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MAKER: Connecting Students' Hands-On Experiences to Manufacturing Education with a Validated Survey and Augmented Reality Module

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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.

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MAKER: Connecting Students' Hands-On Experiences to Manufacturing Education with a Validated Survey and Augmented Reality Module

This project presents the design and preliminary use of an augmented reality (AR) learning module developed to support experiential learning in manufacturing and engineering technology education. The AR environment allows students to assemble and evaluate a structural system within a naturalistic setting, encouraging exploration of materials, spatial relationships, and design decisions through direct interaction.

To inform the design, a mixed-methods survey captured students' formative experiences and early exposure to hands-on activities. Analysis of 150 responses indicated that building, tinkering, and interaction with physical systems were among the most frequently cited influences on engineering interest. These findings guided the development of the AR module to emphasize assembly, environmental context, and exploratory decision-making rather than prescriptive instruction.

The module was piloted with 72 participants, who engaged with material selection, assembly, and design reasoning tasks. Preliminary results suggest that the experience supports engagement with manufacturing-relevant concepts and provides a flexible platform for integrating experiential activities into applied coursework. Together, the survey-informed design process and AR artifact illustrate a replicable approach for connecting students' prior experiences to manufacturing education.

Introduction and Motivation

Hands-on learning and interaction with physical systems are foundational to manufacturing and engineering technology education. Prior research has shown that early experiences involving building, material manipulation, and exploratory interaction play a critical role in the development of engineering thinking and technical curiosity (Bagiati & Evangelou, 2016; Earle & Coakley, 2019). These formative experiences frequently occur outside formal classroom environments, yet they continue to shape how students engage with engineering concepts later in their academic pathways.

Research in environmental identity development further suggests that sustained interaction with natural environments supports the development of problem-solving skills, spatial reasoning, and meaning-making processes that align closely with engineering practice (Green et al., 2016; Klaar & Öhman, 2014). Studies of outdoor and informal STEM learning contexts have suggested that such experiences can influence long-term interest and engagement in technical fields, including engineering and engineering technology programs (Seaman et al., 2024). Despite this evidence, engineering education has limited mechanisms for systematically identifying which experiences students bring with them into coursework and for translating those experiences into instructional design.

At the same time, immersive instructional technologies such as augmented reality (AR) have shown promise in supporting discovery-based and experiential learning in engineering education (Azzam et al., 2023; Ibáñez & Delgado-Kloos, 2018). However, existing AR applications are often designed without direct grounding in students' formative experiences, limiting their potential relevance and impact. Building on prior work integrating environmental identity into AR-based learning environments (Metwaly et al., 2025), this project addresses this gap by using empirical data on students' early hands-on experiences to inform the design of an interactive AR learning artifact for manufacturing education. By aligning immersive learning design with the experiential foundations that students associate with early engineering curiosity, the project seeks to create instructional tools that better support engagement, exploration, and applied learning.

The AR module is intended as a supporting instructional tool rather than a standalone laboratory exercise. It serves three complementary roles: reinforcing course concepts through interactive visualization, providing a bridge between students' intuitive understanding and formal engineering reasoning, and increasing engagement by connecting learning tasks to experiences students associate with their initial interest in engineering.

Student-Informed Design Process

The AR learning artifact was developed using a student-informed design approach in which survey data served as a practical input for shaping interaction and task structure. A mixed-methods survey was administered to capture students' formative experiences, early exposure to hands-on activities, and influences on interest in engineering and technical pathways. The instrument included both structured items and open-ended prompts, allowing participants to describe specific experiences that shaped their technical curiosity. Analysis of survey responses highlighted recurring themes related to hands-on building, tinkering, interaction with physical systems, and engagement with structures and mechanical processes. These findings were translated into design requirements for the AR environment, emphasizing open-ended assembly, material selection, and spatial reasoning while avoiding rigid step-by-step instruction. The use of a naturalistic setting and modular components reflects the types of activities participants associated with early technical curiosity, allowing the design to align with how students first engaged with engineering-related thinking.

AR Artifact Design and Interaction

The AR learning artifact was designed as an interactive environment that supports exploratory, hands-on engagement with manufacturing-relevant concepts through assembly and spatial reasoning (Figure 1). Rather than presenting a fixed instructional sequence, the environment invites students to interact with modular components within a naturalistic setting, encouraging experimentation, comparison of alternatives, and iterative refinement of design choices.

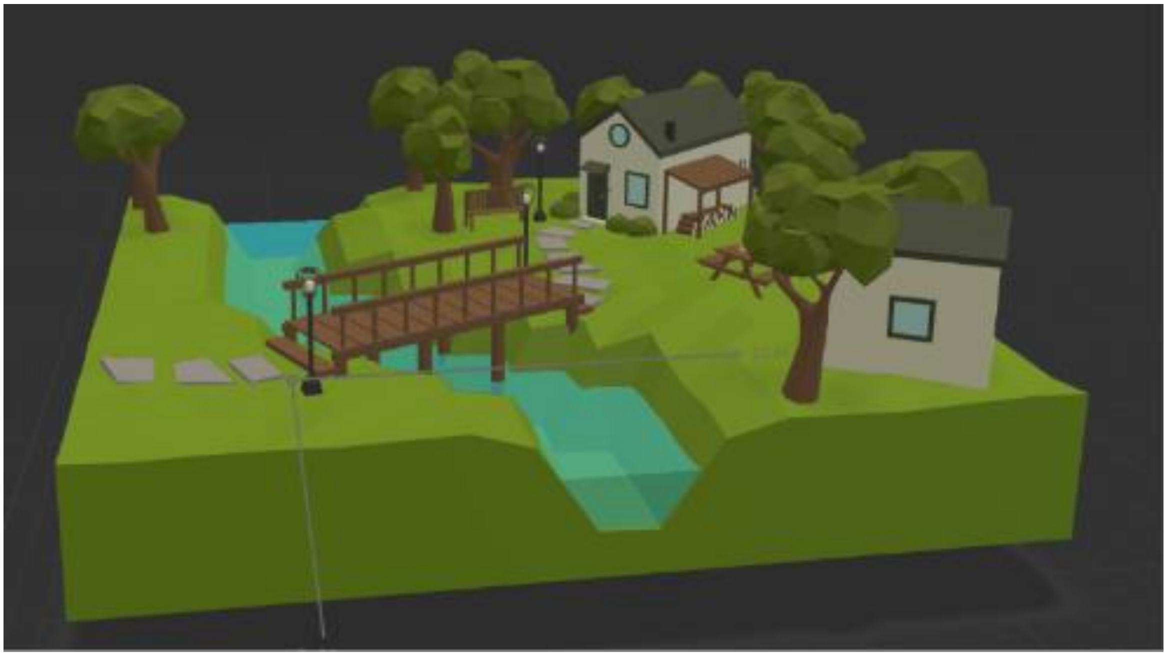

Figure 1. AR learning environment used in the interactive module.

Within the AR environment, students are tasked with assembling a structural system by selecting and placing planks in three-dimensional space. The interface allows users to manipulate elements directly, adjust configurations, and observe how their choices affect the overall structure. Visual cues and spatial feedback support alignment and placement, while the absence of prescriptive instructions encourages students to reason through decisions based on intuition, prior experience, and observation. This interaction model reflects the kinds of hands-on and exploratory activities identified through the student-informed design process.

The artifact prioritizes interaction over formal instruction, emphasizing physical arrangement, material comparison, and spatial relationships central to manufacturing and engineering technology tasks. This approach supports engagement with practices such as assembly, configuration, and design evaluation while remaining adaptable across instructional contexts. While the activity is presented within a naturalistic environment, the interaction is designed to reinforce concepts relevant to manufacturing and engineering technology. These include material selection, evaluation of structural integrity, and reasoning about how design choices influence system performance under load. Students must make trade-offs between visually different components, interpret environmental cues, and evaluate outcomes based on their selections.

Preliminary Classroom Deployment and Student Feedback

The AR activity was implemented during a scheduled laboratory session in a Mechanical Engineering Technology course focused on fluid power. The activity was completed individually and required approximately 15 minutes. Students were first provided brief instructions on installing Adobe Aero and accessing the module through a QR code. To support effective interaction with the AR environment, students were asked to distribute themselves throughout the lab space to avoid visual obstruction and ensure accurate spatial tracking. They then engaged with the module independently before completing a short post-activity survey.

The preliminary classroom deployment included 72 engineering technology students. The participants in the AR deployment were predominantly undergraduate students between the ages of 18–23, with the majority identifying as juniors and seniors. Most students were enrolled in Mechanical Engineering Technology or closely related programs, with smaller representation from manufacturing, electrical, and mechatronics tracks. The demographic distribution reflects the typical population of upper-division engineering technology courses in which this type of instructional tool would be implemented.

Following interaction with the AR environment, students completed a brief post-survey reflecting on the instructional value and experiential impact of the activity. The results indicate strong positive perceptions of the AR module as a learning tool (Figure 2).

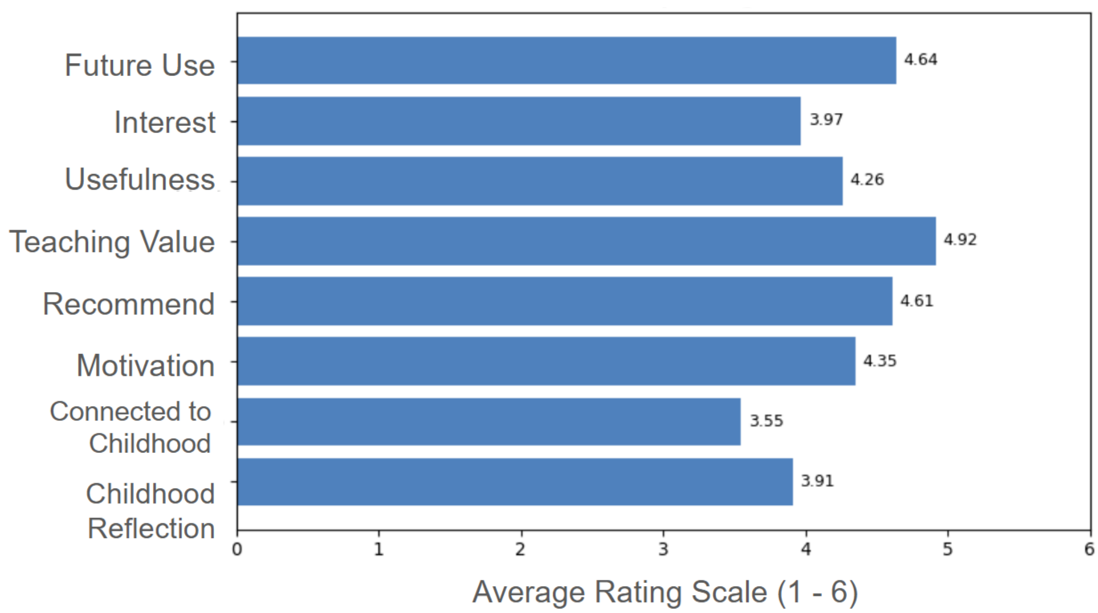

Figure 2. Average student ratings following interaction with the AR learning module.

Students reported high agreement that AR activities of this type could support the teaching of engineering concepts ($M = 4.92$ on a 6-point scale, $90.5\% \geq 4$) and expressed interest in using similar modules in future courses ($M = 4.64$, $79.7\% \geq 4$). Participants also indicated that the activity would be useful for learning other engineering topics ($M = 4.26$, $87.8\% \geq 4$) and that they would recommend the experience to peers ($M = 4.61$, $82.4\% \geq 4$). Measures of engagement reflected similar trends, with students reporting increased enthusiasm for learning engineering concepts (M = 3.97, 77% ≥ 4) and greater motivation toward engineering coursework overall (M = 4.35, 78% ≥ 4).

Several survey items also captured reflective responses aligned with the project's experiential design goals. Approximately half of participants indicated that the AR activity reminded them of why they were initially interested in engineering (M = 3.55), and a majority reported that it evoked childhood experiences connected to their technical curiosity (M = 3.91, 61% ≥ 4). Together, these findings suggest that the AR environment supported both perceived instructional value and personal engagement, reinforcing the connection between experiential learning and manufacturing-relevant education.

Implications for Manufacturing Education

The AR learning artifact demonstrates how student-informed interactive tools can support key competencies in engineering technology education. The activity encourages students to evaluate design choices, reason about material behavior, and consider how constraints influence system performance. These interactions align with ABET-related outcomes such as problem-solving, design evaluation, and effective use of modern engineering tools, while remaining appropriate as a supplemental activity within existing coursework.

Feedback from the preliminary deployment informed several planned refinements, including improved differentiation between components and the integration of guidance to support decision-making during interaction. These adjustments aim to enhance clarity while preserving the exploratory nature of the activity.

More broadly, the findings suggest that experiential activities emphasizing open-ended interaction, familiar contexts, and iterative decision-making can strengthen connections between students' prior experiences and formal engineering concepts. This student-informed design approach provides a replicable framework for developing instructional tools that leverage learners' existing knowledge while supporting engagement in manufacturing-related learning.

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