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# A Mixed-Methods Investigation into the Influence of Outdoor Experiences on Engineering Career Choices

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## Abstract

This paper presents the development, validation, and administration of a mixed-methods survey designed to examine how formative outdoor experiences influence undergraduate students' decisions to pursue engineering or engineering technology. Drawing on environmental development methodology and STEM education research, the instrument combines Likert-scale items that measure nature-related attitudes with open-ended prompts that elicit personal accounts of formative experiences. The survey was developed through an iterative process that combined a literature review, faculty expertise, and cognitive pretesting to ensure alignment between the constructs and students' interpretations. The instrument targets four subconstructs of environmental influence: emotional and spatial connection to nature, specific formative experiences, integration of nature and engineering, and other influences on career choice, while also collecting demographic information. Additional safeguards, such as attention checks, were implemented to maintain response quality. The instrument was distributed to 189 undergraduate students in a Mechanical Engineering Technology program, yielding 150 complete responses after exclusions. Validation included expert panel review to confirm content relevance and reliability testing that produced strong internal consistency (Cronbach's $\alpha = 0.78$-$0.89$, McDonald's $\omega = 0.80$-$0.90$). Designed as an adaptable instrument, the tool enables researchers and educators to examine how environmental and experiential contexts relate to student engagement, engineering interest, and career pathways. The methodology also supports potential application in manufacturing and technology education contexts by connecting students' formative experiences to applied learning environments. By contributing a validated and replicable instrument, this work equips the engineering education community with a means to systematically link formative experiences to technical learning to increase engagement.

## Introduction

Understanding why students choose to pursue engineering and manufacturing-oriented engineering technology pathways has been widely examined in STEM education research [1], [2]. Prior work has studied influences such as parental encouragement, classroom exposure, and career awareness. However, formative experiences outside formal educational settings, particularly those involving interaction with natural or physical environments, remain comparatively underexplored. Research on informal and experiential learning suggests that meaningful learning and identity development often emerge through real-world interactions, where individuals engage with physical systems, materials, and environmental phenomena [3], [4]. These early experiences have been shown to support cognitive development, curiosity, and problem-solving, all of which align closely with engineering practice [5].

Early interactions with physical environments have also been linked to the development of engineering-related thinking. Studies on children's engagement with building materials and open-ended play environments suggest that activities such as constructing structures, manipulating objects, and experimenting with natural systems can foster foundational engineering concepts [6], [7]. These findings align with work on environmental identity development, which emphasizes that repeated interaction with natural environments contributes to how individuals perceive their relationship with science and engineering domains [8], [9]. In engineering technology and manufacturing-focused programs, learning is often centered on applied systems such as fluid power, materials processing, and production systems. These domains require an understanding of physical interactions and system behavior that may originate from earlier experiential learning contexts. Despite this connection, there are limited validated instruments that systematically examine how formative outdoor or informal experiences relate to students' interest in engineering and manufacturing-oriented pathways at the postsecondary level. Existing studies have explored engagement and experiential learning in engineering contexts [10], [11], but fewer tools focus specifically on capturing the role of early experiences in shaping these pathways.

To address this gap, this study presents the development and validation of a mixed-methods survey designed to examine the relationship between formative outdoor experiences and interest in engineering and engineering technology. The instrument integrates Likert-scale items with open-ended responses to capture both patterns in student attitudes and the meaning they assign to their experiences. Its design draws on prior work in environmental identity development, nature-based learning, and STEM education [12], [13], while remaining tailored to postsecondary engineering contexts. In addition to supporting research on student pathways, the instrument is intended to provide educators with a structured way to identify experiential factors that may inform curriculum design and the integration of hands-on or context-based learning activities.

The survey includes components addressing connection to nature, specific formative experiences, relationships between nature and engineering concepts, and other influences on career choice. To extend the instrument's relevance to manufacturing and engineering technology education, a dedicated component was included to examine how students relate natural phenomena, such as flow, pressure, and environmental forces, to fluid power concepts. Fluid power is a foundational topic in many mechanical and manufacturing systems and provides a concrete domain through which connections between early experiential learning and later technical understanding can be explored. This paper focuses on the design, development, and validation of the survey instrument as a replicable tool for use in engineering and manufacturing education research.

## Related Work

Prior research has established that early interactions with physical and natural environments play a meaningful role in the development of technical thinking and STEM-related identity. Studies suggest that children's early interpretations of how the world functions form a foundation for later engineering reasoning and problem-solving [6], [14]. Nature-based STEM experiences have also been shown to positively influence environmental attitudes and engineering perceptions, reinforcing connections between experiential learning and technical interest [15]. Additional work highlights the persistence of these effects over time, with outdoor and place-based experiences contributing to sustained engagement with STEM fields [16]. At the postsecondary level, place-based and nature-centered learning environments have been shown to strengthen science and engineering identity, suggesting continuity between early experiences and later academic and career pathways [9].

A separate body of work examines the integration of outdoor and nature-based contexts into engineering education. Learning in natural environments has been shown to reduce cognitive load, support collaboration, and foster understanding of complex engineering concepts [4]. Broader reviews and empirical studies further demonstrate that experiential and outdoor learning environments can enhance problem-solving, teamwork, and engagement, which are central to engineering and manufacturing-focused curricula [17], [18], [19]. These approaches have also been associated with broadening participation in STEM and increasing student motivation [13]. Despite these advances, relatively limited work has focused on systematically capturing how formative outdoor and informal experiences influence students' interest in engineering and engineering technology pathways. While recent studies emphasize the importance of experiential learning in higher education [3], [5], fewer validated instruments explicitly measure the connection between early experiential contexts and later engagement in applied engineering and manufacturing domains. Prior work has also explored survey-based approaches for examining engineering pathways and outcomes [20], though these instruments primarily focus on traditional academic and career-related factors.

This gap highlights the need for a structured and validated instrument capable of capturing how formative experiential contexts relate to students' interest in engineering and manufacturing-oriented pathways.

## Instrument Design & Development

The survey developed for this study is a mixed-methods tool designed to examine the relationship between early outdoor experiences and interest in engineering or engineering technology within manufacturing-oriented educational contexts. It combines Likert-style items that measure emotional and spatial connections to nature with open-ended questions that prompt participants to recall specific formative activities and symbolic associations. The survey consists of six sections: demographics; emotional and spatial connection to nature; specific formative experiences; integration of nature and engineering; other influences on career choice; and fluid power in natural systems. Together, these sections are intended to capture both the broader environmental contexts students experienced and the personal narratives that connect those experiences to technical curiosity and career direction. The inclusion of a dedicated fluid power section reflects its role as a core topic in manufacturing and engineering technology curricula, particularly in relation to energy transfer and system behavior. Grounded in environmental identity development research and engineering education inquiry, the instrument is designed to examine how formative outdoor experiences relate to interest in applied engineering and engineering technology pathways.

The instrument is organized around multiple constructs and item types. Each construct was represented by multiple items, with Likert-scale sections containing between three and nine items, depending on the construct. The "Connection to Nature" construct is measured primarily through Likert-scale items assessing outdoor engagement, comfort in natural environments, and perceived links between nature and curiosity about engineering. The "Engineering and Nature Integration" construct is measured through Likert-scale items examining whether students view natural systems as relevant to engineering thinking and design. The "Specific Formative Experiences" section relies on open-ended prompts to capture detailed narratives about outdoor experiences that shaped technical curiosity. The "Fluid Power and Nature" section combines scaled and open-ended items to examine how students connect natural fluid phenomena to formal engineering concepts. Demographic and categorical items provide contextual information about background, prior exposure, and other influences on career choice.

Survey development began with a comprehensive review of environmental identity frameworks and studies on STEM persistence. Drawing on instruments that measure environmental affinity and STEM identity, the initial item pool was designed to reflect constructs such as connection to nature, spatial reasoning, and early technical curiosity, which are foundational to hands-on, manufacturing-oriented engineering education. Faculty with expertise in environmental identity development and engineering education collaboratively reviewed the drafts, ensuring relevance to both psychological theory and disciplinary context. Cognitive pretesting was conducted with a small group of representative students to examine how participants interpreted each item and to refine wording for clarity and construct alignment. This iterative process helped ensure that survey items captured students' intended meanings while remaining accessible across varying technical backgrounds. Through successive revisions, the instrument established a clear linkage between theoretical constructs and their operationalization in survey items, grounding the final design in both theory and pedagogical relevance for applied engineering education settings.

The instrument comprises six sections, each serving a distinct purpose in capturing students' formative experiences and technical orientation. The demographics section extends beyond standard background variables to include indicators of prior exposure to nature and engineering. Students were asked where they grew up (urban, suburban, rural), whether they participated in STEM-related groups such as robotics or science fairs, and whether they engaged in environmental activities or clubs. The emotional and spatial connection to nature section measures general affinity for nature, perceived influence of nature on engineering interest, and primary outdoor settings during childhood. This was designed to connect participants' formative environments to their reported outdoor engagement. The specific formative experiences section, presented through open-ended prompts, sought detailed narratives of a singular outdoor encounter that sparked interest in engineering, its perceived influence on career choice, and how such an experience might inspire a future nature-based engineering project. The integration of nature and engineering section probed attitudes toward incorporating natural processes into engineering solutions, reaffirming the linkage between environmental contexts and technical problem-solving. The other influences section collected data on additional factors, such as family members, mentors, or media, that may have shaped career pathways. Finally, the fluid power in natural systems section was developed to explicitly address manufacturing-relevant technical content. This section focuses on participants' confidence in relating natural fluid phenomena, such as rivers or wind patterns, to formal fluid power concepts taught in manufacturing and engineering technology curricula. Open-ended prompts further encourage participants to reflect on how natural systems might inspire environmentally responsible fluid power applications. Together, these sections support both quantitative analysis of defined constructs and qualitative interpretation of students' formative experiences, engineering-related perceptions, and applied technical reasoning.

### Validation

Validation proceeded in two interwoven streams. First, expert review panels composed of three scholars with expertise in survey methodology, environmental psychology, and engineering education evaluated item clarity, coverage, and alignment with the study's constructs. This process ensured robust content validity and led to refinements in wording and structure. To safeguard data quality, two negatively connoted "attention check" items (items 5 and 9 in Section 1) were embedded to detect inattentive or random responding. Responses failing these checks (n=12) were excluded from analysis.

Likert-scale items were measured on a 6-point scale ranging from low agreement or frequency to high agreement or frequency. For analysis, Likert-scale items within each construct were grouped and aggregated using mean composite scores to represent broader dimensions such as nature affinity and engineering-related perceptions. Open-ended responses were analyzed qualitatively to identify recurring themes, while categorical items were summarized using frequency distributions.

Internal consistency was assessed for the Likert-scale portions of the instrument using Cronbach's alpha and McDonald's omega, which ranged from 0.78 to 0.89 and 0.80 to 0.90 across conceptual domains. Exploratory factor analysis was used to examine whether scaled items grouped into coherent constructs aligned with the intended domains, such as connection to nature and engineering-related perceptions. The results indicated consistent clustering within these conceptual groupings. Normality tests, including Shapiro-Wilk and D'Agostino-Pearson, showed that individual items were non-normally distributed, supporting the use of nonparametric procedures. Construct validity was further examined using Kruskal-Wallis tests followed by Dunn's post-hoc comparisons, which identified significant differences across selected response groups on key items. Together, these analyses indicate that the instrument can distinguish among varying levels of nature affinity and perceived engineering influence.

### Data Collection

The finalized survey instrument was administered via an online platform to 189 students enrolled in a Mechanical Engineering Technology course at a large public university. Conducted during class time, the survey achieved 150 complete responses. The sample was primarily aged 18-23, with most participants at the junior level. The cohort was predominantly male (approximately ~91%), and a majority reported growing up in suburban environments, with additional representation from rural and urban backgrounds (Figure 1). These variables were collected to contextualize responses and support the interpretation of how formative experiences relate to engineering interest. This high completion rate indicates that the instrument was both accessible and manageable within the classroom setting.

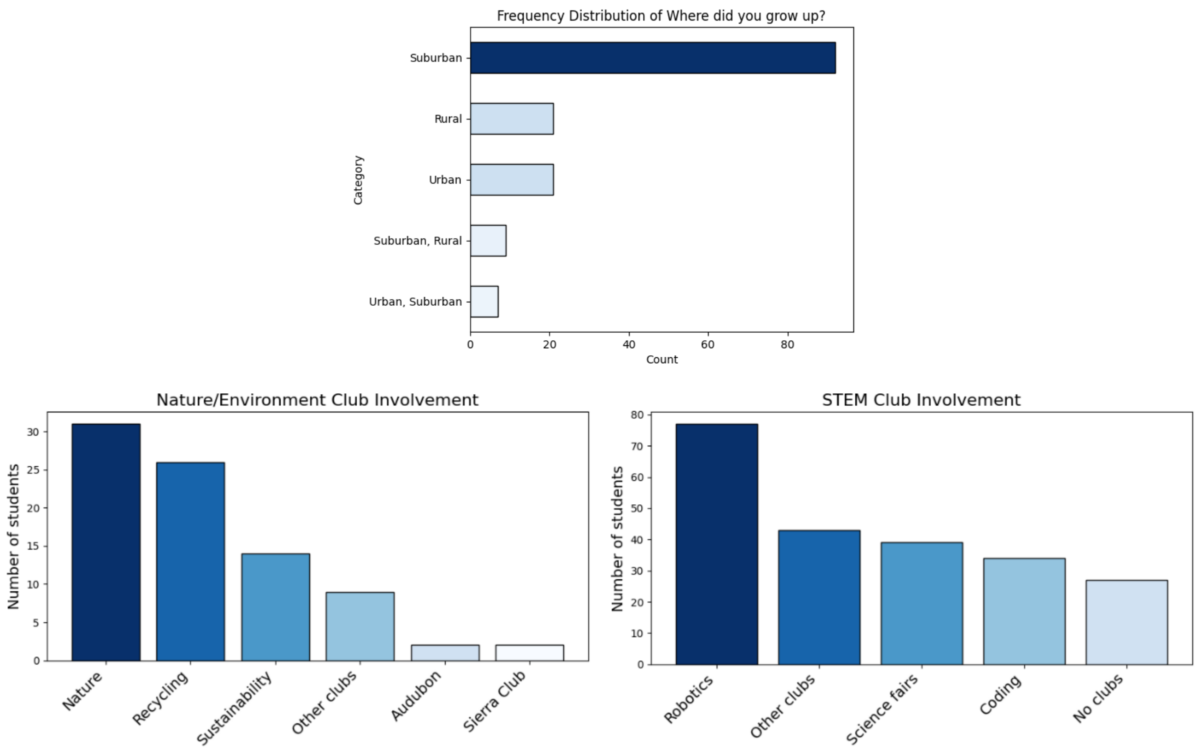


**Figure 1. Demographics Data**

### Illustrative Findings

The following analyses illustrate the range of insights generated by the instrument, including quantitative trends across constructs, relationships between variables, and qualitative themes derived from open-ended responses.

**Table 1. Likert-Scale Items Constructs and Average Scores**
**(Scale: 1 = Strongly Disagree, 6 = Strongly Agree)**

| Construct | Example Item | Avg. Score |
|---|---|---|
| Nature Affinity | I like to spend time outdoors in natural settings (e.g., woods, rivers, mountains, local parks, etc.). | 5.09 |
| Childhood Nature Engagement | On average, how often were you outdoors as a child within a week? | 4.77 |
| Nature-Inspired Curiosity | When I was a child, meaningful engagement to me involved nature (e.g., building things with natural materials, observing wildlife). | 4.21 |
| Engineering Orientation | I believe engineering can help address the environmental challenges I observed during my outdoor experiences. | 4.61 |
| Nature as Design Model | I often find that natural processes inspire engineering solutions (e.g., how the design of a tree can inspire structural engineering). | 4.21 |

**Table 2. Construct Pair Correlation Scores**

| Construct Pair | Example Items | Correlation Score |
|---|---|---|
| Curiosity & Engineering Interest | Early experiences in nature sparked my curiosity about how things work (Q6) / Childhood experiences in nature inspired me to explore engineering (Q7) | 0.71 |
| Design Inspiration & Career Orientation | Natural processes inspire engineering solutions (Q13) / I would like to work on projects that incorporate nature-inspired solutions (Q14) | 0.61 |

Likert-scale responses indicate consistently high levels of nature affinity among participants. Students reported frequent outdoor activity during childhood ($M = 4.77/6$) and strong enjoyment of natural settings such as woods, rivers, and parks ($M = 5.09/6$), as shown in Table 1. Responses linking nature to engineering also showed positive trends, with participants agreeing that engineering can address environmental challenges observed in outdoor contexts ($M = 4.61$) and that natural processes can inspire engineering solutions ($M = 4.21$). These results demonstrate that the instrument captures both general affinity for nature and its connection to engineering-related thinking.

Evidence of construct validity is supported through nonparametric statistical analysis. A Kruskal-Wallis test comparing engineering orientation across levels of self-reported nature affinity (Q1.1) produced a significant omnibus result ($H = 23.379$, $p < .001$). Dunn's post-hoc comparisons with Bonferroni correction indicated that students reporting the highest levels of nature affinity (score = 6) exhibited significantly higher engineering orientation than those with moderate scores (3 and 4). Other pairwise comparisons were not significant, suggesting that the instrument differentiates most strongly between high and moderate levels of nature affinity.

Correlation analysis further supports internal consistency across constructs. Early curiosity about natural systems (Q6) was strongly associated with later interest in exploring engineering (Q7, r = .71), while belief in nature as a design model (Q13) was positively related to interest in pursuing nature-inspired engineering projects (Q14, r = .61), as shown in Table 2.

**Table 3. Themes Based on Open-Ended Responses**

| Theme | Frequency of Mentions | Example |
|---|---|---|
| **Building Construction** | 44 | "Mainly experiences when seeing buildings or man-made structures made me curios as to how they worked" |
| **Water-Based Systems & Power Generation** | 41 | "Observing bodies of water such as creeks, rivers, and streams helped me understand and become curious about current and fluid power. Waves and the amount of force water has intrigued me as a kid." |
| **Vehicles** | 27 | "I would ride my bike and was curious on why it was easier to ride on different surfaces like pavement rather than grass." |
| **Biomimicry** | 19 | "When I was younger, my family and I went on a hiking trip, and we ran across a beaver making a home in a river. I was curious on how the beaver was able to create a wooden house in a river. I was more fascinated by the house being able to withstand the current of the river." |

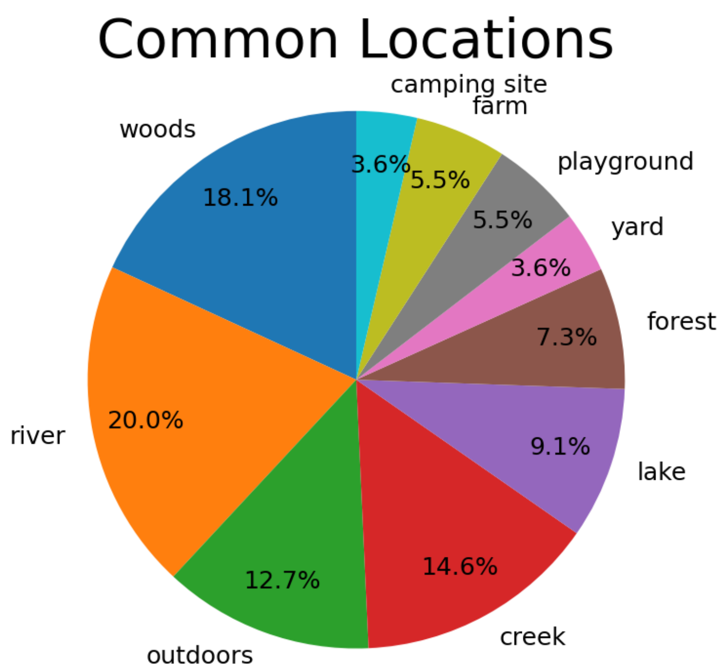


**Figure 2. Distribution of common outdoor locations in open-ended responses.**

The richness of the open-ended responses demonstrates another dimension of the tool's value. Students described formative experiences that ranged from building structures to experimenting with water flow or mechanical systems. Thematic coding, supported by term-frequency modeling and assisted categorization methods, revealed recurring categories such as building and construction, water and power generation, vehicles and mechanical curiosity, and biomimicry (Table 3). Students often referenced concrete objects like bridges, dams, bikes, or turbines, underscoring that the survey elicited specific and detailed accounts rather than abstract reflections. In addition, students identified particular outdoor locations, such as rivers, trails, and campgrounds, which are shown in Figure 2. Together, these qualitative findings illustrate how formative outdoor experiences are linked to modes of thinking aligned with applied engineering and manufacturing-oriented technical pathways.

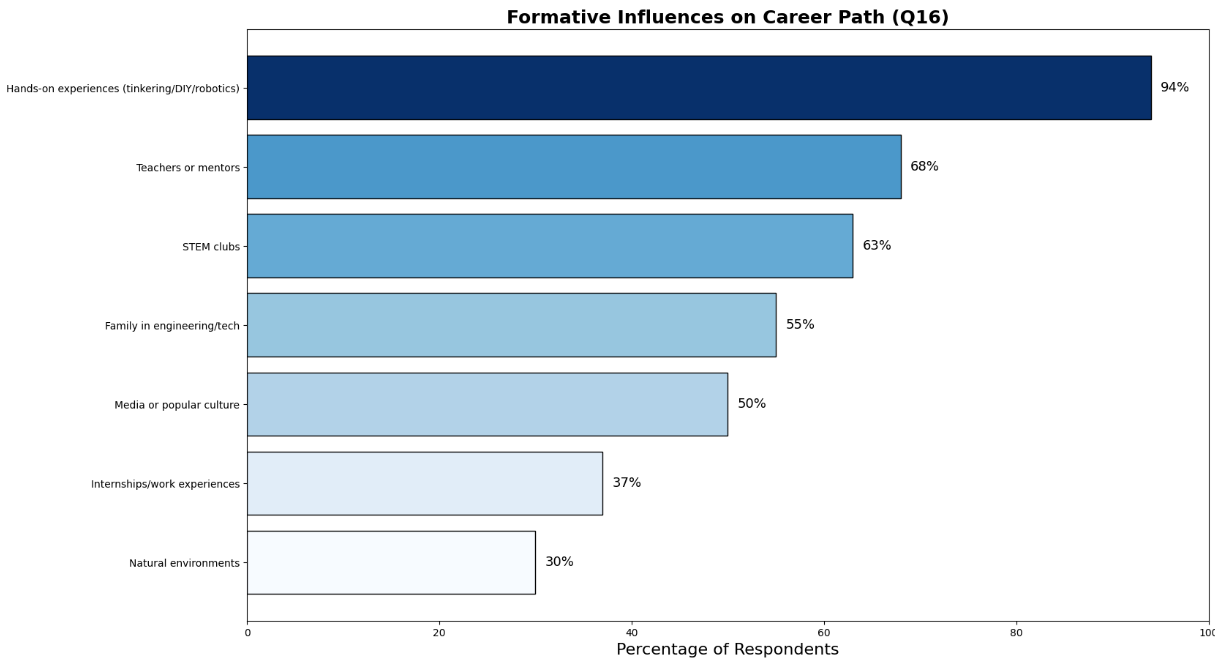


**Figure 3. Influences on students' career path choices**

Finally, the multiple-choice item on formative influences situates outdoor experiences within a broader set of career-shaping factors. Hands-on activities such as tinkering, DIY projects, and robotics were most frequently reported (94%), followed by teachers or mentors (68%), participation in STEM clubs (63%), and family members working in engineering or technology (55%). Media and popular culture influenced about half of the respondents, while internships or related work experiences were cited by 37%. Notably, 30% of students identified natural environments as a formative influence, a smaller proportion than technical or social drivers, indicating that natural environments remain a meaningful, though less dominant, contributor to engineering pathway development (Figure 3).

While the findings above reflect general influences on engineering pathways, the survey also captures manufacturing-relevant perspectives through a dedicated fluid power section. Students reported moderate confidence in relating natural fluid phenomena, such as rivers or wind patterns, to formal fluid power principles, including pressure drops (Q17, M = 3.70, SD = 0.96). In contrast, agreement was higher for the statement that nature provides good models for understanding sustainable fluid power systems (Q18, M = 4.47, SD = 1.01). This suggests that while students conceptually recognize the relevance of natural systems to manufacturing-oriented fluid power applications, they experience difficulty translating these intuitions into formal technical understanding.

## Discussion

The analyses presented in this paper illustrate the range of interpretations that the survey instrument can support, rather than serving as definitive findings. By examining quantitative responses alongside qualitative inputs, the example analyses demonstrate how the instrument captures both general patterns of nature affinity and applied, manufacturing-relevant reasoning. The inclusion of a fluid power section further highlights the instrument's ability to surface distinctions between conceptual alignment and technical confidence within an applied engineering context.

These results suggest that the instrument can be used by educators and researchers to identify experiential factors that shape how students interpret and engage with engineering concepts, particularly in hands-on and manufacturing-oriented learning environments. Insights derived from the survey, including students' reported connections to natural environments, formative experiences with physical systems, and perceptions of how nature relates to engineering, can inform the design of instructional activities that connect prior experiences to formal topics such as fluid power, materials, and system behavior. For example, themes such as building structures, observing water flow, and interacting with mechanical or vehicle-based systems can guide the design of instructional activities such as hands-on laboratory exercises, physical demonstrations, or augmented reality learning modules, where students construct systems or interact with physical processes to explore how environmental or material conditions influence performance. These modules can be intentionally designed to build on students' prior experiences and evaluated in terms of learning outcomes, engagement, retention, or connections to formative experiences. The examples shown in Figure 4 illustrate how experiential data captured by the instrument can be translated into applied learning contexts that bridge intuitive understanding and formal engineering concepts.

Importantly, the instrument is designed with flexibility in mind. While the current deployment emphasized general connections between outdoor experiences and engineering interest, the tool can be adapted to examine discipline-specific pathways, including manufacturing-oriented domains such as fluid power, construction, or robotics. Maintaining a broader framing also enables cross-disciplinary and cross-institutional comparisons, supporting future studies that seek to understand variation in how formative experiences shape engineering and engineering technology trajectories.

**Figure 4. Conceptual examples of such AR-based learning scenarios are shown to demonstrate how these themes can be operationalized in practice.**

## Limitations

This study is based on a single institutional sample within a manufacturing-oriented engineering technology program, which may limit generalizability to other populations and disciplines. Additionally, the findings presented are illustrative and intended to demonstrate the analytical capabilities of the instrument rather than establish causal relationships. Future work should apply the survey across multiple institutions and contexts to further evaluate its robustness and broader applicability.

## Conclusion

This paper introduced and validated a mixed-methods survey designed to examine how formative outdoor experiences relate to interest in engineering and engineering technology, with relevance to applied and manufacturing-oriented educational contexts. The instrument captures both quantitative measures of nature affinity and qualitative accounts of formative experiences, including domain-specific perspectives such as fluid power. Validation results support the internal consistency and construct structure of the survey, demonstrating its suitability for research and educational use. Because the instrument is adaptable, it can be deployed in discipline-specific studies or across multiple programs and institutions to enable broader comparison. By providing a structured and flexible tool, this work supports future research and educational design efforts aimed at understanding and leveraging experiential pathways into engineering and manufacturing fields.

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