# Transforming manufacturing education:

The path to train the Industry 4.0 workforce

# Contents

# Introduction

Innovation not only drives much of the way we live and work in society at large, but it's also instrumental to the product design and manufacturing industry. In manufacturing, a confluence of many technological innovations for designing, fabricating, automating, and collecting data has ushered in Industry 4.0 (IR4.0) workflow advancements. Consequently, IR4.0 technologies have advanced too fast for manufacturing training to keep up with workforce needs.

Just as the manufacturing transition to Industry 4.0 is underway, there is also an educational transformation effort underway to update how key manufacturing personnel learn the skills and workflows for the modern workforce. One of the key objectives of this educational reform is to reduce the "time to talent" with modular, hands-on teaching methods that prepare students with the skills for Industry 4.0 manufacturing careers in less time than traditional methods.
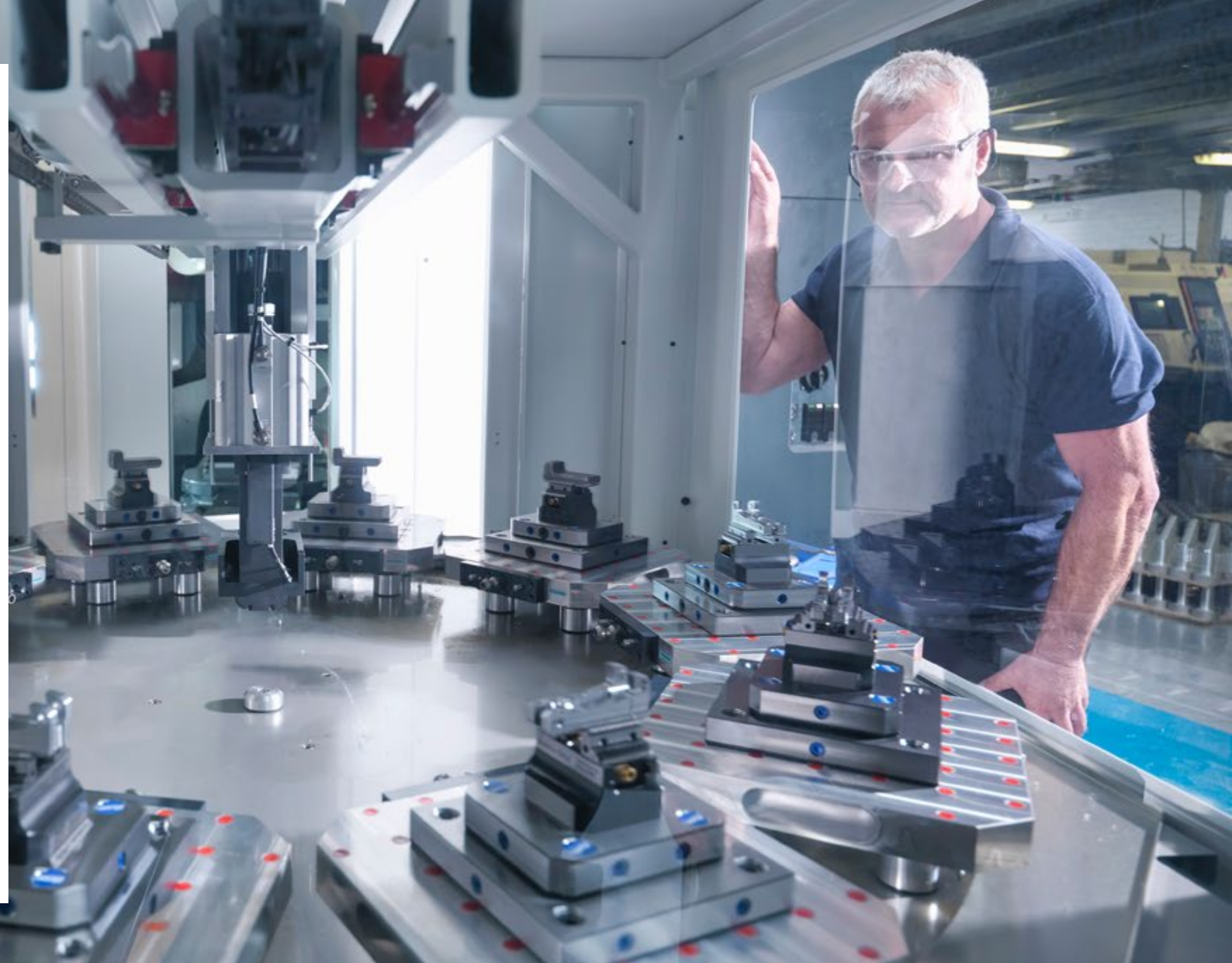
This ebook helps educators understand the Industry 4.0 skill requirements, examine how educational institutions have introduced new programs to prepare their students, and chart a stepwise approach to defining, developing, and imparting the new skills needed in the Industry 4.0 workforce.
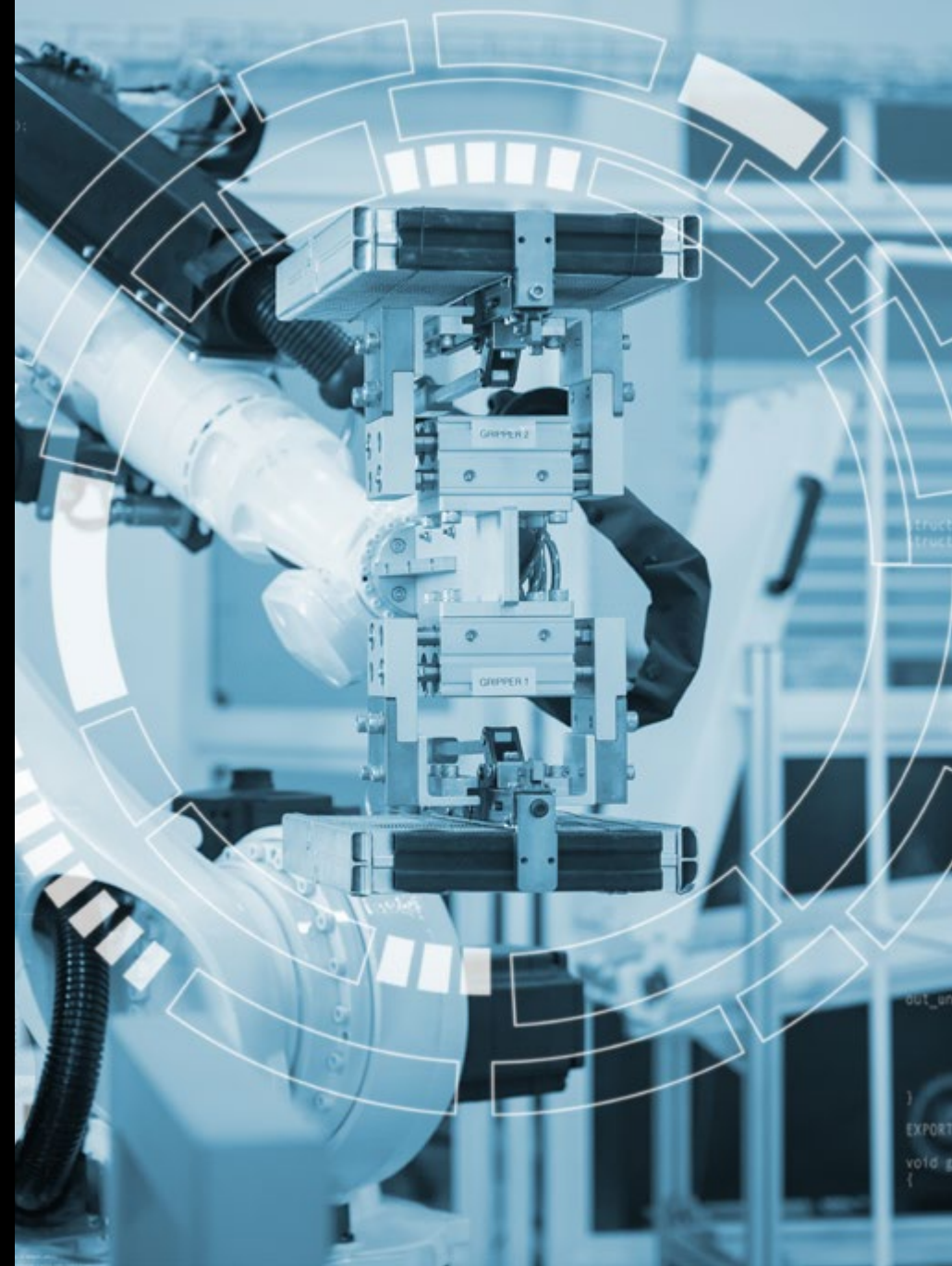
# Industry 4.0 workforce development outlook

To help industry and academia develop the advanced IR4.0 manufacturing workforce, the American Society of Mechanical Engineers (ASME) and Autodesk conducted a research study to identify the future workflows and skills needed for the mechanical engineering, manufacturing engineering, and CNC machinist roles over the next decade. In the resulting Future of Manufacturing white paper, the study shows that each role will share a combination of common skills (both technical and soft skills), as well as interdisciplinary skills that will enable a more collaborative and productive work environment.

With the IR4.0 workforce in place, newly connected, more collaborative, and circular workflows will evolve, enabling manufacturing operations to streamline work and achieve higher efficiencies. The new workflows represent the most promising change businesses can undergo to realize the outcomes they want: improved productivity, profitability, competitiveness, sustainability, and circular design methods.

# Industry 4.0 technologies will reshape the industry workforce

Today's workforce needs training in the latest technological skills to design and build the more complex products in demand today. These more intelligent, sustainable, and customizable products will require manufacturing professionals to have a deep understanding of technology including artificial intelligence (AI), machine learning (ML), integrated software platforms, robotics, and additive manufacturing to improve decision-making and production processes.

These and other IR4.0 technologies will require new skills for mechanical engineers, manufacturing engineers, and CNC machinists.

As the Future of Manufacturing white paper points out, many of the current skills in today's workforce are based on Industry 3.0 or earlier technologies. Adopting Industry 4.0 technologies in the classroom will expose students to the actual tools and workflows they will use in their jobs and equip them to face the problem-solving challenges in advanced manufacturing.

Among its recommendations, the Future of Manufacturing white paper emphasizes adopting new software platforms that converge several functions and disciplines across common data environments for quicker collaboration and shrinking time-to-market. New IR4.0 workflows use these integrated software platforms to make designing and building smarter, customised and more complex products practical on a global scale.

## What are the Industry 4.0 emerging technologies?

### Design for Manufacturing (DfM)
Implement more circular, connected workflows and processes to improve manufacturability, customization and automation

### Operations technology (OT) infrastructure

### AI/ML-driven technologies
*(e.g. generative design)*
Utilizes data and learning algorithms to surface data and operational insights that can be used to improve designs (with generative design) and highlight manufacturing bottlenecks in the production cycle

### Cloud-based software platforms
*(e.g. integrated computer-aided design and manufacturing–CAD/CAM)*
Converges application workflows across product design, engineering, manufacturing engineering and machining

### Manufacturing execution systems (MES)

### Product lifecycle management (PLM)

### Business intelligence (BI) solutions
Analyze and visualize data to extract useful product and operational data trends and insights

### Centralized data management across manufacturing systems
Consolidates data from sources to make more data-driven decisions across the manufacturing systems
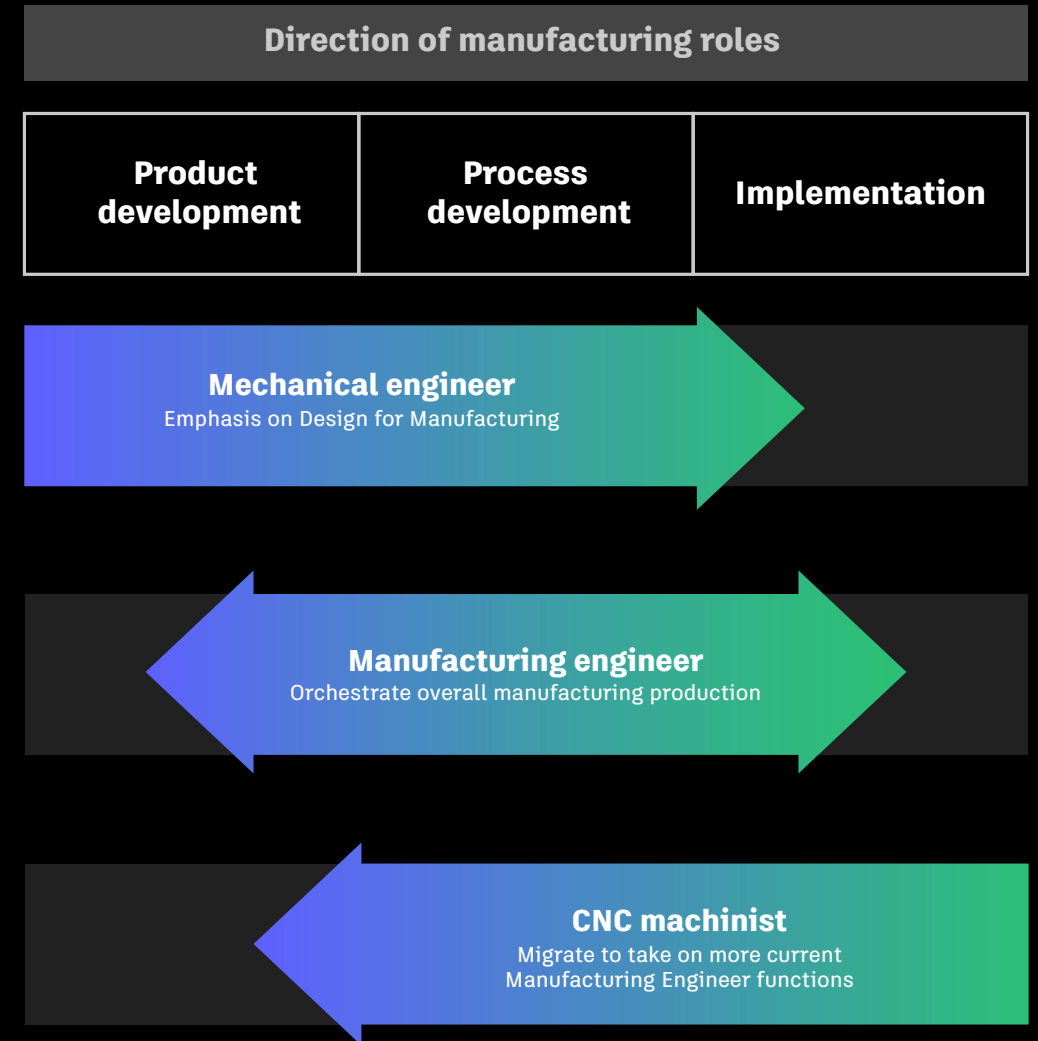
# IR4.0 will revamp product design and manufacturing

To capitalize on Industry 4.0 technological capabilities to design and build more efficiently and effectively, manufacturing workflows need reengineering to make mechanical engineers, manufacturing engineers, and CNC machinists more interdisciplinary and collaborative with each other.

- Mechanical engineers continue to improve upon engineering designs and become more involved in manufacturing implementations processing production data results to improve designs for manufacturability.

- Manufacturing engineers expand focus from manufacturing processes to managing the overall production operations and analyze globally distributed systems including machining tools, robotic systems, and additive manufacturing.

- The CNC machinists' roles will also evolve dramatically from a CNC operator to an engineering technician who programs CNC machines and over time will take on other manufacturing engineering functions like quality control.

Utilizing a single software platform such as Fusion 360 that supports all three design and manufacturing roles enables more collaboration between teams. It streamlines work by removing the overhead to switch between programs and uploading different file types to execute their specific workflow tasks. And it also reduces rework stemming from incompatible files from different CAD and CAM apps and helps shorten product development cycles.

## How are manufacturing job roles changing?

| Direction of manufacturing roles | | |
| --- | --- | --- |
| Product development | Process development | Implementation |

**Mechanical engineer**
Emphasis on Design for Manufacturing

**Manufacturing engineer**
Orchestrate overall manufacturing production

**CNC machinist**
Migrate to take on more current
Manufacturing Engineer functions

**Business outcomes**

# Improved results rely on an IR4.0 workforce

The IR4.0 workforce will require current IR4.0 skills and workflow training to achieve what the Future of Manufacturing white paper notes as the leading manufacturing business objectives: increased productivity, profitability, and shorter product development cycles. IR4.0 technologies are generally more programmable, which creates opportunities for automation that increases productivity. For example, generative design automates prototype modeling in the design phase, while robotic assembly and machining automation improves manufacturing productivity.



**The Bechtel Innovation Design Center at Purdue University uses Autodesk® Fusion 360® as part of a teaching environment that mimics a commercial Industry 4.0-adopted shop**

The university recognized the industry need for accelerated "time to talent" and interdisciplinary training. The center allows student access to a modern shop of CNC machines, 3D printing, CAD/CAM software, a cloud library of models, and tooling presets for design and engineering projects. The environment mimics a commercial Industry 4.0-adopted shop where any person can move fluidly from station to station, giving students a strong facsimile of the IR4.0 work environment.

Student projects are first simulated on a digital twin of the essential parts and machining processes in Fusion 360. This digital simulation process emphasizes the importance of time-and resource-saving workflows to reduce rework and physical waste. These modern tools and digital capabilities help accelerate learning and teach students more efficient design and manufacturing methodologies.

# What are the Industry 4.0 skills gaps?

To prepare mechanical engineers, manufacturing engineers, and CNC machinists for the Industry 4.0 workforce, they must learn the hard, soft, and interdisciplinary skills to close the gaps for each job.

As the Future of Manufacturing white paper indicates, the three positions will interact with each other at more points across the design and manufacturing process and require a wider range of interdisciplinary skills and knowledge to work with the different manufacturing functions.

According to the research survey respondents, the most important hard skills needed across all three roles are Design for Manufacturing (DfM) and AI/ML skills. Mechanical engineers apply AI/ML skills, including generative design, to help analyze and optimize product designs. Manufacturing engineers use AI/ML techniques to configure intelligent, self-optimizing machines to automate production processes across manufacturing systems. CNC machinists use AI/ML training to identify efficiency and quality improvement opportunities.

For each manufacturing role, there are a number of additional hard and interdisciplinary skills gaps to address. See the following infographic for a clear picture of how those skills apply to each role and in some cases overlap between roles.

# Where are the future skills focused?

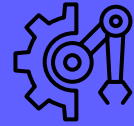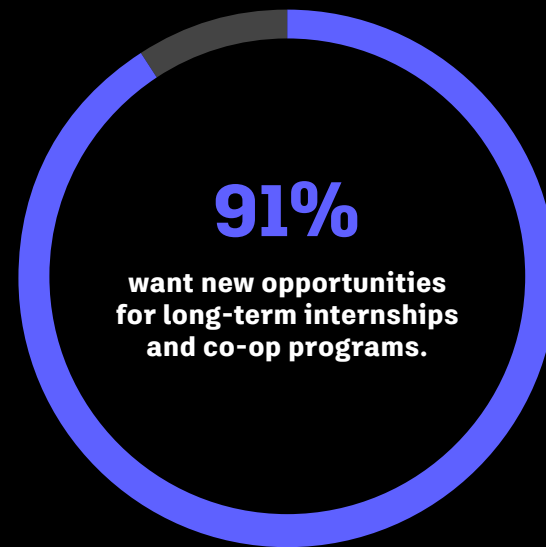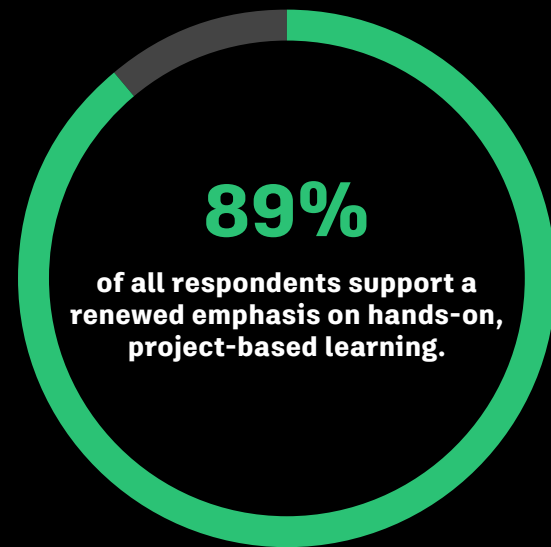| Mechanical engineers | | Manufacturing engineers | | CNC machinists | |
|---|---|---|---|---|---|
| **Current** | | **Current** | | **Current** | |
| **Hard skills** | **Interdisciplinary skills** | **Hard skills** | **Interdisciplinary skills** | **Hard skills** | |
| · CAD software<br>· Analytical software (Matlab and Minitab)<br>· Programming tools<br>· ERP software<br>· Financial analysis software | · Quality assurance and control (QA/QC) | · CAD software<br>· Analytical software (Matlab and Minitab)<br>· Lean manufacturing<br>· Process improvement<br>· Machine tools and hardware | · Quality assurance and control (QA/QC) | · CAD software<br>· CAM software<br>· ERP software<br>· CNC machining<br>· Workholding, machine kinematics, and geometric dimensioning and tolerancing (GD&T)<br>· Machine tools and hardware<br>· Analytical and industrial control software | |
| **Future** | | **Future** | | **Future** | |
| **Soft skills** | **Interdisciplinary skills** | **Soft skills** | **Interdisciplinary skills** | **Soft skills** | **Interdisciplinary skills** |
| · Problem-solving<br>· Communications<br>· Collaboration | · Experience with systems engineering<br>· Knowledge of electrical and software engineering<br>· Focus on sustainability | · Problem-solving<br>· Communications<br>· Collaboration | · Focus on sustainability<br>· Mechanical engineering fundamentals<br>· Factory line automation | · Problem-solving<br>· Communications<br>· Collaboration | · Product development<br>· Quality assurance and control (QA/QC) |
| **Hard skills** | | **Hard skills** | | **Hard skills** | |
| · AI/ML<br>· Design for Manufacturing<br>· Integrated CAD/CAM and Generative Design<br>· Coding/Programming<br>· 3D modeling and design<br>· Data analytics and visualization<br>· Prototyping<br>· Engineering and digital twin simulation | | · CNC machining<br>· AI/ML<br>· Design for Manufacturing<br>· Robotics/cobotics<br>· Integrated CAD/CAM<br>· Additive and hybrid manufacturing<br>· Operations technology (OT)<br>· AR/VR | | · AI/ML<br>· Robotics/cobotics<br>· Integrated CAD/CAM<br>· Additive and hybrid manufacturing<br>· Predictive/preventative maintenance<br>· Five-axis or higher machines | |

# What is education's role?

**The Future of Manufacturing white paper recommends that manufacturing educators take a comprehensive view of the industry's current needs and adopt new pedagogies that teach IR4.0 advanced manufacturing knowledge, technologies, and skills with more real-world, hands-on learning content. This strategy reduces the "time to talent" and supports graduates obtaining credentials and certifications for modern software, machines, and roles.**

The research surveys of high-level industry professionals and manufacturing academics found that:

**89%**
of all respondents support a renewed emphasis on hands-on, project-based learning.

**91%**
want new opportunities for long-term internships and co-op programs.

**84%**
believe manufacturing employers and academia should partner on new types of certification programs based on employer needs.

# Where can education get help?

Many educational institutions may not have the resources to create new advanced manufacturing curricula quickly enough to keep pace with industry requirements and close the skills gap. To keep up with the rapid manufacturing technology changes, academia can partner with technology companies, industry consortiums, and government agencies. The Future of Manufacturing white paper cited the role of government agencies as potential resources to fund scholarships, apprenticeships, and state-of-the-art manufacturing equipment.

The paper also recommended that academia partner with leading Industry 4.0 technology companies and commercial manufacturers to devise new training programs, modular learning content, and certifications that teach generative design, Design for Manufacturing (DfM), integrated CAD/CAM tools, centralized data analysis and visualization, additive/hybrid manufacturing, and robotics/cobotics. Existing ready-to-use and industry-validated learning content and role-based certifications from technology companies can help ease the burden on educators.

**Industry**

**Reduce "time to talent"**

**Education**

**Government**
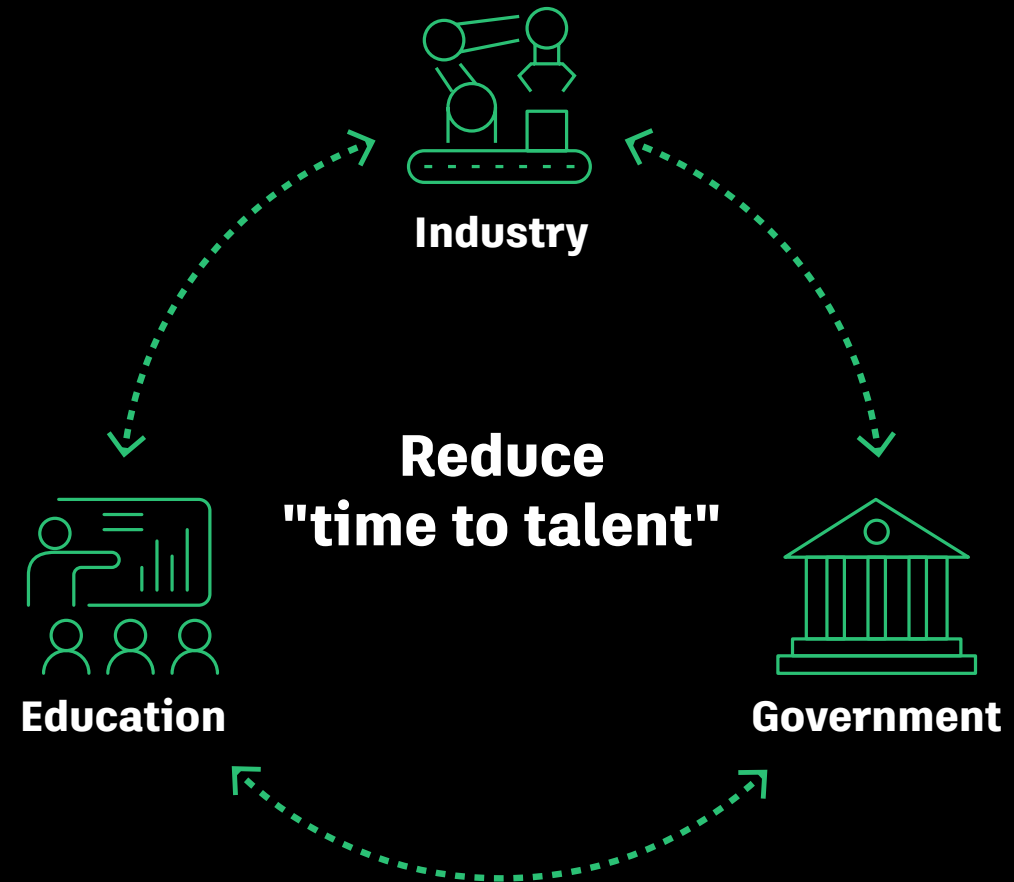
| Industry | Education | Government |
|---|---|---|
| Technology for education | Advanced manufacturing skills development | Workforce development programs |
| Interns, co-ops | Project-based learning | Financial funding |
| Faculty advisors | Updated curriculum | |
| Certifications | Digital credentials | |

# What does an Industry 4.0 educational program look like?

Advanced manufacturing programs have been developed to train the Industry 4.0 workforce and help close the industry skills gap. Autodesk has worked with companies and educational institutions worldwide, sharing research, knowledge, and technology to support new advanced manufacturing education and vocational training programs.

## Danville Community College (DCC) creates its Integrated Machining Technology (IMT) program

IMT takes a short-form, modular approach to teaching specific, project-oriented skills using the latest integrated CAD/CAM tools including Fusion 360 and emphasizing hands-on applied learning in the lab. The program focuses on developing hard technical skills on the latest advanced manufacturing technologies, as well as improving the soft skills of communication and collaborative problem-solving skills within a manufacturing simulation experience. IMT's success underscores the importance of developing a mix of technical skills and soft skills to develop leadership characteristics that will benefit students—as well as their employers—throughout their careers. DCC maintains close relationships with many local manufacturers to stay on top of current industry needs and to better simulate modern manufacturing scenarios in the IMT program.

The IMT DCC program helps supply a pipeline of manufacturing talent to the many manufacturing businesses in the Danville-Pittsylvania County region of Virginia. It also shows the effectiveness of taking a modular, skills-based approach to teaching new IR4.0 technologies, workflows, and skills to build a modern manufacturing workforce.



A "blueprint" to teach Industry 4.0 and advanced manufacturing skills

**Integrated Machining Technology– Danville Community College**

Legend:
- Advanced manufacturing
- Soft skills
- Inspection course
- Manufacturing simulation
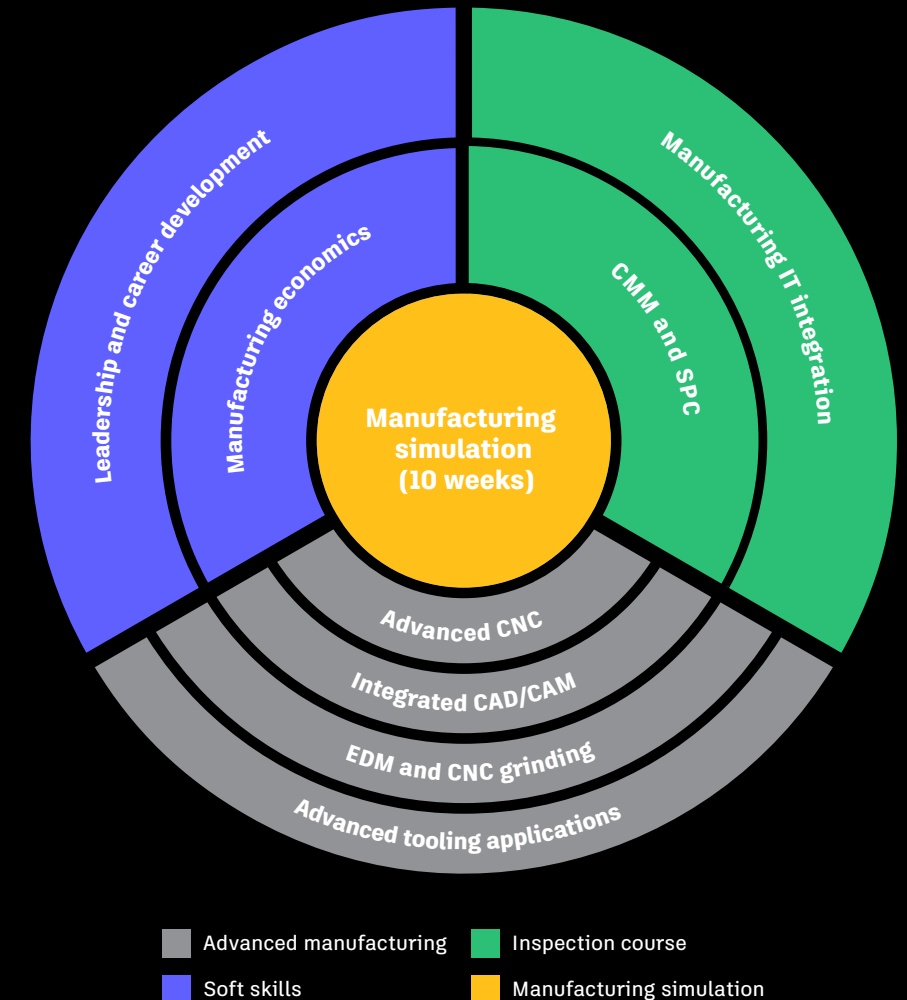
# Introducing generative design into a traditional CAD/CAM lesson

To illustrate how an Industry 3.0 workflow lesson can be updated to an Industry 4.0 lesson with the addition of generative design and hybrid manufacturing, take the following example of designing a brake caliper. This example shows how Industry 4.0 skills can be incorporated into current coursework without redesigning the entire course. Collectively, incremental Industry 4.0 training improvements can lead to an impactful, transformative change.

| Step 1 | Step 2 | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 |
|---|---|---|---|---|---|---|
| **Task:** Design basic brake caliper using traditional parametric modeling techniques | **Task:** Program brake caliper using integrated CAD/CAM and traditional CNC subtractive machines | **Task:** Design alternate brake caliper using GD and targeting x% weight decrease and y% strength increase | **Task:** Explore manufacturing processes for traditional and GD brake calipers | **Task:** Produce GD brake caliper using hybrid manufacturing processes | **Task:** Establish production layout and integrate robotics/cobotics into production | **Task:** Explore electronics integration into parking brake system |
| **Skills:** Integrated CAD/CAM<br><br>Design for Manufacturing | **Skills:** Integrated CAD/CAM<br><br>Multi-axis CNC machining | **Skills:** Generative design<br><br>AM overview<br><br>Multi-axis CNC machining<br><br>Simulation | **Skills:** Additive manufacturing<br><br>Simulation<br><br>Multi-axis machining<br><br>Integrated CAD/CAM | **Skills:** Additive manufacturing<br><br>Integrated CAD/CAM<br><br>Multi-axis machining | **Skills:** Generative design<br><br>Robotics | **Skills:** Additive manufacturing<br><br>Simulation<br><br>Multi-axis machining<br><br>Integrated CAD/CAM electronics |

- ⬛ Industry 3.0
- 🟩 Industry 4.0

# Education transformation

## Today

**Disparate.**
**Disconnected.**
**Different.**

- Mechanical engineer ⌄
- Manufacturing engineer ⌄
- CNC machinist ⌄
- Production ⌄

### Industry 3.0

Legacy CAD/legacy CAM

Task-specific robotics and application-specific automation; disparate data applications

Siloed workflows and teams

## Digital transformation

Collect and organize data on a single platform

Connect teams to access and exchange data

Converged cloud applications

## Workflow transformation

Redesign workflows

Reimagine roles and responsibilities; upskill and reskill

Collaborate across disciplines leveraging cloud solutions

## Business transformation

Leverage emerging technologies including AI/ML, GD, AM, cobotics

Visualize and analyze data for process automation and optimization

Remove current silos

## Tomorrow

**Converged.**
**Connected.**
**Collaborative.**

- Mechanical engineer
- Manufacturing engineer
- CNC machinist
- Production
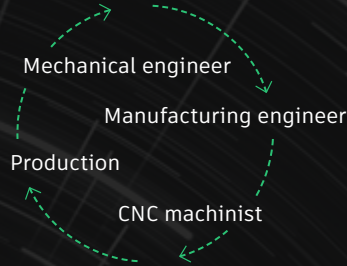
### Industry 4.0

Converged cloud and data platforms (e.g., integrated CAD/CAM)

AI/ML applications, generative design, data analytics, AM, cobotics

Unified production orchestrated across distributed systems

Connected workflows and cross-functional collaboration

# The path to train the new Industry 4.0 workforce

The following steps can help guide educational institutions to update their programs to give students the knowledge and skills needed to succeed in the Industry 4.0 workforce.

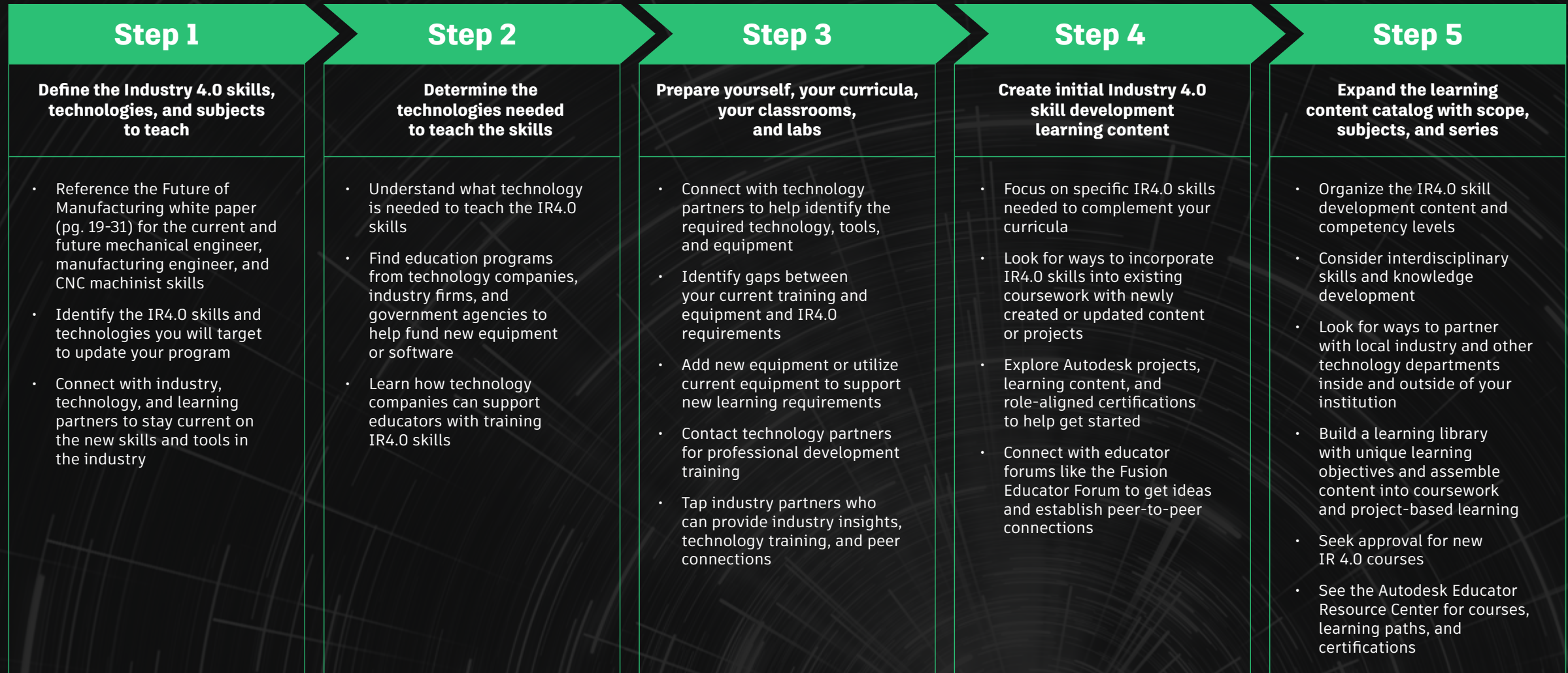| Step 1 | Step 2 | Step 3 | Step 4 | Step 5 |
|---|---|---|---|---|
| **Define the Industry 4.0 skills, technologies, and subjects to teach** | **Determine the technologies needed to teach the skills** | **Prepare yourself, your curricula, your classrooms, and labs** | **Create initial Industry 4.0 skill development learning content** | **Expand the learning content catalog with scope, subjects, and series** |
| • Reference the Future of Manufacturing white paper (pg. 19-31) for the current and future mechanical engineer, manufacturing engineer, and CNC machinist skills<br><br>• Identify the IR4.0 skills and technologies you will target to update your program<br><br>• Connect with industry, technology, and learning partners to stay current on the new skills and tools in the industry | • Understand what technology is needed to teach the IR4.0 skills<br><br>• Find education programs from technology companies, industry firms, and government agencies to help fund new equipment or software<br><br>• Learn how technology companies can support educators with training IR4.0 skills | • Connect with technology partners to help identify the required technology, tools, and equipment<br><br>• Identify gaps between your current training and equipment and IR4.0 requirements<br><br>• Add new equipment or utilize current equipment to support new learning requirements<br><br>• Contact technology partners for professional development training<br><br>• Tap industry partners who can provide industry insights, technology training, and peer connections | • Focus on specific IR4.0 skills needed to complement your curricula<br><br>• Look for ways to incorporate IR4.0 skills into existing coursework with newly created or updated content or projects<br><br>• Explore Autodesk projects, learning content, and role-aligned certifications to help get started<br><br>• Connect with educator forums like the Fusion Educator Forum to get ideas and establish peer-to-peer connections | • Organize the IR4.0 skill development content and competency levels<br><br>• Consider interdisciplinary skills and knowledge development<br><br>• Look for ways to partner with local industry and other technology departments inside and outside of your institution<br><br>• Build a learning library with unique learning objectives and assemble content into coursework and project-based learning<br><br>• Seek approval for new IR 4.0 courses<br><br>• See the Autodesk Educator Resource Center for courses, learning paths, and certifications |

**Conclusion**

# Help is here

While the transition to Industry 4.0 is far from complete, this new era of manufacturing is here to stay. Industry firms cannot succeed fully in their digital transformation without a properly trained workforce. This transition will require collaboration between academia, technology and industry partners, and government. Technology companies including Autodesk—with its tens of thousands of commercial customers and partnerships with governmental and research agencies—can be the connector between all three entities.

For several decades, Autodesk has invested in and worked with educational institutions to help them teach the most advanced design and make tools. Autodesk continues to build its Autodesk Learning Partner network and engage with agencies to provide educational resources for teaching the IR4.0 skills and technologies that will build a more sustainable world.

Autodesk understands the Industry 4.0 skills needed. It has the technologies, learning resources, and best practices to help educators teach students those skills to succeed in the Industry 4.0 workforce. And its technology and learning partners can support educators every step of the way. Learn more about partnering with Autodesk for advanced manufacturing training by exploring Fusion 360 for education.

# Resources

Educators play a vital role in building tomorrow's workforce. Take the next step and reshape your curriculum for the modern industry with software, courses, learning paths, and more.

**Request a fully-funded workshop led by Autodesk Learning Partners**

→ **Fusion 360 workshop**

**Get started with Autodesk Fusion 360**

→ **Unlock your access**

**Discover learning pathways on the Educator Resource Center for CAD**

→ **Learn more**

**Discover learning pathways on the Educator Resource Center for CAM**

→ **Learn more**

**AUTODESK**