Matt Bennett
MGSE 5146
Dr. Sue Kelley
Spring 2026

Project-Based Instruction in high school environmental science: integrating Permaculture design challenges (disaster response, redesign, recovery) and an Indigenous knowledge lens.

1. Introduction and definitions

Project Based Instruction (PBI) is a teaching method where students gain academic knowledge and transferable skills by working for an extended period to investigate and respond to an authentic, engaging, and complex question, problem, or challenge. Students make important choices for the direction of their undertaking, reflect, critique, and make revisions along the way and at the conclusion, present their projects publicly - ideally inspiring real world impact. In contrast to minimally-guided inquiry based learning, PBI teachers intensively plan thoughtfully bounded projects and integrate educational supports using a variety of techniques to ensure students acquire a mix of learning objectives for both academic content and skill-building. Some of these teacher moves include just-in-time direct instruction, scaffolding of various kinds, teacher modeling, Socratic questioning, formative feedback loops, think-alouds, milestone checkpoints, resource curation, and protocols & routines.

Permaculture is a design system developed in the 1970s by Bill Mollison and David Holmgren that organizes ecological, agricultural, and social design around the three ethics of Earth Care, People Care, and Fair Share. The iterative process is built on the scientific method, calling for prolonged and thoughtful observation before designing and implementing an intervention to achieve a set of goals, which is then followed by more observation and refinement of goals, design, and intervention. The design process also relies on a set of principles drawn from observation of natural ecosystems (design from patterns to details, use edges and value the marginal, use and value diversity, etc.). Originally articulated as a method for designing low-input, regenerative food systems, Permaculture has since broadened into a general design approach for human settlements, with water and sanitation, renewable energy systems, natural building, and even the design of the organizations, businesses, and governance systems that support them. Within this frame, appropriate technology - low-cost or DIY-built, locally repairable, energy-conserving tools, equipment, and appliances that are matched to the resources and skills of the community using them - sits naturally as the technical layer of an otherwise ecological design grammar.

By “disaster response, redesign, and recovery” I mean three distinct design phases. Response is the immediate triage of food, shelter, water, and safety needs in the days and weeks following a disruption. Redesign is the rebuilding of damaged systems in new ways, perhaps temporarily, with sustainable goals in mind, but still operating within post-disaster resource limitations. The last stage is recovery, the long-term restoration of ecological, social, and economic functions so that a community becomes more vibrant, more resilient, and more regenerative compared to the pre-disaster normal. Following Kimmerer (2013), I use “Indigenous design traditions” interchangeably with “Indigenous knowledge” to mean place-based ecological knowledge built over generations of careful observation and sustained relationship, treating the more-than-human world as kin rather than resource and integrating empirical rigor with ethical obligation.

As a Permaculture instructor for adults, I hope to develop and teach my own PBI curriculum for high school environmental science utilizing Permaculture Design. The design-challenges would be centered around meeting human needs in scenarios involving disaster response, redesign and recovery. The curriculum would also study Indigenous design traditions from around the world for inspiration to imagine new and improved integrated food, shelter, water, and even social systems to meet all of Maslow's Hierarchy of Needs (physiological, safety, love and belonging, esteem, self-actualization). Towards this end, I am researching to see if the literature supports this methodology and to discover evidence-based guidance on how best to deliver this content.

The six articles below were chosen to test that question from four angles: PBI as an instructional method (Krajcik et al.); Permaculture as content (Akram et al.; Lebo & Eames); Indigenous knowledge as a way of knowing (Matindike & Ramdhany; German et al.); and disaster education as a pedagogical problem in its own right, where the literature has shown that conventional instruction fails to convert knowledge into action (Nakano & Yamori). Lebo & Eames and German et al. additionally serve as the application-side accounts of what Permaculture-framed and Indigenous-knowledge-integrated science teaching actually looks like when enacted in real secondary classrooms.

2. Article Summaries and Best Practices to Implement

Krajcik et al. (2023) - Research

Krajcik and colleagues (2023), writing in the *American Educational Research Journal*, report a cluster-randomized efficacy trial of the Multiple Literacies in Project-Based Learning (ML-PBL) science curriculum across 46 Michigan schools and 2,371 third-grade students, comparing outcomes to business-as-usual instruction. Students in ML-PBL classrooms showed a 0.277 standard-deviation gain on a standardized science test and reported significantly higher levels of self-reflection and collaboration during science activities. The effect held across racial, socioeconomic, and reading-level subgroups, with a slight negative outcome for students who are English Learners (ELs) - a caveat my TESOL studies suggest may stem from insufficient teacher training in scaffolding and differentiating for ELs, since interactive projects without explicit linguistic supports can become less accessible than conventional instruction. Even with that caveat, this is the strongest evidence in my set that well-implemented PBL outperforms conventional science instruction. However, the setting of this study is third grade, not high school, so the article cannot answer my inquiry question on its own. What it does establish is that PBL works in science under controlled conditions when implemented through a specific set of design principles - driving question, sustained investigation, public artifact, formative assessment, and three-dimensional alignment with the *Framework for K–12 Science Education* - and it leaves open whether those same principles carry to a secondary environmental science unit organized around Permaculture and disaster scenarios.

Krajcik et al. point to six concrete moves that distinguish ML-PBL from typical project-flavored instruction and would translate directly into a Permaculture-PBI environmental science unit. First, anchor each disaster scenario in a single explicit driving question that is named at the start, returned to weekly, and refined as students' understanding grows. Second, plan for sustained investigation across weeks rather than single-day activities - Krajcik's units run on multi-week timescales, which is what allows iteration, revision, and conceptual depth to develop. Third, build toward a public artifact: a designed schoolyard installation, a community presentation, a published proposal. As a result, students' work has a real audience beyond the gradebook. Fourth, use formative assessment continuously, with regular check-ins, rubric-mediated feedback, and visible revision cycles, rather than relying on a summative end-of-unit test. Fifth, design for three-dimensional alignment, integrating disciplinary core ideas (ecology, water systems, energy flows), science and engineering practices (modeling, designing solutions, argumentation), and crosscutting concepts (systems, cycles, cause and effect). This alignment also makes the curriculum legible to administrators and standards-aligned reviewers. Sixth, anticipate the EL accessibility gap up front. Krajcik's slight negative finding for English Learners is a warning that without explicit linguistic scaffolds (sentence frames, multilingual glossaries, structured peer talk, visual supports drawn from SIOP or WIDA), interactive projects can widen rather than close the access gap. For a unit designed to draw on Indigenous knowledge-holders and on immigrant family expertise, this scaffolding is doubly necessary because the students with the most to contribute may be the ones the conventional ML-PBL design accidentally excludes.

Matindike & Ramdhany (2025) - Research

Matindike and Ramdhany (2025), writing in *Research in Science & Technological Education*, conduct a PRISMA-style systematic review of empirical studies that incorporate Indigenous Knowledge (IK) into integrated STEM instruction, coding the literature for grade level, IK domain represented, integration strategy, and reported student outcomes. Their cross-study synthesis surfaces three findings that emerge only from aggregating across the literature. IK integration appears most often in environmental and biological science topics, making this review's evidence base especially relevant to environmental-science curriculum design. Genuine integration - as opposed to tokenistic reference - requires sustained, multi-year partnership with knowledge holders rather than textbook quotations or one-time guest visits, and this is the distinction that reliably separates programs which actually shift student outcomes from programs that do not. The outcomes researchers report are overwhelmingly attitudinal and motivational (interest, motivation, sense of belonging, identity) rather than disciplinary content gains on standardized assessments. For my inquiry this review is the cornerstone source on the Indigenous knowledge lens: it tells me what genuine IK integration looks like procedurally, what depth of partnership is realistic to plan for, and which student outcomes I should plan to measure if I were to enact the unit I am imagining.

Matindike and Ramdhany point to four design moves that translate directly into a Permaculture-PBI environmental science unit drawing on Indigenous knowledge. First, treat Indigenous knowledge as substantive disciplinary content rather than cultural enrichment - specific agro-ecological, architectural, or medicinal practices co-taught with named knowledge holders, not decorative mentions sprinkled into a Western curriculum. Second, build the partnership before the unit is taught - the review's strongest finding is that programs which actually shift student outcomes are anchored in sustained, multi-year co-design with the same knowledge holders, which means the partnership timeline starts a year or more before the first student walks in, not the week the unit begins. Third, design assessment to measure engagement and identity outcomes alongside content mastery, not *instead of* it - the review's outcome pattern is overwhelmingly attitudinal because that is where IK integration reliably produces gains, but a unit that fails to also measure disciplinary science learning leaves itself exposed to the charge that cultural integration came at the cost of rigor. Fourth, choose IK content from the environmental and biological domains where the review's evidence base is concentrated - water cycles, soil and forest ecology, seasonal calendars, plant–pollinator relationships, animal behavior - both because these are the topics where IK and Western-science co-teaching has been most thoroughly documented and because they map cleanly onto the disaster response, redesign, and recovery framing of my curriculum.

Akram et al. (2025) - Research

Akram and colleagues (2025), in *Natural Sciences Education*, report a cross-sectional survey of 1,304 Pakistani secondary and higher-secondary students (561 boys, 743 girls) from private schools in Lahore, examining how students perceive Permaculture as a tool for environmental literacy. The 35-item Permaculture Environmental Literacy Scale (5-point Likert, 1 = strongly agree; Cronbach's α = .885) covered three subscales - Permaculture science, Permaculture practice, and Permaculture sustainability. Students near-uniformly endorsed “Humans are as much a part of the ecosystem as plants and other animals” ($M = 1.456$) and “Conservation is for human survival” ($M = 1.473$), with 77% agreement on nature–human interconnection; they rejected materialist framings ($M = 2.71$) and the fatalist claim that individual action cannot matter ($M = 2.862$). Inferentially: no gender difference ($p = .870$); significant age effect ($F = 11.391$, $p < .001$), older students grasping Permaculture more comprehensively; significant differences by current and previous degree program ($p = .037, .046$); but no relationship to academic grades ($p = .829$) - exposure to varied academic fields shifts environmental literacy more than grade-tier performance does. Because the study isolates the conceptual lens rather than testing any pedagogy, it is the strongest available student-voice evidence that Permaculture as content shifts environmental literacy independent of method; the authors call for “experimental and longitudinal studies” (p. 14) to confirm whether views translate to behavior. For my inquiry it supplies what I need on one front: evidence that Permaculture as content shifts environmental literacy - attitudes, awareness, and self-reported willingness to act. What it does not show is whether Permaculture framing produces measurable gains in disciplinary science knowledge, which is a distinct empirical question (parallel to the one Matindike & Ramdhany flag for Indigenous knowledge integration) that would need separate evidence before I can claim Permaculture-themed PBI works as a science-content vehicle and not just an attitudinal one.

Still, in order to achieve the attitudinal gains, Akram et al. point to six empirically warranted moves for a Permaculture-PBI environmental science unit. First, open with hands-on Permaculture design before formal definitions. Akram observes that “engaging in hands-on activities also helped people develop a deeper emotional connection to environmental challenges” (p. 12), challenging knowledge-first orthodoxy. In my case, this would mean front-loading the first design challenge before lecturing on the three ethics and twelve principles. Second, do not gate by academic performance. The study showed students at all performance levels engaged with Permaculture comparably, so do not relegate this content to honors sections. Third, do not gender-stereotype the framing, as boys and girls held statistically identical views, so encourage student choice within the bounds of the unit's driving question. Fourth, calibrate complexity by age, as the significant age effect indicates 11th–12th graders can handle full systems analysis (water + soil + social design combined) where younger students benefit from concrete single-system entry points. Fifth, since students exposed to varied academic fields outperformed the category of students' grades as a predictor of literacy outcomes, it is best to explicitly bring in social studies, economics, ethics, and design thinking alongside the environmental science content, not as optional extension. Sixth, build agency-affirming moments into the spine. Students in the study rejected the fatalist claim that individual practices cannot change the world, so pair every disaster-response analysis with at least one designed and partially implemented student response, converting expressed agency into demonstrated agency.

Nakano & Yamori (2021) - Research

Nakano and Yamori (2021), writing in the *International Journal of Disaster Risk Reduction*, argue that conventional disaster risk reduction (DRR) education fails to convert knowledge into behavior because it operates within a “transmission paradigm” defined by three habits: (1) an active-instructor / passive-learner stance, (2) one-way knowledge transmission, and (3) short-term knowledge evaluation. They propose a replacement “proactive attitude paradigm” built on (1) instructor-learner fusion, (2) participation in a community of practice, and (3) long-term commitment evaluation. The case-study warrant comes from a teacher-training intervention in Nuwakot, Nepal: DRR class delivery rose from 3 of 27 schools in the baseline year to 10 of 17 schools in year two and 36 DRR classes in year three, demonstrating uptake under the new paradigm. Still, the authors are honest that only 2 of 8 schools could be reached for long-term follow-up, so the behavioral durability claim is suggestive rather than proven.

For a project-based, Permaculture-framed environmental science curriculum centered on disaster scenarios, the article points to four moves. First, design lessons as fusion events, where students and teachers solve an authentic local problem together, rather than sitting through lectures with worksheets. The Permaculture design cycle (observe → analyze → design → implement → reflect) is already structured this way. Second, anchor the course in a community of practice by partnering with local emergency managers, Indigenous practitioners, growers, or municipal planners so students rehearse the role of a contributing member, not a recipient of content. Third, replace short-term knowledge tests with long-term commitment evidence as the primary assessment, for example: design portfolios, implemented school-yard installations, community presentations, and follow-up check-ins months later. Fourth, build in mechanisms for the curriculum to outlive the course (peer mentoring, student-led drills, alumni return visits), since Nakano and Yamori's own follow-up failure is the cautionary tale: without structural continuity, even well-designed proactive-paradigm interventions can potentially dissolve once the lead instructor steps away.

German et al. (2023) - Application

German, Hernandez, and Scherr (2023), writing in *The Science Teacher*, describe a roughly two-week place-based water unit in a 10th-grade chemistry classroom that pairs an open-ended filtration challenge with student-driven community research and explicit Indigenous knowledge integration. Students contaminate their own water (soil, oil, food coloring, coffee grounds) and design filtration or distillation systems from sand, gravel, coffee filters, and paper towels, then watch the documentary *Thirsty for Justice* and conduct informal interviews with family and community members about local water issues. They self-select a research focus: mercury contamination, Indigenous water rights, hydroelectric dam impacts, or local quality testing using 15-parameter strips for pH, nitrates, hardness, and other variables. At the conclusion, students presented their findings as slide shows, posters, or videos. The unit names its theoretical lineage explicitly, drawing on traditional ecological knowledge from local Maidu and Wintu tribal members as content rather than enrichment, and the authors are candid about how the lesson worked: students who had grown up around irrigation systems shared knowledge the teacher lacked, becoming “the experts and teachers” - a structural inversion of the conventional knowledge-transmission classroom.

German et al. point to five moves that map cleanly onto the Permaculture-PBI-with-IK-lens framing. First, start with student-generated mess rather than teacher-prepared “dirty water” - students contaminating their own water samples is itself a meaningful design constraint, since they understand exactly what is in there. Second, release control on the design phase: the authors are explicit that prescriptive instructions kill creativity, and refining a design across multiple iterations (rather than nailing it on day one) is the actual engineering practice you want students rehearsing. Third, treat community members and family as primary sources, structuring informal interviews with prompts students take home rather than relying on textbook citations. This is the procedural form of Matindike & Ramdhany's “sustained partnership” finding, applied at the lesson level. Fourth, name and credit specific Indigenous knowledge holders (in their case, Maidu and Wintu tribal partners) as the source of the ecological framing. This is what the systematic-review literature calls genuine integration as opposed to tokenism. Fifth, let students self-select research focus from a curated menu, for example: environmental justice, contamination, water rights, local testing. This way individual investigations cohere with the unit's driving question while honoring student identity and prior knowledge as legitimate inputs to the science classroom.

Lebo & Eames (2015) - Application

Lebo and Eames (2015), writing in the *Australian Journal of Environmental Education*, report an interpretive mixed-methods case study in which Lebo himself co-taught a 12-week Permaculture-framed science and sustainability unit alongside one male mid-career science teacher (with no prior Permaculture knowledge) and 18 14-year-old students at a small secondary school in Hamilton, New Zealand, that Lebo and Eames describe as “mixed-race” - a city whose population draws principally from Pākehā (European-descended), Māori, Pasifika, and Asian communities. The intervention was structured as a three-unit “transformative chronology:” (1) Environmental Chemistry, opened with global climate change to function as a disorienting dilemma; (2) Ecological Principles, examining how natural systems achieve dynamic stability through diversity and feedback loops; and (3) Plants for Food, exposing students to original-Permaculture practices that mimic ecological design. The unit was anchored by two local field trips: a community food forest 1 km from school (≈20 fruit trees in two sheet-mulched clusters) and a 10-acre "Eco-Hostel" Permaculture site 7 km away with a water-retaining swale, chicken tractor, hot compost pile, and biologically diverse organic garden. Data came from pre/post questionnaires (including identical concept-mapping exercises with a 16-term word bank), 31 days of participant observation across 12 weeks, three focus-group student interviews, and three teacher interviews. All 16 students who attended the Eco-Hostel field trip agreed or strongly agreed both that the trip "helped me see Permaculture in action" and that "Permaculture is a good way to solve environmental problems"; the class mean on "enjoyed learning science with a focus on the environment" was 3.5/5 (SD = 0.7); on average, students made slightly more sustainability-themed conceptual connections after the unit (M = 1.8 → 2.2 per concept map), but the rising standard deviation (1.4 → 2.2) indicates the gains were unevenly distributed across students. Additionally, five of six students who reported not enjoying science in school agreed or were neutral that they enjoyed learning science with an environmental focus, so the unit reached the disengaged subgroup that traditional instruction had lost. The teacher began skeptical and ended saying he would "be using Permaculture more across the board," reframing biology from "the science of learning names" to "the science of process."

Lebo and Eames offer six moves that can be lifted directly into a Permaculture-PBI environmental science unit. First, sequence units as a transformative chronology rather than a content checklist. Open with a disorienting dilemma (climate change, a local disaster, a redesign challenge) so subsequent ecological and design content lands as response rather than abstraction; the order matters because relevance is built, not declared - the same affective claim Akram et al. make from the hands-on side. Second, replace the scaffolding metaphor with a trellis metaphor. The teacher designs supports that suggest where to grow without prescribing exactly what that growth looks like, allowing students to "weave in and out, branch laterally, or even reach out and grow on to another trellis." Concretely, this means publishing learning targets and constraints up front, but leaving the route through them genuinely open. Third, treat cultivating attitudes and trellising learning as twin moves, not a single pedagogy. The data showed previously disengaged students gained motivation while previously engaged students gained sustainability content, so the same trellis structure served different purposes for different student types. Fourth, run at least two local field trips, perhaps to a community Permaculture site and to a working farm or eco-property, late enough in the unit so that students arrive having already studied the relevant ecology and chemistry, so the trips function as recognition events ("I saw that in class") rather than introductions. Fifth, bring in a credentialed scientist-practitioner as the More Knowledgeable Other (MKO). Lebo notes that the participating teacher's initial reservations were lifted only when he saw the visiting Permaculturist as "the scientist coming in," not "some hippy." For Permaculture content to land in mainstream science classrooms, the visiting expert's scientific credibility is the essential credential. Sixth, frame the design as “science education through Permaculture” rather than “Permaculture through science education” - meaning the state and school environmental science standards remain the disciplinary content students are expected to master, while Permaculture functions as the pedagogical lens and process through which they acquire that content meaningfully. This distinction matters for both rigor and political defensibility: it prevents the unit from being read as substituting Permaculture for the science curriculum, and it clarifies for administrators that Permaculture is a delivery mechanism aligned with standards, not a replacement for them.

3. Compare and Contrast - Research vs. Application

All six articles converge on three core content claims: environmental science learning is built rather than transmitted, students function as knowledge contributors rather than recipients, and superficial inclusion of either Indigenous knowledge or disaster preparedness content fails to produce engagement, identity, or behavioral outcomes. The substantive difference between categories is scope of claim, as the four research articles establish what is true across cases (Krajcik et al.'s cluster-randomized trial, Matindike & Ramdhany's PRISMA review, Akram et al.'s 1,304-student survey, Nakano & Yamori's theoretical synthesis), while the two application articles document what is possible in a single localized case (Lebo & Eames's twelve-week New Zealand Permaculture unit; German et al.'s two-week California water unit). The application ideas could be adjusted to support the research literature in four ways: embed validated pre/post instruments (Akram's Permaculture Environmental Literacy Scale, Cronbach's $\alpha = .885$; Lebo & Eames's 16-term concept-mapping exercise) to ground their conclusions in stronger quantitative data; adopt Krajcik's explicit driving-question fidelity so the unit reads as PBI rather than project-flavored coverage; structure community partnerships as multi-year co-design rather than single-unit contact, per Matindike & Ramdhany; and replace end-of-unit assessment with Nakano & Yamori's long-term commitment evidence - design portfolios revisited months out, follow-up check-ins, alumni return visits.

4. Consolidated Implications for Classroom Instruction and Reflection

Across the six articles, the practical guidance falls into three sustained overlaps and one real tension worth naming. The first overlap is the affective-engagement-precedes-cognitive-transmission claim: Lebo & Eames's disorienting dilemma, Akram et al.'s doing-precedes-caring finding, and German et al.'s student-generated-mess opening all argue for the same opening sequence: encounter first, content second. The second overlap surrounds sustained, named partnership with knowledge holders: Matindike & Ramdhany establish it as the threshold for genuine Indigenous knowledge integration, German et al. enact it with named Maidu and Wintu partners, Nakano & Yamori frame it as the community-of-practice requirement of the proactive attitude paradigm, and Lebo & Eames identify the credentialed scientist-Permaculturist as the essential More Knowledgeable Other for teacher buy-in. The third overlap is long-term, attitudinally-inclusive assessment: Nakano & Yamori's long-term commitment evaluation, Matindike & Ramdhany's instruction to measure engagement and identity alongside content, and Krajcik's combined standards-aligned plus PBL-specific assessments all reject end-of-unit content tests as sufficient evidence of learning. The real tension surfaces between Krajcik's curriculum-fidelity finding, that the ML-PBL trial succeeds because teachers implement a pre-designed curriculum with high fidelity to its driving question, contrasts with the localized practitioner adaptation visible in Lebo & Eames and German et al., where the unit's quality depends on the specific community site, the named knowledge holders, and the student lifeworld it draws on. For a Permaculture-PBI environmental science unit centered on disaster response, redesign, and recovery, the synthesis is to hold high fidelity on the driving question and the proactive attitude paradigm structure, but design the unit to be filled in by local partnerships and student inquiry rather than scripted in advance via the trellis-not-scaffold pedagogy Lebo & Eames advocate.

This research process largely reaffirmed the curriculum vision I came in with, as the literature supports a Permaculture-framed PBI environmental science course with disaster scenarios as its design contexts and Indigenous knowledge as a substantive lens. It provided a number of insights and guidelines for the curriculum, but it also surfaced one revision I had not anticipated: the depth of relationship and partnership required for effective Indigenous knowledge integration. Matindike & Ramdhany's review establishes, and German et al. enacts, that what distinguishes genuine IK integration is sustained, multi-year co-design with named knowledge holders rather than attribution alone. I had been thinking about the course in terms of content, which Indigenous design solutions to study, how to credit knowledge holders accurately, which historical and present examples to draw on, but the literature has convinced me that without the proper relational scaffolding, even careful attribution lands as taking without reciprocity - what Kimmerer (2024) frames as a failure to honor the principle that “gratitude and reciprocity are the currency of a gift economy.”

This insight reframed two of my own past experiences in light of each other. I have participated in Permaculture offerings that drew on Indigenous design solutions with attribution but without cultural continuity through engagement. I have also been a participant in the Regenerative Design Institute's Regenerative Design and Nature Awareness program, where Indigenous leaders visited the cohort repeatedly across the nine-month curriculum and shaped how we encountered the land. I had experienced both formats but had not, until this research process, prioritized the relational aspect when designing this particular course. The literature surfaces it as the high-priority condition for IK integration. This means that in order to structure this course to honor Indigenous wisdom keepers, I need to begin sharing this vision with my Indigenous colleagues now, a year or more before the course begins, so the course is actually rooted in genuine co-design rather than ending up with a lesson here on the architectural review of Indigenous shelters and a lesson there on the Mayan Milpa system of cyclical forest garden management.

A second insight, this one from Lebo & Eames, bears specifically on implementation: their finding that the visiting Permaculturist needed to be credible as “the scientist coming in,” not “some hippy,” for the participating teacher's reservations to lift. With a BS in mechanical engineering and an active Permaculture instructor practice, I would meet Lebo's More Knowledgeable Other (MKO) bar myself, which lowers the implementation barrier this curriculum would otherwise face. For any other scientist or Permaculture practitioner I bring in, I would ensure they carry comparable credentials. Indigenous knowledge holders, however, are not held to scientific or Permaculture credentialing - that would be the kind of category error the literature warns against - but they should bring their own bona fides: standing within their community, lineage and recognition in their tradition, and the practiced relationship with land and culture that no Western credential measures.

A third insight came from sitting with Lebo & Eames's directive to teach “science education through Permaculture” rather than “Permaculture through science education,” and reflecting on what that imperative means in light of the adult Permaculture education I already teach. In my adult Permaculture courses, students arrive with - or quickly acquire - the underlying environmental science (soil composition and biology, water cycles, ecological succession), which lets us focus on Pattern Language, sit-spot practices for enhancing the senses and observation skills, base map analysis, refined zone and sector analysis, dozens of design elements and functions, random assembly design exercises, and the interesting history of Permaculture itself. In a high school environmental science course, the underlying science is what students need to acquire, so that has to be the focus - meaning the emphasis is on environmental science content standards, not on the nuances of Permaculture design. In the later units of long-term recovery, basic coverage of these topics could certainly be useful - but they must be used to inspire and teach the learning of environmental science, not solely toward their own ends. Recognizing that inversion has clarified for me what the unit's first weeks have to do, and where my adult-education instincts will need to be set aside in service of what high school students actually need to acquire.

Lastly, the literature's shared finding that affective engagement must precede knowledge transmission led me to a counterintuitive structural decision: the course should not open with Permaculture. The opening days of get-to-know-you activities and interest surveys must also include a pre-test (Akram's Permaculture Environmental Literacy Scale and Lebo & Eames's concept maps). Then, content would begin with the first Disaster Response design challenge, for example, “What would you do to survive a sudden polar vortex deep freeze that knocks out the electricity?” The students' first attempt surfaces the design gaps that motivate them to learn the first environmental science lesson on atmospheric science (and touches briefly on climate change as the forcing that is making such patterns more chaotic). Then as a precursor to the second iteration of design, I could bring in Indigenous cold-climate knowledge - Inuit and Sámi shelter, fire-keeping, and body-heat conservation traditions - as a substantive contribution to a problem students are already engaged in. Sámi inclusion has personal weight in my case: my Finnish heritage gives me cultural proximity to shared geography, though without Indigenous Sámi identity, and modeling that ancestral curiosity without overclaim is itself a stance I want students to encounter. At the end of the unit, the students redesign their solutions for the same scenario, this time incorporating academic language into their presentations and learnings from IK, which closes the loop on the pattern: encounter under constraint, recognize the science gap, integrate science and IK, and iterate.

The remaining phases follow that arc with progressively richer framing. The redesign phase could bring in appropriate technology in earnest and introduce Permaculture lightly through the three ethics and a few design principles. A possible project here would be the water purification project detailed in German et al. (2023), where students contaminate their own water and design filtration systems from low-cost local materials, this time adapted to a post-disaster context where the municipal supply has been compromised. The recovery phase makes sense to integrate more of the Permaculture lens, including mapping and scales of permanence, along with Indigenous knowledge partners' restoration ecology and long-term land relationship as core content. A post-test would close each unit, and the year, covering engagement and identity alongside standards-aligned content and PBL-specific assessments. This data would provide the measurable attitudinal and conceptual shifts that the application papers in my literature set neglected to quantify, as well as provide assurance to school administrators, parents, and the next teacher who inherits the curriculum that the unit is meeting, and hopefully exceeding, state and school environmental science content standards.

References

Akram, T. M., Ahmad, S., Asghar, M. A., Hafeez, R., Nazir, A., & Kirmani, N. S. (2025). Students' perspectives on Permaculture as a tool for environmental literacy. *Natural Sciences Education, 54*, e70034. https://doi.org/10.1002/nse2.70034

German, M., Hernandez, J., & Scherr, R. (2023). Connecting the science of water to students' communities. *The Science Teacher, 90*(6).

Kimmerer, R. W. (2013). *Braiding sweetgrass: Indigenous wisdom, scientific knowledge, and the teachings of plants*. Minneapolis, MN: Milkweed Editions.

Kimmerer, R. W. (2024). *The serviceberry: Abundance and reciprocity in the natural world*. New York, NY: Scribner.

Krajcik, J., Schneider, B., Miller, E. A., Chen, I.-C., Bradford, L., Baker, Q., . . . Peek-Brown, D. (2023). Assessing the effect of project-based learning on science learning in elementary schools. *American Educational Research Journal, 60*(1), 70–102. https://doi.org/10.3102/00028312221129247

Lebo, N., & Eames, C. (2015). Cultivating attitudes and trellising learning: A Permaculture approach to science and sustainability education. *Australian Journal of Environmental Education, 31*(1), 46–59. https://doi.org/10.1017/aee.2015.23

Matindike, F., & Ramdhany, V. (2025). Incorporating indigenous knowledge perspectives in integrated STEM education: A systematic review. *Research in Science & Technological Education, 43*(3), 1022–1042. https://doi.org/10.1080/02635143.2024.2413675

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: The National Academies Press.

Nakano, G., & Yamori, K. (2021). Disaster risk reduction education that enhances the proactive attitudes of learners: A bridge between knowledge and behavior. *International Journal of Disaster Risk Reduction, 66*, 102620. https://doi.org/10.1016/j.ijdrr.2021.102620