivores they can observe in the field at any given time.

An important layer of the cultural significance of milkweed activities, for both students and teachers, is examining how incorporating Indigenous science knowledge can deepen understanding of phenology. Indigenous communities position species as relatives; milkweed are plant relatives. Broadening students' understanding of multiple perspectives and IWK in science is an important first step in fostering intentional relationality and responsibility that we, as humans, need to have with the natural world.

Likewise, building teacher knowledge and self-efficacy is critical. Teachers across many districts cite a common barrier to the inclusion of IWK in their science classrooms, often saying "we don't know what we don't know." Science educators are leery of misstepping or providing inaccurate information to their students. This undertaking can be less overwhelming if we remember that our goals are to take *incremental* steps in demonstrating how Indigenous and Western science knowledge interact. We intend for this article to provide a starting place for such important conversations.

Lesson materials list and safety considerations

Lesson 1: Investigating phenophases. Materials needed: Student copies of student guide to phenology (Supplemental File 3), milkweed phenophases word and picture sort (Supplemental File 1), monarch/milkweed chat stations (Supplemental File 2), and for outdoors a clipboard.

Safety: Students should wear safety goggles and wash their hands after handling samples of milkweed, as the milkweed latex may be a skin or eye irritant.

Lesson 2: Investigating interactions across phenophases. Materials needed: Phenology, Damage, and Invertebrate Guide (Supplemental File 4).

Lesson 3, 4 and 5: Cultural Significance of Milkweed Jigsaw. Materials needed: Refer to Table 1 for Jigsaw readings; Access to computer or tablet; Table 2, (Guided questions targeted to the four readings) printed; Supplemental File 5. Guided questions with possible answers targeted to the four readings; Supplemental 6. Seven Most Important Words or Supplemental File 7. Word sort for four readings.

ONLINE SUPPLEMENTARY FILES

1. Common Milkweed Phenophases Word and Picture Sort
2. Monarch and Milkweed Chat Stations
3. Student Guide to Phenology
4. Herbivore Damage and Invertebrate Guide
5. Guided Questions with Possible Answers Targeted to the Four Readings.
6. Seven Most Important Words
7. Connecting to the *Next Generation Science Standards*
8. Connections to the Common Core State Standards
9. Assessment Rubric Aligned with *Next Generation Science Standards*
10. Rubric Aligned with Common Core State Standards

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the author.

SUPPLEMENTARY MATERIAL

Supplemental data for this article can be accessed online https://doi.org/10.1080/00368555.2024.2388822

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