A Sociotechnical Module: Integrating Indigenous Use of Materials in a Material Science Course

Vivien Papp, University of San Diego

Vivien Papp graduated from the University of San Diego in 2026 as an Honors student with a B.S./B.A. with a Sustainability concentration in Integrated Engineering. She is a member of the Navajo Nation and her interests include wildlife conservation, habitat restoration, and environmental justice. She enjoys hiking, camping, and spending time outdoors, especially with her dog, Keke. She was selected by faculty to receive the Outstanding Senior Award in Integrated Engineering. She is also a member of the Alcalá 100 and completed the Industry Scholars Program with the 2024–2025 cohort. She was the inaugural speaker for the USD Tribal Liaison Indigenous Speaker Series to elevate Indigenous voices where she spoke on the motivation, impact, and result of her work for this sociotechnical module.

Dr. Susan M Lord, University of San Diego

Susan Lord is Professor and Chair of Integrated Engineering at the University of San Diego. She received a BS from Cornell University in Materials Science and Electrical Engineering (EE) and MS and PhD in EE from Stanford University. Her research focuses on the study and promotion of equity in engineering including student pathways and inclusive teaching. She has won best paper awards from the Journal of Engineering Education, IEEE Transactions on Education, and Education Sciences. Dr. Lord is a Fellow of the IEEE and ASEE and received the 2018 IEEE Undergraduate Teaching Award. She is a coauthor of The Borderlands of Education: Latinas in Engineering. She is a co-Director of the National Effective Teaching Institute (NETI).

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Abstract

Indigenous Traditional Knowledge (ITK) is rarely integrated into technical engineering curricula, despite offering valuable alternatives to dominant Western material paradigms, particularly in the context of sustainability. To address this gap, we designed and implemented a one-class-period sociotechnical module using backward course design for a required third-year introduction to materials science course at a small private university. The module aligns learning objectives with targeted activities to support meaningful engagement with Indigenous perspectives on material use.

The module centers on materials of cultural and functional significance in Indigenous communities, guiding students to connect material identity, technical function, and geographic context through a regional lens from various North American tribes and nations such as the Kumeyaay of California and the Tlingit of the Pacific Northwest Coast. Indigenous approaches to material selection foreground reciprocity, adaptability, and sustainability, offering valuable frameworks for engineering education. These perspectives were intentionally embedded into the learning design through Indigenous knowledge systems and practices, including the Honorable Harvest and Full-Use Principle.

Student learning was assessed using three sources of data: an exit ticket, post-class homework, and an anonymous post-class survey. The study investigated how engagement with the module influenced student perceptions of value in engineering and identified specific instructional features that supported or hindered student learning.

Exit ticket responses demonstrated immediate student engagement with the Full-Use Principle and the ability to interpret Indigenous technologies as sophisticated engineered solutions rooted in both material properties and cultural practice. Post-class homework showed that students successfully synthesized technical reasoning with cultural ethics, specifically by applying the Honorable Harvest as a design constraint rather than an abstract concept during material selection. Finally, the survey confirmed that the module broadened students' perceptions of material value, with respondents spontaneously highlighting Indigenous sustainability frameworks as essential components of modern engineering education.

Analysis of student work provided pedagogical insights for future revisions. This work offers a practical model for implementing culturally responsive, sociotechnical instruction that enhances student capacity to navigate complex, interdisciplinary engineering challenges.

Introduction

The motivation for this project stems from a recognized gap in conventional technical education: the typical exclusion of Indigenous Traditional Knowledge (ITK) from university-level engineering curricula. Such knowledge can be powerful for engineering students in considering how to sustainably address today's urgent challenges. Because materials are all around us and have been used for many generations, Materials Science courses are a promising venue to incorporate such knowledge. We capitalized on an opportunity to explore the Indigenous use of materials in a Materials Science and Engineering course. The authors include a fourth-year undergraduate engineering student from an Indigenous heritage and an engineering instructor with decades of experience in engineering education. We designed, implemented, and assessed a module on the Indigenous use of materials for a third-year required Introduction to Materials Science course as part of an undergraduate honors thesis.

The goal of this work is not only to enrich the materials science curriculum but also to provide a model for developing a culturally responsive instructional approach in technical fields, thereby enhancing student capacity to address complex, interdisciplinary challenges like sustainability by leveraging diverse knowledge systems.

This study investigated two research questions: (RQ1) *How does engagement with a sociotechnical module on ITK influence engineering students' perceptions of what is valuable in engineering, particularly concerning sustainability and the role of diverse knowledge systems?* and (RQ2) *What specific instructional features of the module successfully supported or hindered student learning and engagement with the core concepts of ITK?*

In this paper, we first provide background on ITK in engineering education, use of materials in Indigenous communities, and integrating sociotechnical modules into technical coursework. Next, we overview the materials science course context before detailing the module design process, including learning objectives, slide development, and related assignments. Then we describe the logistics for module implementation and evaluation including exit ticket, post-class homework, and anonymous post-class survey data. We then discuss next steps, concluding with instructor reflection, lessons learned, and a final overview of the paper's contributions.

Background

Indigenous Traditional Knowledge and Engineering Education

Integrating ITK into technical curricula is an ethical and pedagogical imperative for cultivating culturally responsive engineering education. A "Both-Ways" [1] and Etuaptmumk ("Two-Eyed Seeing") [2] approach strategically blends Western science with Indigenous paradigms, fostering a richer understanding of complex problem-solving [3], [4] and highlighting sustainable frameworks for resource stewardship [5]–[7]. By challenging the historical divide between these knowledge systems [8], education can address the underrepresentation of Indigenous peoples in STEM [9] and align science learning with local experiences to improve engagement and critical perspectives of all students [10]. Some research has investigated interviewing Navajo engineers regarding the connection between Navajo and engineering practices to provide a foundation for integrating engineering concepts within K-12 classes [11].

Our work is consistent with efforts to diversify the approach to engineering education and problem-solving by integrating Indigenous knowledge into the dominant curriculum [2]. Despite strong advocacy for diverse knowledge systems, a gap remains in the literature regarding incorporating ITK within core engineering disciplines in college. This project addresses the lack of practical, tested curricula by presenting a module for a required materials science course. This integration is a vital step toward decolonizing education systems [12]. Effective implementation requires moving beyond the marginalization of Indigenous histories [13] to active collaboration with Indigenous communities, ensuring that co-created content authentically encapsulates genuine knowledge frameworks [14]–[16].

Use of Materials in Indigenous Communities

Indigenous Traditional Knowledge often highlights the sociotechnical complexity of material selection, where technical performance (e.g., strength, durability) is inseparable from cultural values (e.g., spirituality, reciprocity) [17], [18]. Indigenous material practices are also guided by the Honorable Harvest, a framework articulated by Dr. Robin Wall Kimmerer, an enrolled member of the Citizen Potawatomi Nation [19], which provides an ethical foundation for material use and responsible resource management emphasizing reciprocity and gratitude [20], and the Full-Use Principle, which mandates utilizing every component of a harvested resource to minimize waste and demonstrate sociotechnical and spiritual respect for the living world [21].

Given the importance of place for Indigenous communities, one way to consider materials is by geographic region. Figure 1 shows a map of various regions in North America [22] and Table 1 identifies organic and inorganic materials for those regions. The Southwest region has a deep spiritual and cultural connection to Turquoise, a hydrous copper aluminum phosphate mineral ($CuAl_6(PO_4)_4(OH)_8 \cdot 4H_2O$) spiritually prized as a guide and protector [23]. In the Great Plains, bison sinew was prized for its high elastic modulus (≈ 411,000 psi) and pliability, demonstrating sophisticated materials engineering in its application for high-tension bow-making and rope [24], [25]. The Inuit and Aleut qajaq (kayak) represents an inventive Indigenous engineering structure that uses driftwood and whale or walrus bone frames covered in fat-sealed sealskin to achieve lightweight strength and waterproof performance suited to Arctic environments [26]–[29].

In the Northwest Coast, the Western Red Cedar is a significant material whose properties include high strength, straight grain, lightweight, and natural rot resistance [30], making it especially well-suited for applications such as plankhouses, canoes, and totem poles. In California, specifically among the Kumeyaay, the willow tree combines structural strength with inherent anti-fungal and pest-deterrent properties to create durable, food-preserving baskets [31]. In the Mesoamerican region, Indigenous peoples pioneered advanced materials science by mixing latex with morning glory juice to vulcanize rubber for ballgames, footwear, and adhesives millennia before European contact [17], [32].

Table 1. Examples of Important Materials in Various Regions.

Region	Southwest	Great Plains	Pacific Northwest	Northwest Coast	California	Meso-America
Material	Turquoise, Silver, Shells	Bison Sinew, Bison Hide, Porcupine Quills, Bones	Driftwood, Baleen, Sealskin	Western Red Cedar, Woods	Willow, Pine, Tule Reeds	Rubber, Morning Glory

Figure 1. Image of the map introduced at the beginning of the module showcasing the various regions that will be discussed.

Sociotechnical Modules in Engineering Education

Including ITK in engineering classes involves sociotechnical thinking which is an important research topic. This integration shifts the focus from engineering practices in isolation to understanding how technical solutions interact with human and ecological systems. Such integration also helps curricula to achieve ABET accreditation student outcomes relating to ethical, global, cultural, social, environmental, and economic impacts [33]. Researchers have investigated various approaches to integrate sociotechnical thinking in engineering curricula [34], [35] including courses [34]–[39], case studies [40], and micro-insertions [41] or modules [42]–[44].

Modules have been shown to be effective in a variety of class sizes and deliberately connect technical problem-solving with social, environmental, and economic considerations [42], [45], [46]. Consistent with the literature, in this paper a module is defined as a cohesive unit of learning centered on specific content and learning objectives, designed to be completed within a single class period. The module includes instructional slides, structured class activities, and pre- and post-class assignments intended for preparation, reinforcement, and assessment.

Research has highlighted pedagogical considerations and challenges related to integrating sociotechnical topics effectively within engineering curricula drawing from examples in Materials Science [42]. Sociotechnical modules have been successfully explored specifically within materials science classes on topics such as plastic straws [47] and recycling [48]. Findings reveal that students find these modules relevant and engaging and the modules help students see broader economic, environmental and/or social considerations for materials science and engineering design [42]. Thus, we chose to use a sociotechnical module for this project.

Methods

Materials Science Course

Engineering Materials Science is a required third-year course for all Integrated Engineering majors at the University of San Diego. Students in this course are assigned to cooperative learning homework teams of three to four students for the semester and submit weekly homework solutions as a team (see for example, [49]). Class activities feature active learning, consistent with the course instructor's educational philosophy and best practices [50]. This is the first course in Materials Science for students at this university and uses Callister and Rethwisch's textbook [51].

The catalog description includes elements of typical introductory classes but also offers possibilities for broader exploration of sociotechnical considerations.

> *This course connects materials science and engineering to technical real-world applications. Examines the relationships between structure and properties for materials including metals, polymers, ceramics, composites, insulators, and semiconductors. Topics include atomic and crystal structure, defects, diffusion, phase diagrams, mechanical properties, and semiconductor physics. Explores materials selection for engineering design including sociotechnical considerations.*

A module on Indigenous use of materials fits well with the overall course description as well as the programmatic mission of the Integrated Engineering department to situate technical content within social, environmental, and economic contexts, as well as the university's broader liberal arts mission to foster an inclusive and sustainable education [52], [53].

This module addresses several course learning objectives stated on the syllabus as shown in Table 2.

Table 2. Materials Science Course Learning Objectives Addressed by the Module.

Course Learning Objective	Addressed in Module
Explain the importance of materials science in everyday life	Culturally relevancy, role of materials in everyday life of various tribes
Describe how the structure of a material may be designed to produce desired properties for particular applications.	Indigenous material processing such as animal hide, brain tanning, vulcanization of rubber using morning glory
Given a materials design problem, evaluate the available options, select one of the options, and justify your choice.	Post-Class Homework Design Problem (Question 2)

Design of the Module on Indigenous Use of Materials

We employed a backward course design approach [54] by first establishing learning objectives and then ensuring that all instructional activities and assessments aligned with those goals. We also incorporated active learning exercises to enhance student engagement and capitalized on the use of cooperative learning homework teams throughout the course [50], [55].

Module Learning Objectives

We developed specific learning objectives for this module organized into three thematic categories including technical understanding, cultural context, and reflective insight (Table 3). In the technical category (#1), students analyze the engineering properties of materials like bison sinew or willow to explain how physical characteristics inform traditional functions. The cultural category (#2) requires students to identify non-technical factors influencing material selection such as community needs and sacred traditions. Finally, the reflective category (#3) asks students to characterize the value of incorporating Indigenous knowledge into engineering, which directly addresses our RQ1 regarding shifts in student perceptions.

Table 3. Module Learning Objectives.

1. Describe Indigenous use of materials
    a. Provide three examples of Indigenous materials and their historical and/or contemporary uses
    b. Describe how specific material properties (e.g., anti-fungal willow, bison sinew) informed their traditional uses

2. Describe the significance of sacred materials when it comes to cultural practice and/or tradition within a specific geographic region

3. Characterize the overall significance of incorporating Indigenous materials and perspectives into engineering education

Designing the Module Content

In addition to the learning objectives, the module consists of a pre-class homework assignment, in-class activities with presentation slides, an exit ticket, post-class homework, an anonymous post-class survey, and exam questions. To ensure ethical compliance and enable the publication of our findings, we obtained Institutional Review Board (IRB) approval.

We selected specific materials for the module based on their technical relevance to a materials science curriculum and their capacity to demonstrate Indigenous engineering principles. By adopting a regional structure, we highlighted how material science is rooted in environmental adaptation and sustainability. This approach emphasizes the important Indigenous concepts of the Honorable Harvest and Full-Use principles as frameworks for balancing mechanical requirements with cultural values. The resulting module structure allows students to explore diverse materials while grounding their technical analysis in specific geographic and cultural contexts.

For the pre-class homework we included several questions on students' weekly homework as shown in Table 4. These questions introduced the Honorable Harvest and Full-Use principles and encouraged student reflection.

Table 4. Pre-Class Homework Prompts: Question 1, 2, and 3. [Bolding is in the homework itself.]

1) Watch the video The Honorable Harvest by MacArthur Genius Award winner Dr. Robin Wall Kimmerer [20]. In 3 - 5 sentences, describe how the concept of respectful resource use could impact how we extract, manufacture, or dispose of materials today. Can you think of a modern example of a material that could benefit from this mindset? 2) Read this article about "Types of Native American Artifacts" and then answer the following questions [56]: a) What type of materials are found in the Saugus Iron Works area and what were they used for? b) Identify themes that you noticed as you read the article. 3) Respond **individually** to the following questions: (Please type your answers and include your name.) a) What stood out to you from the "Types of Native American Artifacts" article and the "Honorable Harvest" video? b) If you came across the same stones, ceramics, and natural materials described in the article, how would you use them to meet your daily needs? Would you have used them in similar ways as the Indigenous people described, or would you have tried something different? Explain why.

For the presentation slides, a "Context Matters" slide prefaces the technical content to acknowledge Indigenous peoples as contemporary knowledge bearers whose traditions remain relevant today. This introduction establishes sustainability, context, and environment as the overarching themes linking Indigenous paradigms with engineering principles. Early in the module, we presented a map of North America as a reference point to ground the technical discussion in the specific regions of the Northwest Coast, Great Plains, California, Southwest, and Mesoamerica (Figure 1).

Throughout each region included in the module, we discuss cultural values in context alongside technical material properties. The module sequence begins in the Southwest with turquoise and silver working before transitioning to the Pacific Northwest and Northwest Coast regions. We then transition to the Great Plains to analyze bison sinew and reinforce technical concepts of tensile strength and elastic modulus previously covered in this materials science course. The California section narrows focus to the Kumeyaay and serves as a bridge to a collaborative discussion on the Honorable Harvest and responsible resource management. The content concludes with a Mesoamerican highlight that provides a polymer recap through the study of rubber vulcanization.

A specific example of the importance of cultural context is found in the Pacific Northwest Coast, including the Tlingit nation, where the Western red cedar is essential for creating totem poles that depict guardian spirits and complex records of lineage and history [57], [58]. In the module, we specifically address the harmful Western rhetoric of being "low on the totem pole" which is misunderstood in the West as being of the least importance. For the Indigenous creators of the totem pole, the lowest figures are often the most significant because they are carved from the largest, foundational section of the tree and sit at eye level [59].

Furthermore, we designed the module to include multiple opportunities for student engagement through active learning including guided notetaking, think-pair-share activities, and group discussion. This approach enhances student learning [55] and ensures students remain focused on technical details while contributing to the sociotechnical discourse.

Assessment

For this paper, our assessment focuses on the data collected in the exit ticket, the post-class homework assignment, and an anonymous post-class survey. The exit ticket served as an in-class tool for capturing immediate student takeaways. The homework provided a deeper look into student learning by requiring an individual reflection question (HW-I) and a technical Group Design Problem (HW-G) that integrated Indigenous engineering principles with material properties. Finally, the survey (S1–S10) offered a candid platform for students to evaluate the technical relevance of the content and the effectiveness of the instructional design.

Assessment: Exit Ticket

For the exit ticket, students wrote their responses on post-it notes at the end of the module which they put on the board at the front of the classroom. We designed this activity to facilitate immediate active recall. By collecting these responses before students left the classroom, we were able to incorporate real-time student perspectives directly into the module evaluation process.

Assessment: Post-Class Homework

The post-class assessments were designed to explore shifts in students' perspectives and their ability to synthesize technical and sociotechnical concepts. As part of their weekly homework completed in cooperative learning teams, students were asked the questions shown in Table 5. The first component consisted of a three-part individual reflection (HW-I) targeted at gathering information on student responses to the module and investigating where content impacted their thinking.

The second component featured a group design problem (HW-G) requiring students to justify material selection based on both technical properties and sociotechnical principles. Students were assigned to either a Coastal or Plains group to diversify the data. This task prompted students to balance mechanical properties with the principles of the Honorable Harvest, considering resource availability and sustainable extraction. Analyzing these data allows us to evaluate whether student interests lean toward technical material intersections or the social functions of engineering within a community based on the materials they chose to research independently.

Table 5. Post-Class Homework Prompts: Individual Reflection (HW-I) and Group Design Problem (HW-G). [Bolding is in the homework itself.]

Code	**Assignment Component**	**Question Prompt**
HW-I	Individual Reflection	1) Reflecting on the module we did in class on October 30, 2025 on Indigenous materials, please answer these questions **individually**. a. How did the module challenge or expand your thinking about material design? b. What surprised you about how certain materials were used? c. Were there any materials discussed that you now see differently?
HW-G	Group Design Problem	2) Imagine you live in **one** of these geographic regions: Coastal or Plains As a group, brainstorm the types of materials present in your assigned region. **Explain** how at least two materials could address cultural values or physical needs within your geographic region. Choose one example discussed in detail in the module from class and one material that was not discussed in-depth from the module. Include any appropriate citations. **Explain** why you chose the materials you did, what needs they address, and what material properties were critical in making your decisions. Also recall the principles of an Honorable Harvest as you consider how much of your chosen materials would be needed to serve a purpose and how much of that material would realistically be available for use. **Please write in complete sentences.**

Assessment: Anonymous Post-Class Survey

We designed an anonymous post-class electronic survey (S1–S10) to gather candid student feedback regarding both the integrated Indigenous content and the overall module design. The survey included five Likert-scale questions (S1–S5) and five open-ended prompts (S6–S10), as shown in Tables 6 and 7. A link to this survey was distributed at the end of the module, with follow-up emails sent afterward to encourage participation.

Table 6. Likert-Scale Anonymous Post-Class Survey Questions (S1–S5) on a Scale of 1 (Strongly Disagree) to 5 (Strongly Agree). [Bolding is in the survey itself.]

Code	**Question Prompt**
S1	I believe the examples of Indigenous material use presented in the module have **relevant technical applications** in modern engineering.
S2	The module effectively demonstrated that **Indigenous knowledge** is a valuable component of a modern engineering education.
S3	Learning about Indigenous material usage broadened my perception of what is **valuable** in the field of materials science.
S4	The module demonstrated how **Indigenous practices** can inform modern, sustainable material design and usage.
S5	Prior to this module, I had not considered the **cultural importance** of materials in technical applications.

Table 7. Short Response, Open-Ended Questions Included in Anonymous Post-Class Survey.

Code	**Question Prompt**
S6	Which aspect(s) of the module (e.g. slide, topic, or activity) was most helpful for your learning?
S7	What are your biggest takeaways from the module?
S8	What, if anything, did you find confusing or unclear from the module?
S9	How could this module be improved for future students?
S10	Feel free to share any additional comments you may have about the module or its instruction.

Implementing the Module

On October 30, 2025, the first author of this paper facilitated this module in one 80-minute class period in *Engineering Materials Science*. The class included four fourth-year, two third-year, and one second-year student. There were six Integrated Engineering majors (four with a

Sustainability concentration, one with a Biomedical concentration, and one Independent Plan of Study concentration) and one Physics major. Thus, most of the class were familiar with the Integrated Engineering program's sociotechnical focus. Within this group, five students were women. Five students attended the module in person. The lecture notes were provided to all students. The two students who did not attend the module reviewed the notes, participated in the homework assignment, and were invited to complete the survey.

Findings: Student Response and Evaluation

The evaluation of the module included data from exit tickets, post-class homework, and the anonymous post-class survey. Each assessment category reveals insights into student learning regarding the value of sociotechnical themes in engineering education and enables a comprehensive assessment of the module's impact.

Exit Ticket

The exit ticket responses are listed in Table 8. Common themes centered on ITK and sustainability, particularly the ethical use of resources and the importance of the Full-Use Principle. Multiple students emphasized the significance of "using the WHOLE animal" and highlighted ideas related to "sustainable extraction and use of natural resources." These responses affirm the effectiveness of conveying principles of ethical stewardship and the Full-Use Principle.

Student Two distinguishes an innovative design example in referencing the "development of the kayak and the origins of the name," directly linking cultural context with technical function. This response demonstrates an emerging ability to interpret Indigenous technologies as engineered solutions informed by both material properties and cultural practices.

Overall, the distribution of responses suggests successful integration of the module's objectives. The prevalence of sociotechnical and sustainability-focused reflections indicates that ethical resource use and cultural context were effectively communicated. Responses addressing technical material properties show meaningful engagement with core materials science concepts. The smaller number of responses connecting Indigenous practices to modern engineering illuminates an area for potential expansion but nevertheless confirms that the module prompted reflection on the long-term relevance of ITK in contemporary design.

Table 8. Exit Ticket Student Responses.

<u>Student One</u> ● Animals & plants can be used for a wide range of purposes ● A lot of today's materials were inspired by those of Indigenous tribes ● Although all these tribes were located all over — they had very similar culture and values
<u>Student Two</u> ● Development of the kayak and the origins of the name ● Cultural significance of the totem pole
<u>Student Three</u> ● Using the <u>WHOLE</u> animal ● Mis-interpretation of the meaning of the totem pole ● Indigenous material use was smart → ex. Sinew as elastic
<u>Student Four</u> ● Turquoise → defects are valuable ● Sustainable extraction and use of natural resources (full use of animals) ● Material properties (strength, elastic region) are important to be considered → Bison tendon
<u>Student Five</u> One idea that stood out to me the most was the way that Indigenous communities make sure to source as many materials from one animal/body. It is common to take one thing and discard it elsewhere. Seeing something being used to its full capacity is sustainable.

Post-Class Homework

The post-class homework demonstrated progress toward the learning objectives, including understanding Indigenous material use, recognizing the importance of material properties, and connecting material choices to geographic and environmental contexts.

Post-Class Homework: Individual Reflections (HW-I)

The individual reflection component (HW-I) revealed how the module challenged students' previous assumptions. For example, Person 3 noted that they had not previously considered the use of materials such as bladders, bison sinew, and porcupine quills, expressing surprise at the ingenuity of these applications. Although these uses initially “seemed unconventional,” the student recognized that they “make a lot of sense” when examined through material properties, such as the elasticity of bison sinew. Similarly, Person 4 reflected that they now view animal hide differently, having previously underestimated its applications, particularly citing its waterproofing properties in shelters and kayaks. These reflections indicate that students were able to synthesize technical reasoning with cultural and environmental context.

Students also demonstrated a holistic understanding of material design extending beyond industrial frameworks. One student observed that Indigenous communities selected materials based on cultural and spiritual significance in addition to mechanical performance. Person 7 emphasized this shift in HW-I by referencing turquoise as a material associated with protection, guidance, and ceremony, noting an appreciation for how “materials can hold deeper meaning beyond their structural and aesthetic traits.”

Post-Class Homework: Group Design Problem (HW-G)

When addressing regional design problems (HW-G), students effectively integrated technical and sociocultural reasoning. The Plains group analyzed bison sinew not only for its “tensile strength of 28,000 psi” but as a reflection of the “cultural respect for bison and the principle of Honorable Harvest.” By connecting mechanical performance to the goal “to use as much of the bison as possible to minimize waste,” students demonstrated an ability to treat Indigenous ethics as actionable design constraints rather than abstract concepts. Similarly, the Coastal group, when discussing shells, recognized the dual nature of the material as both a “sacred object and economic resource”. They also noted that harvesting shells primarily when empty ensured that “small quantities can serve community needs while allowing mollusk populations to thrive,” linking ecological health to the high trade value of the material.

This foundational understanding of the Full-Use Principle and ethical harvesting served as a scaffold for the students’ independent research of a material not discussed in-depth by the module. Reflecting on these selections in HW-G reveals diverse student interests:

- **Social Utility**: The Plains group chose sweetgrass because it is a “sacred herb, primarily in purification ceremonies,” while acknowledging the technical utility of its elasticity for weaving.
- **Technical Innovation**: The Coastal group selected kelp because it “bridges traditional ecological knowledge with modern sustainability practices” through its potential as a bioplastic.

Despite these differing points of interest, both groups anchored their final justifications in the Honorable Harvest. For the Plains group, this meant a reciprocal act of “respect and care for the land,” while the Coastal group translated these ethics into specific protocols like “harvesting selectively” to maintain ecosystem health. This indicates that the module successfully reframed Indigenous ethical frameworks as practical considerations for responsible engineering design.

Anonymous Post-Class Survey

The anonymous post-class survey results revealed strong endorsement of both the academic value of the module and its emphasis on sustainability. The survey was completed by five of the seven students. Results from Likert-scale questions (S1–S5) are shown in Table 9. The strongest agreement is seen for S3, where all students strongly agreed that the module broadened their perception of what is valuable in materials science, indicating a successful shift beyond purely technical definitions of material performance. All respondents agreed or strongly agreed that Indigenous knowledge is a valuable component of modern engineering education (S2) and that Indigenous practices can inform modern, sustainable material design (S4). These findings are especially noteworthy as they support our goal of demonstrating that Indigenous knowledge complements, rather than contrasts with, Western engineering frameworks.

More variation is seen in student responses for S1 and S5. The neutral responses to the value of the specific examples, combined with the agreement of the overall value, suggest that some students would like to see different or perhaps more detailed examples (S1). The range of responses on prior experience with cultural importance is not surprising, since most of the students, specifically those within the Integrated Engineering cohort, would have previously taken a course on energy which included some themes derived from Indigenous perspectives (S5).

Starting with S6, students wrote their responses to the open-ended, short-response questions (S6–S10). Students described several features as supporting their learning in S6 of the survey. Student A appreciated separating content by region as it makes “the content more digestible,” and Students C and E similarly highlighted their appreciation for “all of the visual aids and examples.” For S7, regarding key takeaways, three respondents authentically referenced sustainability, although the prompt did not directly ask about it:

- “Indigenous communities used resources locally, intelligently, and sustainably. We can learn from them!!” (Student A)
- “Sustainability can be deeply ingrained in culture - regardless of how physically close tribes are located. Across the US we can be sustainable in wayyyy bigger ways, depending on what we have in our areas,” (Student B)
- “I learned that so much about sustainability in material use can be learned from [I]ndigenous culture,” (Student C)

Students' decision to feature sustainability suggests that the theme was meaningfully internalized rather than superficially acknowledged. These responses underscore the effectiveness of embedding sustainability as a sociotechnical principle rather than an isolated topic.

For issues that were confusing (S8), Student A noted feeling overwhelmed when text was “very close to each other without much space in between.” This suggestion supports improvements made to the module to address readability, comprehension, and engagement. Students gave suggestions for improvement in S9, requesting more opportunities to “write more things on the note paper,” while Student E explained that blanks “force us to actually think instead of simply viewing and ‘understanding’ the material.” These responses reinforced the value of including thoughtful active learning and guided revisions to promote sustained student participation. Students also requested stronger connections to core engineering concepts; Student A expressed interest in “slightly more connection to material science,” specifically citing the elastic region of bison sinew as a good example. Optional open-ended feedback (S10) further reinforced the perceived value and clarity of the module. Student A described the module as “thorough and smart” and highlighted its effectiveness as an introduction to sustainability in a materials science context, while Student C praised the visual design, noting the “vibrant colors and format” as engaging and accessible.

Table 9. Summary of Likert-Scale Student Responses (S1–S5) on Anonymous Post-Class Survey ($N = 5$).

Question	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
S1) I believe the examples of Indigenous material use presented in the module have relevant technical applications in modern engineering.	-	-	2	2	1
S2) The module effectively demonstrated that Indigenous knowledge is a valuable component of modern engineering education.	-	-	-	2	3
S3) Learning about Indigenous material usage broadened my perception of what is valuable in the field of materials science.	-	-	-	-	5
S4) The module demonstrated how Indigenous practices can inform modern, sustainable material design and usage.	-	-	-	1	4
S5) Prior to this module, I had not considered the cultural importance of materials in technical applications.	-	2	1	1	1

Instructor Reflection & Lessons Learned

Highlights of this experience included the opportunity to integrate the first author’s Indigenous heritage with a shared passion for sustainability. This direction emerged from the first author’s undergraduate honors thesis, which sought a topic that was both personally meaningful and academically relevant, while also addressing the broader need to incorporate Indigenous Traditional Knowledge into engineering curricula. The success of the module design was predicated on close collaboration between the authors, with the student’s personal and cultural investment complemented by the second author's pedagogical expertise.

The development process also presented valuable instructional lessons. A primary challenge involved transitioning the module from a research-oriented presentation into an effective teaching tool. Early iterations were information-dense but lacked a clear instructional trajectory. In response, the authors adopted a narrative framework centered on three guiding questions for each material: what the material is, why it is technically useful, and its geographic or cultural origin. This structure helped maintain instructional coherence, supported student engagement, and allowed the content to be refined to better align with specific learning objectives.

The first author's position as an undergraduate presented an opportunity to gain invaluable insight into the nature of sociotechnical instructional design, from defining learning objectives to developing assignments. This experience reinforced the understanding that effective engineering education extends beyond information delivery and emphasizes intentional selection of content that supports a clear pedagogical narrative. Ultimately, the project highlighted the importance of validating Indigenous Traditional Knowledge as an experienced and applied engineering practice and underscored the role of curriculum design in supporting Indigenous visibility and empowerment within engineering education.

Discussion and Future Work

This study was guided by two research questions: (RQ1) *How does engagement with a sociotechnical module on ITK influence engineering students' perceptions of what is valuable in engineering, particularly concerning sustainability and the role of diverse knowledge systems?* and (RQ2) *What specific instructional features of the module successfully supported or hindered student learning and engagement with the core concepts of ITK?*

Regarding RQ1, our assessment showed that students perceived ITK as valuable in engineering, particularly concerning sustainability. Exit ticket responses showed immediate engagement with the Full-Use Principle and recognition of Indigenous technologies as sophisticated engineering solutions rooted in both material properties and cultural practice. Post-class homework (HW-I, HW-G) further demonstrated students' ability to operationalize these concepts by applying the Honorable Harvest as a formal design constraint during material selection, effectively integrating ecological responsibility and cultural ethics into technical justification.

Survey results reinforced these findings. Likert-scale responses (S1–S5) showed strong agreement that the module broadened students' perceptions of what is valuable in materials science and affirmed Indigenous knowledge as a meaningful component of modern engineering education. Students' spontaneous emphasis on sustainability in open-ended responses (S7), despite the absence of explicit prompting, suggests that framing sustainability as a culturally embedded sociotechnical principle was particularly effective.

For RQ2, survey responses highlighted several instructional features that supported student learning, as well as areas for improvement. Students identified the organization of the module by region and the use of effective visual aids (S6) as helpful for making complex material more accessible. Conversely, student feedback (S8) indicated feeling overwhelmed by densely packed text, prompting revisions to improve visual spacing and readability. Requests for additional guided note-taking and deeper connections to core materials science concepts (S9) further informed iterative refinements. In response, subsequent revisions emphasized active engagement through structured note-taking and increased technical depth by shifting from broad multi-regional coverage to focused regional case studies.

We acknowledge that our work is a first step into the broader application and integration of ITK into engineering curricula. Due to the small class size ($N = 7$), future work will involve implementing this module with larger student cohorts to broaden the data pool and expand to other institutions with different student body sizes, whose students may have different backgrounds and approaches to the module's content. Expansion to other institutions can test its applicability across various institutional contexts similar to, and different from the Integrated Engineering curricula which may reveal new insights into student response. Future research may also include a comparative component that contrasts Indigenous material applications with modern Western counterparts, essentially comparing the two in terms of various trade-offs by properties, cost, and other indicators for sustainability. For example, a side-by-side analysis of kayaks made from animal hide versus synthetic polymers would allow students to investigate the fundamental differences between organic and synthetic material performance.

Conclusions

This study examined how engagement with a sociotechnical module influenced students' perceptions of value in engineering and identified the instructional features that most effectively supported engagement with Indigenous Traditional Knowledge. By assessing student learning through an exit ticket, post-class homework, and an anonymous post-class survey, we found that students moved beyond a purely technical view of materials towards an integrated sociotechnical perspective, treating Indigenous ethics such as the Honorable Harvest as functional engineering constraints.

This work validates the design and implementation of a sociotechnical module on Indigenous use of materials within a required third-year materials science course. By intentionally centering ITK, the module addressed a persistent gap in engineering curricula and reframed materials science as a discipline that integrates technical performance with cultural context, ethical responsibility, and sustainability. Analysis of student responses revealed pedagogical insights that will inform future refinements. In particular, student feedback highlighted the effectiveness of the structured material narrative while also indicating the need for increased technical depth through more focused regional comparisons. These findings underscore the value of treating Indigenous knowledge not as supplementary context, but as an applied framework that meaningfully shapes engineering decision-making.

Overall, this module demonstrates the viability of integrating ITK into core engineering coursework through a sociotechnical, design-oriented approach. The positive student outcomes observed in this implementation provide a strong foundation for future work. This work offers a practical model for culturally responsive engineering education that prepares students to navigate complex technical challenges with ethical and interdisciplinary awareness.

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