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WIP: Co-designing high school engineering curriculum to empower the next-generation workforce for advanced manufacturing

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WIP: Co-designing high school advanced manufacturing curriculum through researcher-practitioner partnerships

Abstract

This Work-in-Progress (WIP) project engaged five high school teachers in translating advanced manufacturing concepts into accessible, hands-on learning modules for secondary students. As advanced manufacturing continues to transform industry and society, there is an increasing need to prepare students at earlier stages to understand, experience, and aspire toward careers in this field. Through a collaborative co-design model, K-12 teachers, educational researchers, and engineering faculty developed and implemented curriculum units emphasizing key domains of modern manufacturing, including smart manufacturing, computer numerical control, automation in facility design, and robotics. Each instructional unit spanned approximately four weeks and integrated engineering design and hands-on activities into authentic problem solving contexts to foster curiosity and career awareness of advanced manufacturing among high school students. The co-design process ensured that lessons were pedagogically sound and technically current, aligning with authentic practices in advanced manufacturing. Faculty and researchers provided technical support, classroom visits, and feedback to help teachers translate complex engineering processes into meaningful student experiences. Preliminary observations indicate that students exposed to these modules demonstrated increased engagement with engineering concepts and heightened interest in manufacturing-related career pathways. This work underscores the value of researcher-practitioner partnerships in expanding access to emerging technologies and preparing students for the future manufacturing workforce. The project provided a scalable framework for integrating advanced manufacturing into high school curricula through interdisciplinary collaboration.

Introduction

As advanced manufacturing technologies continue to reshape industry, the workforce demands engineers and technicians who are technically proficient as well as adaptable to rapidly evolving systems [1], [2]. Preparing students to understand and pursue careers in advanced manufacturing must therefore begin well before postsecondary education [3]. High school represents a critical stage for cultivating early awareness, interest, and foundational understanding of manufacturing pathways [4]. However, translating complex, industry-level manufacturing concepts into developmentally appropriate and engaging secondary-level instruction remains a persistent challenge for educators.

This grant-supported initiative, lasting for one academic year (2025-2026), addressed this need by engaging high school teachers in a collaborative curriculum co-design process [5], [6] focused on advanced manufacturing education. Rather than positioning teachers solely as implementers of externally developed curricula, this project centered teachers as co-designers working alongside engineering faculty and educational researchers. Through this partnership, advanced manufacturing concepts were translated into accessible, hands-on learning modules aligned with authentic engineering practices. The project demonstrates how researcher–practitioner collaboration can expand access to emerging technologies and strengthen career-connected learning in secondary education.

Rationale

Effective integration of advanced manufacturing into high school classrooms requires both technical accuracy and pedagogical relevance [7], [8]. Engineering faculty and researchers contribute up-to-date technical knowledge and insight into industry practices, while K-12 teachers bring deep expertise in curriculum standards, student learning needs, and classroom realities. Co-design models leverage these complementary strengths, resulting in instructional materials that are both technically current and instructionally sound [6], [9].

In this initiative, teachers collaborated with engineering faculty and researchers to adapt advanced manufacturing topics (including those often encountered only in postsecondary or industrial settings) into meaningful secondary engineering education experiences. Faculty provided technical mentorship, classroom visits, and iterative feedback, while teachers shaped lesson pacing, scaffolding, and assessment strategies.

Co-designing Courses

Five advanced manufacturing topics were identified as focal areas based on their relevance to modern industry and feasibility for high school integration. Each topic was developed as a standalone instructional module spanning approximately four weeks. Modules emphasized engineering design, hands-on experimentation, and authentic problem-solving contexts to foster student engagement and career awareness. Each module followed high school engineering standards in the state and NGSS to tailor content for students. The following sections summarize each instructional module showcased in this demonstration poster.

Smart Manufacturing

The Smart Manufacturing module introduced students to data-driven and interconnected manufacturing systems. Lessons focused on how sensors, data collection, and decision-making technologies are used to optimize manufacturing processes (e.g., NGSS HS-ETS1-1, HS-ETS1-3, and HS-PS3-3). Students engaged in activities that simulated monitoring system performance, identifying inefficiencies, and proposing improvements using real-time data. Through these experiences, students gained exposure to cyber-physical systems and the role of information technologies in modern manufacturing environments. The module emphasized systems thinking and highlighted career pathways related to industrial engineering, manufacturing systems, and data-informed decision making.

Computer Numerical Control in Manufacturing

The Computer Numerical Control (CNC) module familiarized students with automated machining processes used in manufacturing precision components. Students explored the fundamentals of CNC operation, including tool paths, coordinate systems, and basic programming concepts. Hands-on activities allowed students to design simple components and understand how digital instructions are translated into physical products. By connecting mathematical concepts and design principles to manufacturing applications, the module helped students see the relevance of

STEM coursework to real-world production environments and skilled technical careers (e.g., NGSS HS-ETS1-2 and HS-PS2-6).

Additive Manufacturing

The Additive Manufacturing module focused on layer-by-layer fabrication processes commonly associated with 3D printing. Students investigated how digital designs are converted into physical objects and examined the advantages and limitations of additive manufacturing compared to traditional methods. Through design challenges and prototyping activities, students explored material properties, design constraints, and iteration (e.g., NGSS HS-ETS1-3, and HS-PS1-3). This module emphasized creativity, rapid prototyping, and problem solving while introducing students to careers in product design, manufacturing engineering, and emerging fabrication technologies.

Automation in Manufacturing Facility Design

The Automation in Manufacturing Facility Design module introduced students to the planning and optimization of automated production environments. Students examined how layout design, workflow, and automation technologies influence efficiency, safety, and productivity in manufacturing facilities. Activities challenged students to design facility layouts that balanced human and automated systems while considering space, materials handling, and operational constraints. This module emphasized systems integration and exposed students to roles related to industrial automation, facilities engineering, and operations management (e.g., NGSS HS-ETS1-1, HS-ETS1-3 and HS-PS3-4).

Robotics in Manufacturing

The Robotics in Manufacturing module engaged students in understanding how robotic systems are used to perform repetitive, precise, and hazardous tasks in industrial settings. Students explored basic robotic components, programming logic, and applications such as assembly, inspection, and material handling (e.g., NGSS HS-ETS1-2, HS- ETS1-4 and HS-PS2-1). Hands-on activities allowed students to program and test robotic behaviors while considering safety, efficiency, and reliability. The module highlighted the intersection of mechanical design, electronics, and computer programming, helping students envision pathways into robotics, automation, and advanced manufacturing careers.

Preliminary Outcomes

Across the five instructional modules, preliminary classroom observations following a semi-structured observation protocol indicated increased student engagement with engineering concepts and heightened curiosity about manufacturing-related careers. Teachers indicated in their formative survey responses that they had greater confidence in teaching advanced manufacturing topics than before and found the sustained collaboration with faculty and researchers invaluable for them to integrate advanced engineering topics into high school curricular. Students responded positively in formative surveys to the hands-on, problem-based structure of the modules, which helped demystify complex technologies and connect learning to real-world applications.

Significance

This project demonstrates the value of teacher-centered co-design as a scalable model for integrating advanced manufacturing education into high school curricula. By positioning teachers as partners in curriculum development, the initiative supported professional growth while producing instruction that aligns with authentic engineering practices. The resulting modules offer a framework that can be adapted by other schools and districts seeking to expand access to emerging technologies and strengthen the manufacturing talent pipeline. This demonstration poster highlights how interdisciplinary collaboration can prepare students to understand, experience, and aspire toward careers in advanced manufacturing, addressing critical workforce needs through secondary education.

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