PLTW Engineering
Advanced Manufacturing | Course Outline

Explore the future of manufacturing through a dynamic blend of robotics, artificial intelligence, and smart technology to solve real-world challenges. Students learn how data, automation, and digital tools are transforming industries—in the context of semiconductor fabrication—and how they can be part of this industrial revolution. Through hands-on projects and cutting-edge technology, students gain the skills they need to thrive in tomorrow's high-tech workforce.

Advanced Manufacturing is a full-year course for students in grades 10–12. The course is designed either to serve as a student's first exposure to PLTW or to build upon their prior experience in the PLTW Engineering pathway. In Advanced Manufacturing, students explore the rapidly evolving landscape of Industry 4.0 and the intersection of semiconductor manufacturing, automation, cyber-physical systems, predictive maintenance, artificial intelligence (AI), and data analytics.

This course introduces students to core manufacturing concepts, emerging technologies, and in-demand careers, and challenges students to engineer solutions to authentic problems. Using industry-grade tools such as 3D modeling software, hands-on manufacturing equipment, programming software, and robotic hardware, students gain the technical skills and experience needed to thrive in the smart manufacturing workforce.

Using PLTW's activity-, project-, problem-based (APB) instructional approach, students advance from completing structured activities to solving open-ended projects and problems that provide opportunities to develop planning and technical documentation skills, as well as in-demand, transportable skills such as problem solving, critical thinking, collaboration, communication, and ethical reasoning. Ethical reasoning is particularly important as the course encourages students to consider the impacts of engineering decisions.

Through individual and collaborative team activities, projects, and problems, students create solutions to problems as they practice common engineering design and development protocols, such as design, testing, project management, and peer review.

The following is a summary of the units of study that are included in the course. The course requires a rigorous pace and contains more material than a skilled teacher new to the course may be able to complete in the first iteration. However, building students' enthusiasm for engineering and manufacturing, as well as understanding the role, impact, and practice of engineers, are primary goals of the course.

Advanced Manufacturing Unit Summary

Unit 1	Introduction to Industry 4.0
Unit 2	Advancing Automation in Manufacturing
Unit 3	Digital Simulations and Virtual Integration
Unit 4	Securing Systems in Distributed Manufacturing

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Unit 1: Introduction to Industry 4.0

The course begins by immersing students in the world of Industry 4.0 through active exploration and real-world applications. Students explore a product through reverse engineering and simulate an assembly line to gain hands-on experience with manufacturing processes. Students begin by learning Python programming, then apply their skills to control a six-axis robotic arm, troubleshoot real-world systems, and experiment with AI-assisted code generation. As they master the fundamentals, they use their skills to solve increasingly complex challenges.

Students conclude the unit by applying their understanding of robotic arms, programming, AI, semiconductor fabrication, and optimization to solve an industry-based challenge. Interwoven throughout the unit, students explore key concepts such as supply chain management, automation, and process optimization—all anchored in the context of semiconductor fabrication.

Introduction to Industry 4.0
Lesson 1.1 Robotics in Manufacturing
Lesson 1.2 Application of Automation
Lesson 1.3 Real-World Robotics

Lesson 1.1 Robotics in Manufacturing
Students begin their journey into Industry 4.0 by reverse engineering a product and rebuild it as an assembly line to understand the foundations of manufacturing processes. Building on their foundational knowledge of Industry 4.0 and manufacturing processes, students engage directly with a six-axis robotic arm. They program the robot using Python coding, troubleshoot real-time issues, and explore the power of AI-assisted code generation. Along the way, students investigate key robotics concepts such as absolute vs. relative movement, object manipulation, and human–robot collaboration.

Throughout the lesson, students will explore key topics such as supply chain management, automation, and process optimization, and draw practical connections to semiconductor fabrication. This ongoing comparison serves as a reference point, helping students understand how advanced manufacturing principles are applied in one of the most complex and high precision industries. The lesson also introduces AI prompt engineering, lean manufacturing, and essential tools and processes that power today’s factories.

Lesson 1.2 Application of Automation
Students continue developing their robotic systems by applying a deeper understanding of Cartesian coordinates in the context of field-based tasks. As they begin to recognize the limitations of working with a robotic arm in isolation, they uncover the need for additional tools and technologies introduced in the next unit. Through experimentation and iteration, students explore machine learning and optimize their processes to design an efficient manufacturing workflow that mirrors industrial practices.

Lesson 1.3 Real-World Robotics
Students apply their knowledge of robotics, programming, AI, semiconductor fabrication, and process optimization to solve authentic, contextualized challenges. By integrating these skills, they design and refine solutions that reflect the complexity, precision, and interconnectivity of digitally integrated manufacturing systems.

Unit 2: Advancing Automation in Manufacturing

Having developed foundational skills in robotics and automation, students are now ready to expand their understanding of how these systems integrate into a broader range of smart factory technologies. Students are introduced to key components such as conveyor belts, pneumatic pumps, optical sensors, and other integrated systems used in high-tech manufacturing environments.

As the lesson progresses, students expand their understanding of the Internet of Things (IoT) by working with additional sensors. Programming complexity increases as they integrate and manage diverse inputs, while also learning to use IoT dashboards and AI tools to monitor and optimize system performance.

With the introduction of these sensors, students begin working with large-scale data sets. They analyze and visualize this data to develop predictive models for maintenance scheduling and production optimization.

The lesson culminates with students leveraging their knowledge of sensor data, automation, and AI-driven insights to design and improve a functional manufacturing system.

Advancing Automation in Manufacturing
Lesson 2.1 Smart Factories and Process Monitoring
Lesson 2.2 Real-Time Systems With IoT
Lesson 2.3 Data-Driven Optimization
Lesson 2.4 Industrial Systems Design

Lesson 2.1 Smart Factories and Process Monitoring
After identifying the limitations of working exclusively with a robotic arm, students are introduced to additional smart factory tools such as conveyor belts, pneumatic pumps, optical sensors, and other integrated components. These technologies help students optimize manufacturing processes and deepen their understanding of interconnected systems.

Students then examine high-tech semiconductor factories to explore applications of these tools. Through interactive learning experiences, they engage with the IoT, monitor live processes, and analyze real-time data. They also experiment with AI to further automate and enhance manufacturing workflows.

Lesson 2.2 Real-Time Systems With IoT
Students explore a variety of sensors used for simultaneous process monitoring, which increases the complexity of programming tasks and challenges them to integrate and manage diverse inputs. Using an IoT dashboard, they monitor and optimize their systems in real time.

Throughout the lesson, semiconductor process monitoring continues to serve as the reference point, helping students draw meaningful connections between their sensor applications and modern manufacturing environments.

Lesson 2.3 Data-Driven Optimization
As students build proficiency with the Internet of Things, they begin working with large-scale data sets. They analyze and visualize this data to develop predictive models for tasks such as maintenance scheduling and production optimization. Students also engage with AI tools to interpret data, assess system performance, and refine their solutions based on real-time insights.

Lesson 2.4 Industrial Systems Design
In this culminating lesson, students apply their knowledge of the IoT and newly acquired tools to solve real-world manufacturing challenges. Students integrate sensor data, automation, and AI-driven insights to design and build smart systems that solve real-world industrial challenges.

Unit 3: Digital Systems and Virtual Integration

With a solid grasp of physical automation and real-time data systems, students now explore how these processes can be mirrored and optimized in virtual environments through digital twins and augmented reality. They apply kinematic motion to robotic systems and evaluate them for data monitoring needs, collision risks, and process optimization opportunities.

The unit then expands into augmented reality (AR), where students enhance their interaction with digital systems through immersive visualization. They apply optimization techniques to improve system performance and functionality. The unit concludes with students integrating digital twins and AR to solve practical challenges in smart manufacturing environments.

Digital Systems and Virtual Integration
Lesson 3.1 Digital Twin Foundations
Lesson 3.2 Robotics and System Simulations
Lesson 3.3 Augmented Reality Immersion
Lesson 3.4 Simulated Solutions

Lesson 3.1 Digital Twin Foundations

Students are introduced to a digital twin of their robotic systems and explore the foundational concepts of simulation modeling. By comparing the physical system to its digital counterpart, they gain insight into the development and technical requirements of digital replication. Students conduct a simulation study, apply kinematic motion to robotic tasks, and are exposed to a suite of simulated advanced robotic equipment to support manufacturing tasks.

Lesson 3.2 Robotics and System Simulations

Students begin by programming a robot to perform pick-and-place tasks and simulate complex kinematic motion. They then use robust simulation tools to detect and prevent collisions in automated systems. Building on previous work, students expand their process flow into a detailed sequence of operations and analyze sensor data to identify bottlenecks. Using this data, they develop and validate an optimized offline program for the digital model. Finally, students take on the role of a Plant Manager, refine their robot setup to meet production goals and evaluate the effectiveness of their chosen configuration.

Lesson 3.3 Augmented Reality Immersion

Students engage in Augmented Reality (AR) simulations to deepen their understanding of and interaction with digital systems. They apply optimization techniques to enhance system performance and functionality. Through this exploration, students improve efficiency and accuracy while developing the ability to make faster, data-informed decisions, which are key competencies in modern manufacturing and technology-driven environments.

Lesson 3.4 Simulated Solutions

Students synthesize their knowledge of digital twins and augmented reality to solve authentic challenges in manufacturing. By integrating simulation, visualization, and data-driven analysis, they engineer and enhance solutions that align with current industrial practices. This lesson emphasizes applied problem solving, innovation, and the use of emerging technologies to address complex systems in next-generation manufacturing environments.

Unit 4: Securing Systems in Distributed Manufacturing

Having explored both physical and virtual aspects of smart manufacturing, students now take a systems-level view—integrating their technical knowledge with operational and security considerations to design comprehensive, end-to-end manufacturing solutions. They begin by diagnosing and securing robotic and IoT systems through real-time data analysis, software testing, and cybersecurity practices. Building on this foundation, students expand their perspective to the full manufacturing supply chain—exploring material selection, packaging, logistics, and distribution. The unit concludes with a contextualized problem requiring students to apply their knowledge of automation, AI, digital twins, and augmented reality to design an integrated manufacturing solution. Through hands-on problem solving and system design, students demonstrate their ability to connect technologies, optimize workflows, and address industrial challenges.

Securing Systems in Distributed Manufacturing
4.1 Cybersecurity
4.2 Supply Chain Systems
4.3 Smart Factory Design

Lesson 4.1 Cybersecurity

Students analyze robotic and IoT systems to identify and resolve vulnerabilities. They learn about system confidentiality, integrity, and availability, and the policy of least privilege. They uncover weaknesses such as data integrity errors, untested software, and insecure access points. Students analyze configuration files and implement safeguards to ensure reliable system performance. They also investigate how poor data and unauthorized access can disrupt operations. This lesson emphasizes security polices, system diagnostics, and the importance of cybersecurity principles in modern industrial environments.

Lesson 4.2 Supply Chain Systems

Students broaden their understanding of manufacturing by examining the full supply chain, from raw material selection to product delivery. They explore the rationale behind material choices and analyze packaging, distribution, and logistics strategies. By connecting product design to end-user delivery, students develop a comprehensive view of the supply chain and its critical role in manufacturing operations.

Lesson 4.3 Smart Factory Design

Students draw on their technical foundation of smart manufacturing to design and implement a comprehensive solution to a real-world industrial challenge. Leveraging their experiences with robotic systems, IoT, AI, digital twins, augmented reality, and semiconductor fabrication, they develop an integrated manufacturing process that emphasizes efficiency, adaptability, and innovation. This culminating lesson showcases students' ability to connect emerging technologies, optimize workflows, and apply data-driven insights within a modern, interconnected manufacturing environment.