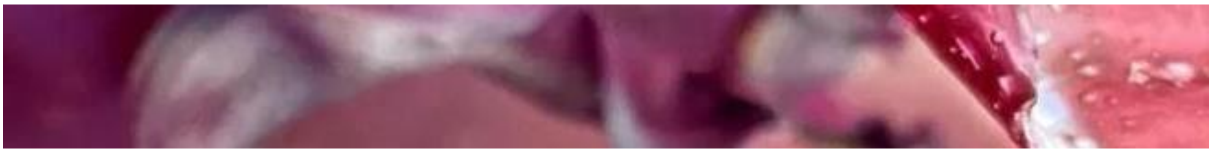

Nurturing Ecological Stewardship in Industrial Design Education

Dan Neubauer

Associate Teaching Professor Industrial Design Iowa State University

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Introduction

The future of responsible and ecological design demands a new generation of industrial designers equipped with the skills to holistically address complex human needs through sustainable innovation. By integrating hands-on experimentation with bio-based materials into design curricula, educators can cultivate the vital competencies students need to create impactful, user-centered solutions that resonate with evolving expectations around environmental responsibility and STEM skills (Avramescu 123).

At its core, this pedagogical approach embeds the exploration of renewable, biodegradable resources like mycelium, algae, food waste, or beef gelatin into the foundational design skills of user research, ideation, prototyping, and iterative refinement. Students at institutions like the College for Creative Studies have undertaken projects prototyping sustainable furniture and packaging using mushroom mycelium composites ("Bio-Based Materials"). The tactile nature of working directly with these bio-materials facilitates rapid mock-ups, user testing, and feedback integration throughout the user-centered design process (Muszyńska et al. 31). On top of this it provides students with a deeper learning opportunity as they begin to develop and experiment with their own material development.

This hands-on engagement moves beyond just theoretical sustainability metrics, fostering sustainable mindsets and material literacy from the ground up. When Pratt Institute students created lighting products using indigenous Mexican materials like salt and beeswax, they gained first-hand experience with the unique properties, potentials, and challenges of these sustainable resources ("Bio-Based Materials"). The multisensory immersion prompted the designers to rethink unsustainable practices and develop innovative, responsible alternatives tailored to real user needs and contexts.

Moreover, the open-ended exploration of shaping and combining bio-materials sparks the creative inquiry vital for user-centered design thinking. The purposeful "play" of hands-on material manipulation inspires them to ask "what if?" questions that lead to bio-inspired breakthrough ideas and solutions. This creative discovery through making allows designers to push boundaries and uncover new possibilities that cannot be replicated through just visuals or descriptions alone. The focus on developing material also provides a more tangible and smaller scope approach toward creating and understanding that oftentimes is lost within designing a product.

Hands-on bio-material projects facilitate the development of holistic design literacy combining technical knowledge with understanding of a materials' origins, applications, and sensorial qualities. This union of analytical and tactile comprehension is crucial for user-centered design, allowing industrial designers to select and apply materials innovatively to meet the needs of users. The resulting material connoisseurship, as fostered at schools like RISD's Nature Lab, enables more resonant and responsible design work addressing user needs ("How Bio-Based Building

Materials").

Considering the impact material development can have on design students, this led me to implement an entire semester long studio with seniors in industrial design. This allowed me to guide student through material research, exploration, experimentation, discussion on impact, and design implementation of their materials.

Methods:

The studio involved undergraduate design students enrolled in a capstone course focused on bio-based and non-petroleum based materials. A total of 20 students participated, each bringing a unique perspective and background in design.

Course Structure

The 16 week course that met in person 12 hours each week was structured into two main phases: **Material Exploration and Experimentation**, and **Design and**

Implementation. This structure allowed ample time for the design students to really explore the material research and creation component of the studio.

Phase 1: Material Exploration and Experimentation

Objective: To encourage students to explore and experiment with non-petroleum-based materials.

Materials: Students were provided with access to a variety of bio-based materials, including but not limited to, plant fibers, mycelium, bioplastics, and recycled organic waste.

Demonstrations of techniques:

To many students, material development and experimentation can be a very intimidating field of practice. To begin the class, I conducted a number of bio material demonstrations that ranged from Casein Plastic production, beef gelatin bio resin, and agar agar thin film. Each of these demonstrations lasted approximately and hour and provided the needed exposure to material production and experimentation for the students to begin their own research, hypothesizing, and experimentation.

Class Deliverables:

Research: Students conducted literature reviews and case studies on existing bio-based materials and their applications.

Experimentation: Students engaged in hands-on experimentation to create and refine new materials. This involved mixing, molding, and testing various combinations to assess properties such as durability, flexibility, and environmental impact.

Documentation: Students maintained detailed logs of their experiments, documenting processes, results, and observations. This was crucial for the iterative refinement of their materials. Each material developed was cataloged with the following data: exact formula and steps of production, Durometer (Shore A or D), tensile strength, Mohs hardness, Thermoplastic qualities, and flame/heat resistance. This allowed students to have a comprehensive resource for new materials they could reference when it came time for designing objects.

Phase 2: Design and Implementation

Objective: To design functional objects utilizing the bio-based materials developed in
Mid-term Review: At the midpoint of the course, students compiled their research findings and material experiments into a comprehensive report. This served as a foundation for the design phase.

Design Process:

Opportunity Space Identification: Throughout the material experimentation stage of the semester, students were tasked with making observations within daily life for opportunities for design intervention or new product development.

Concept Development: Students brainstormed and sketched potential design concepts that could effectively utilize their materials.

Prototyping: Using their refined materials, students created prototypes of their design concepts. This involved iterative testing and refinement to ensure functionality and aesthetic appeal.

Feedback and Iteration: Students presented their prototypes to peers and instructors for feedback, which informed further iterations and improvements.

Final Presentation: At the end of the course, students presented their final designs, highlighting the material properties, design process, and potential applications.

Results:

The students were very receptive to the entire semester. In the beginning they needed some guidance on the scientific process of experimentation with material development. However, drawing a corollary to the design process made it easy for them to connect the two processes. This step allowed for me to easily explain where and what each stage of the process was intended for and how best for them to utilize each step. Working this way allows for a stronger connection to the STEM world as Industrial Design is often times thought to be a fringe discipline of STEM. Though when we closely evaluate the industrial design and its adherence to a user centered approach towards design and innovation we can clearly see many direct connections to STEM. When we bring in material development and exploration, this connection becomes even stronger and more deliberate to STEM. Students that typically lack the creative confidence for early stage ideation and user investigation were very excited to be doing more of a “hard science” approach towards design. This combination of exploration in material and science allowed the students to deeply investigate the material properties and variables to experiment with. One student went so far as to create over 50 different bio foam samples. Continuously experimenting with various additives to beef gelatin to arrive a desired outcome of a closed cell foam that had adequate impact resistance or cushion.

Other students explored various formulae that would help to create a hard plastic resin compound. These students quickly discovered that the fewer additives resulted in more pure, clear, and more rigid “plastic like” materials. The challenge with these hard resin substitutes was finding a delicate balance with rigidity and flexibility. The more rigid the material, the more easily it broke under minimal stress. The students experimented with adding various plasticizers to the formula to arrive at a material that was parallel to a polyolefin class of plastic.

Finally, there were a few students that took entirely different approaches to the creation and experimentation of the bio based material. These students attempted to either recreate an extremely flexible material that could stretch and inflate similar to latex. While another student used a gelatin bio based material formula to act as a fabric stiffener for a reclaimed wool structure. The student working on the inflatable material had defined an agar agar formula that would work well to be pliable and stretchable similar to latex. However, this material did not lend itself to our DIY molding processes, nor did it want to heat seal to create a volume. Ultimately, a cyanoacrylate glue had to be utilized to bond the seams and create an inflatable volume successfully.

Outside of the material experimentation successes and designed object successes, the most profound result came from the students reflections at the end of the semester. Students that had participated in the bio based material studio realized that so much more was possible when it came to materials and non traditional approaches to science, design, and product creation. The students, collectively, had realized that they did not need to rely on petroleum plastics as the primary material for new product development. They were now more equipped with material development skills and the analysis and synthesis required to explain why a certain material should or should not be utilized for a new product. Plastic does have its place within our world, but so often over history has this material been over sourced and utilized, forgoing other potential material choices. These choices, as the students experienced have impacts both on a large system level and individual scale, and if we can at least show and discuss other possibilities for product material and production, then we may begin to slowly move away from the path we are on now. The path currently set to continue to generate millions of tons of plastic objects and plastic waste that has a profoundly negative impact on our ecology and environments.

These initial experiments and designs are only the beginning for these students. We expect they will look back on this experience for the entirety of their career and think about how they may scale some of the processes and formulae up to be competitive with current petroleum plastic production. Further study of course is needed as we look at scaling these materials and processes up. However, early results from the material exploration state of the semester began to show promise for some of the bio material formulae that could lend them to using existing thermoforming manufacturing processes. Many of the material formulae shared similar thermoplastic properties, and with further experimentation and research, we could find a perfect avenue for adoption within existing tooling and machine processes.

Discussion:

From a STEM education perspective, bio-based material exploration provides an interdisciplinary platform for project-based learning integrating science, technology, engineering principles, and design thinking. Hands-on prototyping with bio-composites allows students to apply concepts from fields like materials science, biotechnology, and sustainable manufacturing. For example, Savannah College of Art and Design students designed and fabricated eco-friendly surfboards using bio-based epoxy resins, combining technical material analysis with user-centered form studies ("Sustainability").

Beyond user-centered processes, bio-based material projects intrinsically involve crosspollination across diverse STEM disciplines. When designing sustainable packaging solutions using mycelium at the Biomaterials Lab at Pennsylvania College of Art & Design, students must collaborate across fields like biotechnology, industrial design, and environmental science ("The Benefits"). Building these vital interdisciplinary skills equips designers to address the multifaceted challenges of sustainable innovation. This crossfunctional integration reflects modern product development realities, allowing designers to adapt to changing business needs.

In the real world, major companies like Dell, Nike, Puma, and Philips are already utilizing hands-on materials exploration and sustainable bio-materials in their design processes. Dell incorporates materials like bamboo and mushroom packaging ("How Bio-Based Building Materials"). Nike has an entire Explore Team dedicated to manipulating sustainable textiles and composites ("Sustainability"). Puma's urban mobility concepts emerged from hands-on prototyping with new eco-materials ("How Bio-Based Building Materials"). Philips' designers can experiment with bio-based materials like wood, wool, and bio-plastics in their "Do Explore" lab. Graduates prepared through immersive, experimental curricula will emerge ready to join these cutting-edge sustainable innovation efforts.

Ultimately, by interweaving bio-based materials into the core pedagogy of industrial design education through hands-on experimentation, educators can shape the next generation of creative, sustainable thinkers and STEM problem-solvers. Graduates will emerge with the holistic material literacy, bio-inspired creativity, user-centered processes, and cross-disciplinary collaboration abilities to develop impactful solutions tailored to the evolving needs of users, businesses, and the planet itself.

As society continually raises expectations around environmental responsibility, sustainable innovation, and STEM skills, designers prepared through this immersive, experimental approach will stay adaptable and responsive. The future of design demands a holistic perspective integrating human needs and responsible material utilization - and hands-on bio-material exploration provides the vital skills for creating resonant, eco-conscious solutions centered on both human and ecological contexts.

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