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From Outdoor Experiences to Augmented Reality: Surveying Environmental Roots of Engineering Interest to Guide AR Module Development (NSF EFMA)

Mohammed Metwaly, Purdue University at West Lafayette (COE)

At Purdue University, my journey as a Graduate Research Assistant and Doctoral Student in Computer Engineering merges innovative research with practical applications. The focus of my work revolves around developing mixed reality applications for engineering education purposes.

Selena Maria Nadjarian, Purdue University at West Lafayette (PPI)
Dr. Farid El Breidi, Purdue University - Purdue Polytechnic Institute – West Lafayette

Dr. Farid El Breidi is an Assistant Professor in the School of Engineering Technology at Purdue University. Dr. El Breidi is the director of the Digital Technologies Lab and is actively engaged in research encompassing digital fluid power, digital reality, and engineering pedagogy. He serves as the Principal Investigator for numerous internally and externally funded research projects. These projects have received support from agencies and associations such as the National Science Foundation and the National Fluid Power Association.

Dr. Wade H Goodridge, Utah State University
Carie Green, South Dakota State University
Sarah Adel Bargal

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Abstract

This NSF-funded project investigates how formative outdoor experiences shape undergraduate students' pathways into engineering and engineering technology, with particular relevance to applied and manufacturing-oriented domains. Prior research has shown that early interactions with natural environments, such as building, exploring, and observing physical systems, can influence long-term technical interests, yet engineering education lacks validated tools for measuring these experiences and connecting them to learning design. To address this gap, we developed and validated a mixed-methods survey that captures students' emotional and spatial connections to nature, specific formative experiences, and perspectives on engineering in natural contexts, including a dedicated section on fluid power in natural systems. The survey was administered to 189 Mechanical Engineering Technology students, yielding 150 complete responses, and validation analyses demonstrated strong internal consistency and construct structure across survey sections.

Quantitative results showed high levels of nature affinity and frequent childhood engagement with outdoor environments. Significant relationships emerged between nature-based curiosity and students' perceived relevance of engineering to natural systems. Open-ended responses revealed recurring themes including building and construction, water-based systems and power generation, vehicles, and biomimicry, with frequent references to concrete objects such as bridges, dams, logs, and turbines.

These findings were used to inform the design of an augmented reality learning module that places students in a virtual natural environment where they construct a bridge using virtual logs inspired by participants' reported experiences, with environmental cues such as water, terrain, and wildlife incorporated to reflect the formative settings identified in the survey and support embodied, context-rich interaction. A preliminary pilot deployment of the AR module demonstrated high levels of engagement and prompted students to draw on both intuitive and technical reasoning when making design choices, indicating that the experience effectively connects personal environmental memories with applied engineering decision-making. Together, these results show how validated survey data can drive the development of experiential AR learning environments grounded in students' lived experiences, providing a scalable framework for supporting engagement and development in engineering and manufacturing-oriented education.

Project Overview

Engineering and engineering technology programs, particularly in applied and manufacturing-oriented fields, increasingly emphasize hands-on learning and real-world problem solving in physical and manufactured systems (Azzam et al., 2023, 2024; Metwaly, Breidi, et al., 2025; Metwaly, El Breidi, et al., 2025). However, many students enter these programs with formative experiences that occur outside formal classrooms, such as building structures, interacting with natural systems, or experimenting with materials and tools in outdoor settings (Bagiati & Evangelou, 2016; Earle & Coakley, 2019). Prior research in environmental identity development suggests that these early experiences can strongly shape how individuals relate to technical work (Klaar & Öhman, 2014; Mann, 2025; Seaman et al., 2024; Trina et al., 2024), yet engineering education lacks systematic ways to capture and use this information to inform learning design. As a result, instructional technologies and curricula are often developed without a clear understanding of the experiential foundations that motivate students to engage with engineering.

This project was established to bridge that gap by creating a data-driven framework for connecting students' formative outdoor experiences with applied engineering education. Supported by the National Science Foundation (Grant No. EFMA-2431980), the project treats nature and informal learning not as separate from technical training, but as a meaningful source of insight for understanding how students develop interest in engineering and engineering technology. The goal was to develop tools that could both measure these experiences and translate them into the design of immersive learning environments that resonate with students' prior ways of engaging with physical systems.

Phase I Project Design

Phase I focused on developing a measurement-to-design pipeline connecting formative outdoor experiences to applied engineering learning environments. A survey was developed to capture connections to nature, formative experiences, and attitudes toward engineering in natural contexts, including a fluid power component, and was refined through expert review and pretesting. The survey was administered to 189 undergraduate Mechanical Engineering Technology students, yielding 150 complete responses. Validation demonstrated strong internal consistency, with Cronbach's alpha ranging from 0.78 to 0.89 and McDonald's omega from 0.80 to 0.90 across domains.

Several constructs informed design translation. Connection to Natural Environments captured enjoyment of outdoor settings and frequency of childhood outdoor engagement, reflected in items such as "I like to spend time outdoors in natural settings" and "How often were you outdoors as a child?" Nature-Linked Engineering Interest examined whether students perceived engineering as relevant to natural systems, with representative items such as "Natural processes inspire engineering solutions" and "Engineering can address environmental challenges observed outdoors." Together, these constructs provided evidence that students' formative experiences were environmentally grounded and cognitively linked to engineering thinking.

The dataset combined Likert-scale responses with open-ended narratives. Quantitative analyses examined relationships among nature affinity, curiosity, and engineering orientation, defined here as students' belief that engineering meaningfully connects to the environmental systems and experiences they encountered growing up. Qualitative responses were analyzed using term-frequency modeling and LLM-assisted thematic coding with manual verification. This mixed analytic approach supported both broad pattern detection and interpretation of students' early interactions with physical and natural systems.

Findings were then translated into the design of an augmented reality module, shown in Figure 1. Recurring themes, objects, and environments informed the virtual setting and interaction design, including the selection of structures, materials, and natural features. This created a direct link between measured formative experience and immersive learning design.

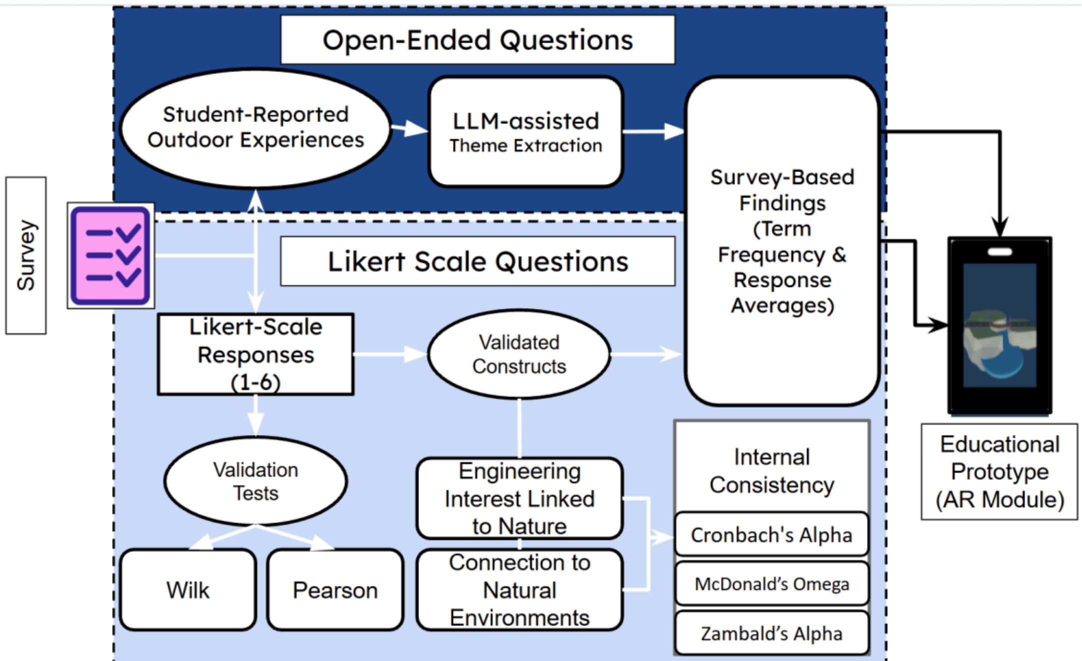

Figure 1. Overview of the survey-to-AR design pipeline

Key Survey Findings

The survey was completed by 150 undergraduate Mechanical Engineering Technology students, with a demographic profile typical of upper-division engineering technology programs, including a predominance of juniors and seniors and a wide range of childhood living environments. Figure 2 summarizes participants' age, gender, academic year, and where they grew up. Participants self-identified childhood setting as urban, suburban, or rural, providing a coarse-grained environmental context for interpreting formative experiences. On a six-point Likert scale, respondents reported high enjoyment of natural settings (M = 5.09) and frequent childhood outdoor activity (M = 4.77). They also expressed agreement that engineering can address environmental challenges observed in outdoor contexts (M = 4.61) and that natural processes can inspire engineering solutions (M = 4.21). Together, these results indicate that students not only value natural environments but also view them as meaningful contexts for technical and engineering thinking.

Beyond these general patterns, open-ended responses revealed the specific kinds of experiences that shaped early technical curiosity. As summarized in Table 2, students most frequently referenced experiences involving structures and construction, water and energy systems, vehicles, and biomimicry. Many described building bridges, experimenting with flowing water, riding bicycles across different surfaces, or observing how animals construct stable structures in natural environments. These accounts demonstrate that students' outdoor experiences were not passive, but deeply connected to physical systems, forces, and material behavior.

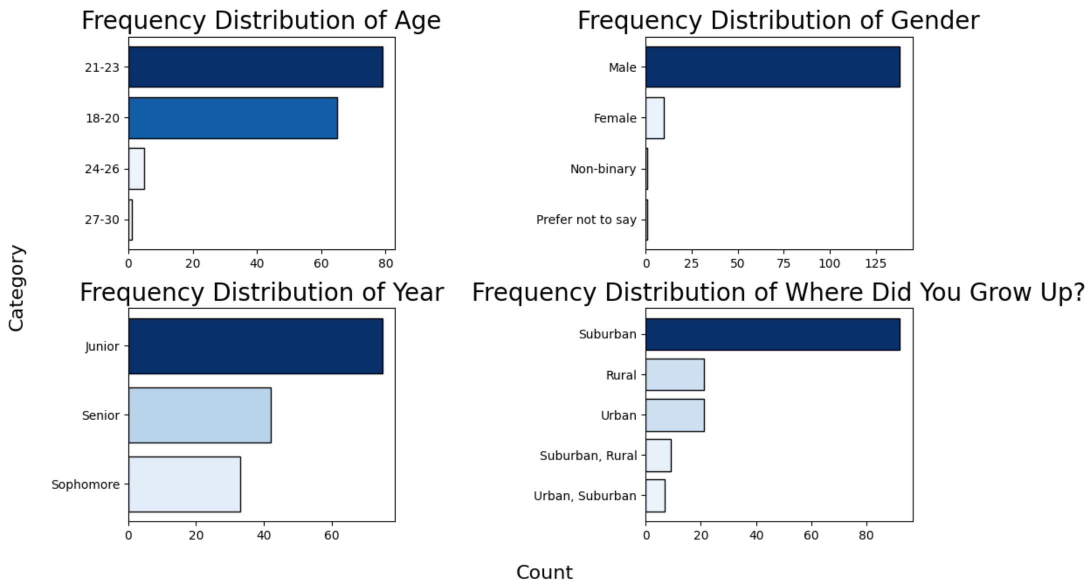

Figure 2. Demographic profile of survey participants.

These themes provided the primary design inputs for the AR learning environment. Because students most often associated early engineering curiosity with building, water flow, and natural structures, the AR module was designed around a water-rich landscape in which learners assemble and test a bridge using log-based components. The survey documented prior experiences and directly informed how those experiences were translated into an interactive learning context.

Table 1. Survey-Derived Experience Themes Informing AR Design

Theme	Example	Frequency of Mentions
Structures and Construction	"I was walking through the woods and had to cross a suspension bridge which prompted me to think of the engineering behind the design and construction of it."	44
Water and Energy Systems	"The watermill, I can run it even when I was a kid, I'm thinking how it can bring water up."	41
Vehicles	"My interest in engines, and how different parts of vehicles influenced my desire to study engineering."	27
Biomimicry	"I was watching a lizard run across the surface of a puddle, and it inspired me to look into how it did that"	19

AR Pilot Findings

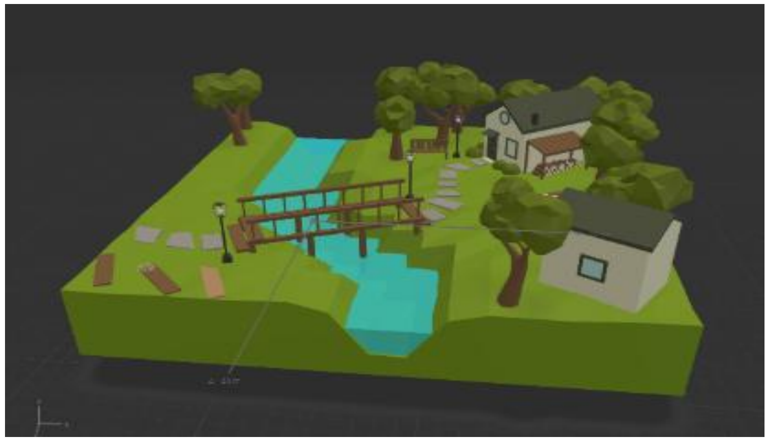

Figure 3. Augmented reality learning environment used in the pilot bridge-building task.

A subset of students participated in a pilot deployment of the AR learning environment derived from the survey findings. In this experience, learners interacted with a naturalistic scene containing water, trees, and log-based structures and were tasked with assembling a bridge across a creek. Observations and post-activity responses indicated that students engaged with the environment in ways that mirrored the formative experiences reported in the survey, shown in Figure 3. Students relied heavily on visual and environmental cues to guide their decisions, including the appearance of materials, the presence of water, and symbolic elements such as spider webs or nests. Many treated these cues as indicators of structural reliability or environmental consequence, avoiding logs they believed were weak or ethically compromised even when technically usable. This behavior reflected a form of situated reasoning in which environmental context shaped engineering judgment. Participants also exhibited decision strategies consistent with real-world engineering problem solving. Rather than selecting parts at random, students described eliminating options, comparing alternatives, and managing uncertainty as they worked toward a viable bridge design. Some participants explicitly connected the AR experience to childhood memories of building or exploring structures outdoors, suggesting that the immersive environment successfully activated the kinds of formative experiences identified in the survey. The module is not intended to recreate childhood experiences verbatim. Rather, it activates contextual cues that allow adult learners to reinterpret formative experiences through formal engineering reasoning.

Implications and Next Steps

This project demonstrates how validated survey data can ground immersive learning environments in students' lived experiences. By identifying outdoor contexts and physical systems associated with early engineering curiosity, the project offers a replicable framework for designing educational technologies aligned with students' prior ways of engaging with the world. Integrating environmental identity measures with augmented reality provides a practical pathway for supporting engagement in applied engineering and engineering technology programs. In the next phase, the survey and AR module will be deployed across additional courses and populations to examine effects on learning, engagement, and persistence. Future work will also explore adapting the instrument to other technical domains and instructional settings.

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