Futures as Pedagogy: Africanfuturism, Ungrading, and Critical AI Literacy for Developing Entrepreneurial Mindset in Engineering Science

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Futures as Pedagogy: Africanfuturism, Ungrading, and Sociotechnical Integration for Developing Entrepreneurial Mindset

Introduction

Engineering science courses play a foundational role in undergraduate engineering curricula. These courses typically emphasize analytical reasoning, mathematical modeling, and technically correct solutions, often under tight curricular and assessment constraints. Homework assignments in such courses are therefore commonly designed to reinforce technical depth [1]. While this emphasis is central to disciplinary formation, it can also limit students' opportunities to engage explicitly with questions of purpose, values, and the broader societal implications of engineering work. As a result, students may experience engineering analysis as technically demanding yet socially abstracted.

Entrepreneurial Mindset (EM), through frameworks that emphasize Curiosity, Connections, and Creating Value [2], offers a lens for addressing this gap. However, EM development is most often situated within design courses, project-based learning environments, or capstone experiences. Comparatively little work has explored how EM might be meaningfully embedded within traditional engineering science courses, where problem framing is typically narrow, and assessment structures are rigid. Sociotechnical integration — the recognition that technical decisions are always shaped by social, cultural, and ethical contexts [3], [4] offers a productive framework for doing so, one that treats technical and social dimensions of engineering as inseparable within constrained course structures.

This paper introduces Material Futures Labs as a pedagogical approach for embedding sociotechnical thinking into homework assignments within a traditional engineering science course. Rather than presenting evidence of learning outcomes, this paper offers a design case focused on how homework assignments were intentionally structured to support sociotechnical integration while preserving technical depth. By foregrounding futures-based pedagogy, culturally situated contexts, and reflective engagement with AI, this work aims to contribute design insights to the Liberal Education/Engineering & Society (LEES) community regarding how sociotechnical reasoning can be meaningfully embedded within the constraints of core engineering science courses.

Research questions

This design case is guided by the research question: *How might we cultivate entrepreneurial-minded engineers who are innovative but also socially accountable within a traditional engineering science course?* This question is exploratory and design-oriented. The goal is not to evaluate effectiveness but to articulate and examine pedagogical design choices under realistic instructional constraints.

Framework

We adopted sociotechnical integration as the guiding framework for our design case. This approach recognizes that technical decisions cannot be separated from their social context and that engineers must consider social factors from the beginning of the design process [3], [4]. This framework enabled us to make these social factors explicit, allowing students to develop an entrepreneurial mindset that is ethically grounded and socially responsive.

Rather than replacing the entrepreneurial mindset, sociotechnical integration expands its scope. It broadens our understanding of curiosity, connections, and creating value by making visible the social, cultural, environmental, and ethical dimensions of engineering practice. Table 1 illustrates how each dimension of the entrepreneurial mindset is deepened through a sociotechnical lens. This expanded perspective guided our design decisions in Mechanics of Materials.

Table 1. Expansion of the Entrepreneurial Mindset through Sociotechnical Integration

Entrepreneurial Mindset	Traditional Framing	Sociotechnical Integration Expansion
Curiosity	Asking questions about how things work and identifying technical gaps and opportunities	Reflexive inquiry about how problems are socially constructed and whose needs are prioritized
Connections	Seeing relationships between technical, business, and customer considerations	How technical decisions interact with the communities, environments, and systems in which they are implemented.
Creating value	Solving problems in ways that are useful and impactful, focusing on performance improvement or market opportunity	Solving problems while considering who benefits, who bears risk, and the broader social and environmental consequences

Also, to introduce sociocultural context into Mechanics of Materials, we incorporated Africanfuturism as a pedagogical tool rather than as an additional theoretical framework. This narrative approach helped us make sociotechnical dimensions visible while reinforcing curiosity, connections, and value creation. We describe its implementation in the design case section.

Methods.

Typical engineering education research publications focus on understanding how educational innovations impact learning, developing theories and models, and evaluating program outcomes [5]. While valuable, this emphasis rarely surfaces the decisions made during the design process itself — the tensions, trade-offs, and contextual judgments that shape how an intervention comes to be. Design cases address this gap by sharing detailed, first-person accounts of design processes and products [6], [7]. Common in fields such as architecture, graphic design, and human-computer interaction, design cases build shared knowledge by making visible how designers reasoned through problems — the contextual judgments and trade-offs that shaped outcomes — so others can draw on those experiences in their own work [5].

This paper presents a design case of the Material Futures Labs assignments developed for a Mechanics of Materials course. Rather than evaluating student learning outcomes, we share how and why we made the pedagogical decisions we did — including constraints we navigated, tensions we encountered, and the iterative reasoning that shaped the final assignment structures. The goal is to make our design process legible and transferable to others seeking to embed sociotechnical thinking within similarly constrained engineering science courses.

The Design Case

For this design case, we selected a Mechanics of Materials course. This course represents a traditional engineering science course that serves a large undergraduate population and follows a structured syllabus focused on analytical problem-solving. The in-person course was offered in Fall 2025 and enrolled 47 students. Within this course, homework plays a central role in reinforcing core content but is constrained by grading efficiency, solution correctness, and alignment with exams.

Working within this context, we designed the Material Futures Labs assignments to integrate sociotechnical thinking and EM into core technical practice. We used Africanfuturism as a pedagogical tool. Through the speculative world of *Binti* [8], we framed mechanics problems within culturally situated and future-oriented contexts, encouraging students to connect technical analysis with broader social and ethical considerations. For example, students are prompted to consider not only whether a material meets allowable stress requirements, but how it supports reconciliation, honors tradition, or contributes to sustainable futures.

As a result, the assignments were designed to assess essential technical concepts while introducing new forms of engagement without increasing grading burden or displacing required content. Homework was intentionally selected as the intervention site because it is a highly normalized and constrained pedagogical form. Designing homework in this context, therefore, presented a meaningful challenge and an opportunity to examine sociotechnical integration without relying on project-based or open-ended formats.

Material Futures Lab Assignments

This section describes the structure and intent of the Material Futures Labs assignments. The focus is on pedagogical design, not on student performance or learning outcomes.

The introduction for the two labs was provided to contextualize the assignment and to help motivate their work (Figure 1).

Introduction: Binti-Inspired Futures

The scenarios in this project series are inspired by *Binti*, a set of award-winning novellas by Nigerian-American author Nnedi Okorafor. *Binti* is an **Africanfuturist** work — a vision of the future rooted in African cultures, histories, and perspectives, and imagining how they might evolve in harmony with advanced technologies, interstellar travel, and encounters with other species.

In *Binti*, engineering and materials science are woven into the story world — from culturally significant personal devices called astrolabes, to living starships, to monumental architecture that bridges cultures. This project draws on those ideas, inviting you to **design speculative materials for futures in which engineering is deeply connected to culture, the environment, and ethics**.

Each lab will present you with a unique Binti-inspired scenario. You'll use **mechanics of materials** concepts, AI-assisted creativity, and futures thinking to:

- Invent a new material and define its mechanical properties.
- Apply course concepts to analyze it under realistic loads.
- Imagine how it shapes society, culture, and the environment.

Figure 1. Introduction provided to students for the Material Futures Labs in the Learning Management System (LMS)

We chose to situate these labs in 2125 to lift contemporary technological constraints and enable more imaginative, generative thinking. We also intentionally embedded students' work within the Africanfuturist world of Binti, requiring them to consider new manufacturing processes and develop materials in direct relationship to specific environmental conditions, cultural values, and community needs. The future setting removes technological limitations; the Africanfuturist context ensures that imaginative thinking remains grounded in socio-cultural purpose.

Assignment 1: Designing a New Material for an Astrolabe in 2125

In the first assignment, I (note that I refer to Nadia Kellam, the first author and teacher of the class) positioned students as material designers working within a speculative Africanfuturist setting in Namibia in the year 2125. Students were tasked with designing a new material for an astrolabe — a small, handheld electronic device similar to a cellphone that also stores each person's history. Prior to proposing their new design, they were required to identify two inspirational materials that exist now (Figure 2).

Scenario:
It's 2125, and astrolabes — intricate personal devices for navigation, communication, and knowledge storage — are now central to daily life. You've been hired by a Namib-based design collective to develop a new **housing material** for astrolabes that

is stronger, lighter, and more beautiful than anything on the market. The material must be durable in desert heat, resistant to dust, and customizable with cultural markings.

Mechanics Focus: Stress, strain, allowable stress
Sharing Method: Digital Gallery & Peer Review in Canvas

Deliverable

1-page Product Sheet + Diagram:

1. **Two Inspirational Materials:** Identify two existing materials (e.g., titanium alloys, carbon fiber, bioplastics) and describe their key mechanical properties and uses.
2. **Your Material:** Describe how your material differs in composition, performance, or aesthetics.
3. **Properties Table & Stress-Strain Diagram:** Include E, yield strength, ultimate strength, toughness, and ductility.
4. **Mechanics Application:** Apply stress/strain or allowable stress analysis to an astrolabe casing.
5. **Speculative Design:** 3–4 sentences on how your material honors cultural traditions while enhancing performance.

Figure 2. Scenario and deliverable for Material Futures Lab #1

For this assignment, students either worked individually or self-selected into teams (up to 3 students per team). Because we did not have a lot of class time to devote to this lab, we had the lab replace one of the homework assignments in the class and had the primary engagement be on a discussion board where they were required to comment on each other's assignments, providing a review of three other projects with three comments. The discussion prompts were: "One thing that really works in this design is…," "One question I have about the mechanics or the material choice is…," and "One idea to push the design further is…."

After the class, where they spent 30 minutes beginning their work for this assignment, students were provided with the following resources: a) a link to the Materials Information website from AZO materials: https://www.azom.com/materials.aspx, b) a link to MatWeb, an online materials information resource: https://www.matweb.com, and c) the link to the GPT that was created for students to use (Figure 3).

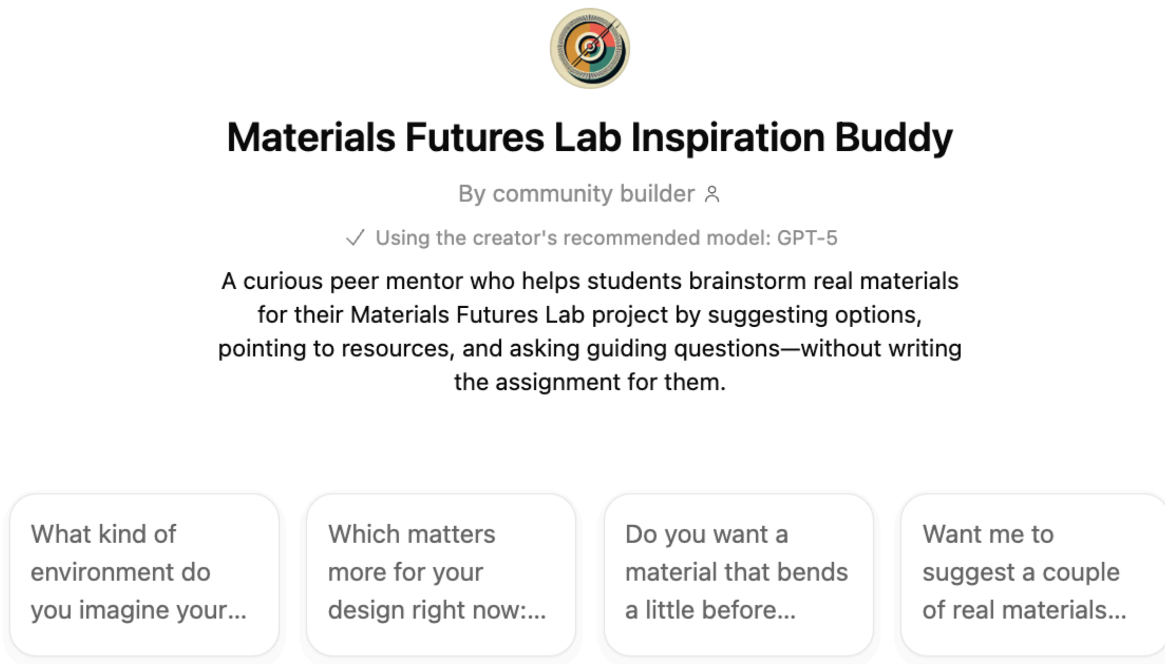

Figure 3. Screenshot of Materials Futures Lab Inspiration Buddy that was created for students to use as a resource for this assignment. It is a GPT that was created in ASU's CreateAI platform (https://ai.asu.edu/create-ai-platform-product-release-notes) and used the LLM, ChatGPT, a university enterprise edition.

A structured product sheet guided student work. The product sheet required articulation of two inspirational materials, a material description of their new, innovative material, key mechanical properties of their proposed material, a stress-strain diagram of their material, a mechanics application, and a reflection on futures-thinking and how this material is a good choice considering the socio-cultural aspects of the context that this material and device is embedded within (figure 4). This structure preserved analytical quality while opening space for curiosity and contextual exploration.

Material Name: ___________________
Slogan / Tagline: *Max 10 words*

1. Two Inspirational Materials

Identify two existing materials (e.g., titanium alloys, carbon fiber, bioplastics) and describe their key mechanical properties and uses.

2. Material Description *(3–4 sentences)*
Describe your material's composition, special features, and why it's perfect for astrolabe housings in 2125. Mention durability in desert heat, resistance to dust, and cultural design

possibilities. Describe how your material differs in composition, performance, or aesthetics from your inspirational materials.

3. Key Mechanical Properties
Fill out a table that provides values for each of the following characteristics of your material: Modulus of Elasticity, Yield Strength, Ultimate Strength, Fracture Toughness, and Ductility.

4. Stress-Strain Diagram
(Insert or draw & label key points: elastic region, yield, ultimate, fracture)

5. Mechanics Application
Select a loading case for your material and astrolabe, share the maximum allowable stress, select an appropriate safety factor, and do a calculation to determine whether the material fails or not.

6. Futures Thinking *(3–4 sentences)*
How does this design integrate tradition and advanced performance?

Figure 4. Product sheet template that student teams completed for this assignment.

We also decided to experiment with ungrading [9] as a supporting mechanism to enable and encourage deeper reflection. We used ungrading for the following three reasons: 1. Ungrading provided a space for complexity that allowed students to justify trade-offs and sit with tension, 2. Ungrading emphasized self-assessment and reasoning over points, encouraging students to develop judgment rather than compliance, and 3. Ungrading aligns with the futures-oriented framing and the assignment so that students could align their grades with their attempts to imagine and design speculatively, whereas more traditional assessment like rubrics might constrain that thinking.

For this Material Futures Lab, I created a quiz in our LMS. The quiz consisted of Likert-style questions followed by an open-ended question. For example, a question of "How would you describe your contribution to your team's (or your own) product sheet?" with options ranging from "I took the lead" to "I did not contribute" was followed by the question, "Give one example of how you contributed." I also asked a few questions about their use of AI in the assignment. The undergraduate student grader and the graduate Teaching Assistant suggested adding a disclaimer before asking about AI use, so students might be more honest about their AI use. This disclaimer was: "The following three questions ask about your use of AI tools (such as the Materials Futures GPT). This is not graded based on whether you did or did not use AI — we're interested in how you approached the assignment and what tools supported your work. Please answer honestly. As a reminder, we encouraged the use of AI for this assignment." The questions that followed included "To what degree did AI tools (like the Materials Futures GPT) influence your submission?" with options ranging from Not at all to Almost entirely. The next question was, "Give one example of an idea that came directly from your own thinking." The following question was, "Give one example of an idea where AI (such as the Materials Futures GPT) helped you get started or inspired you, if at all. Write N/A if you did not use AI." At the end of the quiz, students picked the letter grade they felt that they earned and had to justify their decision. When grading, we read through all their responses, and for most, we used the grade they suggested. For a few, we adjusted the grade slightly. In some instances, the student seemed humble in assigning themselves a lower grade. And in some other instances, the student gave themselves high marks but did not provide evidence of their contributions to the group.

The design intent is to foreground everyday innovation rather than large-scale or heroic engineering projects. Students must select materials and justify design decisions based on environmental conditions, cultural markers, and use scenarios, while applying core mechanics concepts such as stress-strain relationships.

Assignment 2: Designing The Himba Meduse Peace Monument

The second assignment extended the futures-based approach to a sociopolitical context involving reconciliation between the Himba and Meduse communities. Due to space constraints, we will not go into the details of this assignment. Students were tasked with designing a monument that symbolizes peace while withstanding complex loading conditions. This material futures lab was structured similarly to the first one, with an assignment, a product sheet template, ungrading, and encouragement to use AI. This assignment introduced more advanced mechanics concepts, including Mohr's Circle and combined loading analysis. Technical analysis was embedded within a design problem that explicitly foregrounds social meaning, symbolism, and long-term impact.

The second assignment built on the first by increasing expectations for justification, trade-off analysis, and the integration of sociotechnical considerations. Peer review and reflective components further support iterative reasoning. Students prepared their completed template, a mini-ad, and a pitch. All students pitched their work in the final class session of the semester and we brought in two industry experts to respond to their pitches and to talk to the students about their career trajectory and how materials have been important in their work as engineers.

Student Responses to the Design

While a full analysis of student learning outcomes is beyond the scope of this design case, student self-assessments offer an early indication of how the design functioned in practice. The quotes below are drawn from the ungrading quizzes and open-ended reflections collected at the end of each lab (of students who signed the consent form). They are presented not as evidence of learning outcomes but as feedback on the design itself — what students engaged with, what they struggled with, and where the framing appeared to open or constrain thinking.

Several students identified the open-ended nature of the mechanics application as distinctive and valuable. One student noted that "the most valuable parts of these labs are definitely doing the calculation parts when you are not given a concrete problem with set instructions, and you have to figure it out on your own" (Participant 5). Another described the value of working across scales: "The first lab was a handheld device so tighter materials were used like carbon fiber. The second lab was a larger building like monument so a different scale of materials were used like steel, concrete, and marble in many people's labs" (Participant 1). These responses suggest that the scaffolded progression across the two assignments supported students in connecting material selection to engineering context — one of the design intentions.

The Africanfuturist framing also appeared to function as intended for some students, who described actively weaving the narrative into their technical reasoning rather than treating it as background flavor. One student reflected, "I think I did a great job conceptualizing our project, and communicating with my group the scale of it/materials being used/the purpose both in project and in the project's 'story' for why said material is being used. I feel like I did a good job creatively weaving in the book with the project in a way that still expressed my groups and my own way of thinking" (Participant 5). This suggests the speculative framing supported rather than displaced student agency.

At the same time, student self-assessments revealed a tension the design did not fully resolve: the relationship between sociocultural and technical engagement was uneven across students. One student was candid that "the actual mechanics work is rushed, and probably wrong and might not make sense," while separately expressing pride in the cultural and aesthetic dimensions of their design (Participant 1). This unevenness could reflect a genuine trade-off embedded in the design itself — by foregrounding sociocultural context and speculative imagination, some students may have oriented more toward those dimensions at the expense of technical depth. However, other students navigated this differently, describing the two dimensions as distinct contributions they managed deliberately. One noted, "the math and the material was my own idea but AI was good for filling in the context and the meaning of the monument and how it connects to the world around it" (Participant 5) — a distribution of labor that raises interesting questions about whether the sociocultural and technical were genuinely integrated or remained somewhat parallel tracks. A third response suggests that for some students, the technical work was a source of pride precisely because it was self-directed: "The calculations and Mohr's circle I did for the mechanics application were definitely my most proud achievement. If I had more time, I would add more information to the structure of our fountain, to get even more accurate values for our mechanics application" (Participant 5). Together, these responses suggest that the design successfully created space for both modes of engagement, but did not consistently ensure their integration — a distinction worth attending to in future iterations.

The industry pitch session at the close of the second lab also generated reflection worth noting. One student described a shift in orientation after hearing from practitioners: "one moment that shifted my role was when the industry engineers emphasized the need to slow down when trying to work through projects and that having extra time can help significantly improve something rather than getting it all done as fast as possible" (Participant 2). While this speaks more to the pitch event than the assignments themselves, it suggests that situating the work in a professional context — where design decisions are explained and defended — may have reinforced the sociotechnical framing in ways the assignments alone did not.

Taken together, these responses indicate that the design achieved meaningful engagement with its core goals for many students, while also surfacing predictable tensions between imaginative openness and technical accountability. Both are productive findings for future design iterations.

Discussion and Future Work

As we developed the Material Futures Labs, we realized that one tension was not only balancing imaginative freedom and analytical quality, but determining how to evaluate both. Traditional grading systems privilege correctness and convergence, which can limit space for speculative or contextually grounded reasoning. So, we wanted to ensure our assessment structure included social integration and student self-awareness. This is why we incorporated ungrading to shift the focus from producing a single correct answer to articulating and defending reasoning. This approach allowed students to justify trade-offs and demonstrate both technical quality and sociotechnical awareness. However, this reflective self-evaluation and narrative contextualization required greater interpretive engagement from students. This approach could leave students feeling uncertain about how their work is being evaluated. To address this concern, we provided students with clear expectations, structured guidelines, and full contextual framing before each assignment. This worked in a class of 47 students. However, it may present challenges in larger classes, where time constraints and grading logistics could limit the feasibility of reflective evaluation.

Another tension we faced was related to time and workload. We did not want to increase the course's workload by adding separate activities to address social factors. Also, we wanted students to move beyond technical analysis and consider the social contexts in which engineering decisions are made. To address this tension, we contextualized the Material Futures Labs assignments within an Africanfuturist narrative. By embedding the assignments in *Binti's* speculative world, we invited students into a context that encouraged them to question whose knowledge counts, what technologies are valued, and what futures engineering should serve. Unlike traditional approaches that append social considerations after technical analysis [3], [4], this framing required students to begin within a defined social context and design their solutions accordingly. So, technical decisions were not treated as separate from identity, community, or long-term consequences; they were embedded within them from the start. We believe this approach offers an efficient and structurally integrated way to cultivate sociotechnical fluency without increasing workload or sacrificing analytical depth.

Future work will draw on student self-assessments, product sheets, and written reflections to examine how this framing shapes student thinking and practice. The authors seek feedback from the LEES community on the feasibility of speculative, narrative-based assignments in core engineering science courses and on approaches for examining and creating value in ungraded or low-stakes environments.

Conclusion

This design case illustrates one possible approach for embedding sociotechnical thinking into engineering science homework without sacrificing technical depth. The Material Futures Labs combine sociotechnical thinking, a futures-oriented narrative, and ungrading to create a structured space for students to engage engineering science as a socially situated and future-oriented practice. Social context is not treated as an add-on; instead, sociotechnical reasoning is embedded in core mechanics work and supported by aligned assessment practices. The work contributes to LEES conversations on sociotechnical integration and offers a foundation for future empirical and design-based research on EM development in core engineering coursework.

AI Disclosure Statement

Generative AI tools were used to generate and revise portions of text during the writing process, as well as to support idea organization and clarity. All substantive decisions related to the course design, instructional context, design case, and discussion were made by the authors. The authors reviewed, edited, and take full responsibility for the final content of this work.

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