AUTODESK UNIVERSITY

The Future of Manufacturing

PM502253 | Future of Manufacturing: ASME's Research on the Roles, Workflows, and Skills

Summary and Key Takeaways

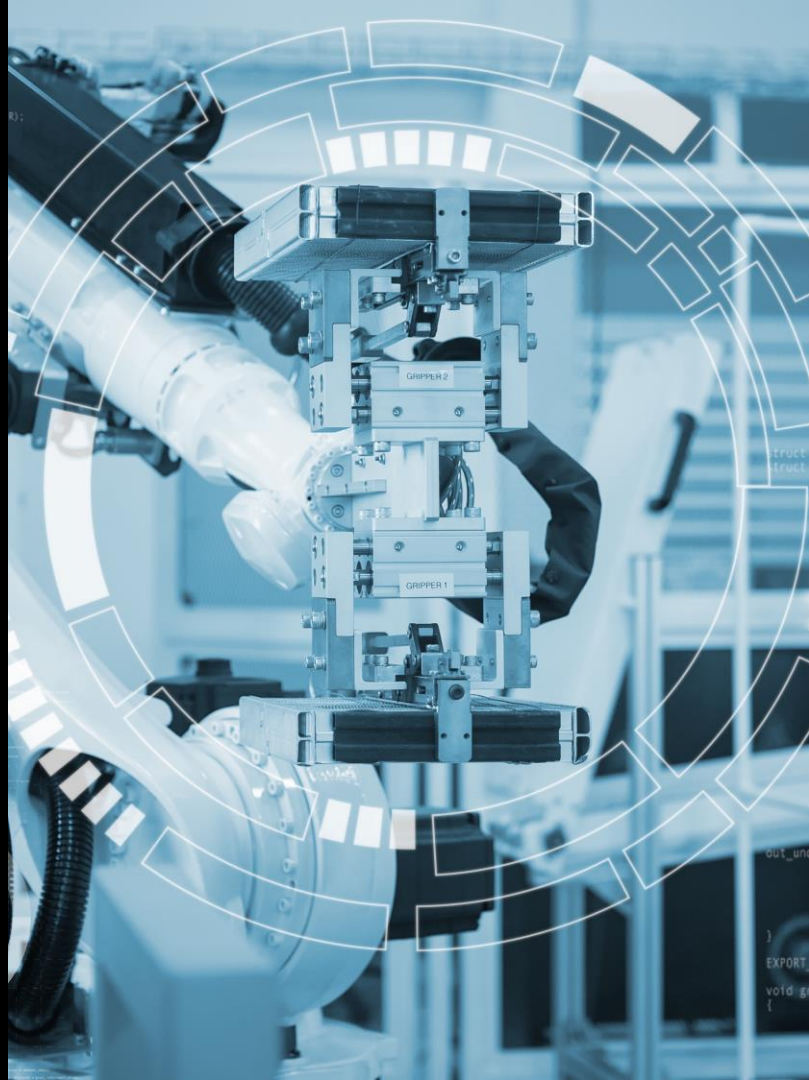
James Warrick

Managing Partner, Beacon Technology Partners LLC

What was the research about?

To provide industry and academic guidance for advanced manufacturing and the future of work, ASME and Autodesk conducted a research study from August 2021 through May 2022 that investigated and identified the future workflows and skills needed for **mechanical engineering**, **manufacturing engineering**, and **CNC machinist** roles over the next decade.

Each role will evolve in its own way, but the study shows that the necessary new skills will consist of a purposeful combination of common skills (both hard and soft skills) that apply to all three positions, and interdisciplinary skills.



How was the research carried out?

The research phases

Phase 1

Literature review

Review of 77 existing sources

Review of existing curricula in US and UK programs

Phase 2

Interviews

30 Individual interviews

10 Academics

20 Industry: US and UK

Phase 3

Surveys

324 Respondents

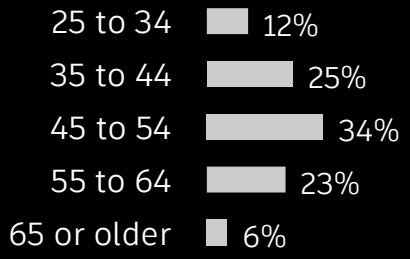
Academics and industry: US, Canada, and UK

Carried out February 1 through March 4, 2022

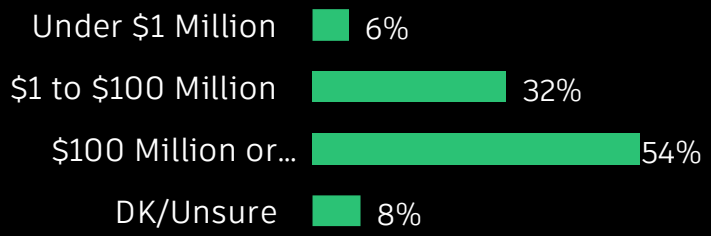
How was the research carried out?

Respondent demographics and locations

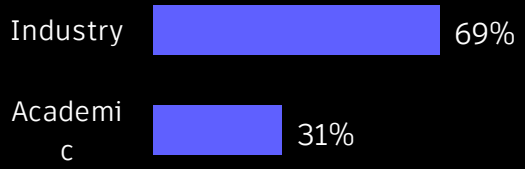
Age

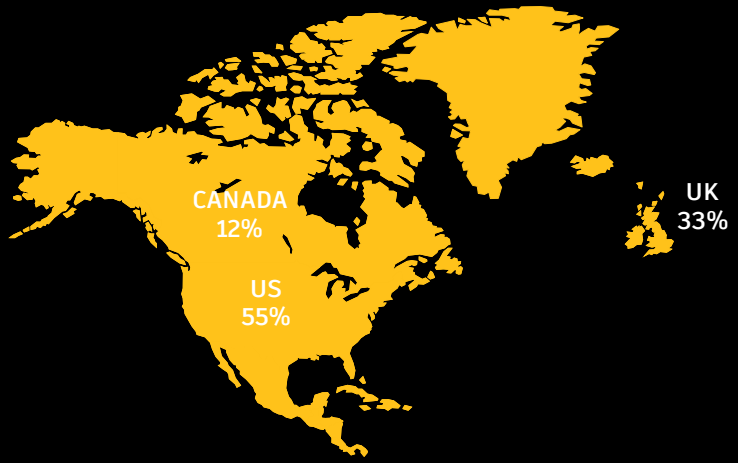


Company size by revenue



Organization type





AUTODESK UNIVERSITY

Technological Change

Industry 4.0

How is technology impacting manufacturing?

- **Industry 4.0** technologies are already in place in factories large and small, and other technologies such as additive manufacturing, advanced data analytics, IIoT and AI/ML are also receiving considerable attention in order to **build productivity** and **competitive advantage**, improve **time to market** and **enhance profitability**.

- The availability and analysis of data from **every stage of the product lifecycle** promises to forward the march towards further advancements in manufacturing.

- There is widespread agreement that more **interdisciplinary collaboration** among engineers and with machinists is necessary to fully embrace a system level view of product development, and an ethos of **continuous improvement** and **lifelong learning** is being more broadly embraced in industry and academia.

- There is a continued demand to nurture the necessary "**soft skills**" - communication, collaboration, and creative problem solving in order to build understanding which can bridge manufacturing disciplines and grapple with new-to-the-world applications and technologies.

Some Industry 4.0 technologies are already in use in manufacturing processes, most prominently

- design for manufacturing
- CNC machining
- product lifecycle management software robotics

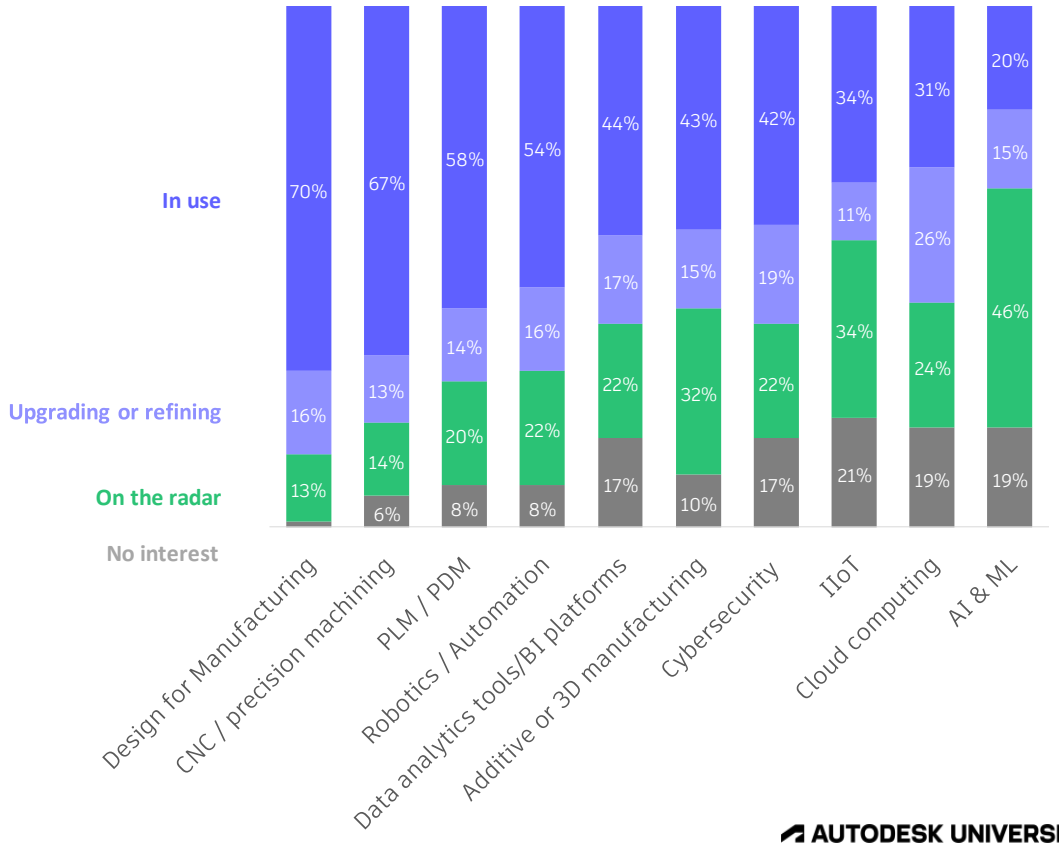
Other technologies being considered or on the radar of respondents include

- additive manufacturing
- advanced data analytics
- industrial Internet of Things
- AI/ML

Which option best describes your current activity for each of the following technology initiatives?

Status of Manufacturing Technology Initiatives

Base: 171 Mechanical and Manufacturing Engineers



Data will drive **closer collaboration** and play a pivotal role in the future of manufacturing.

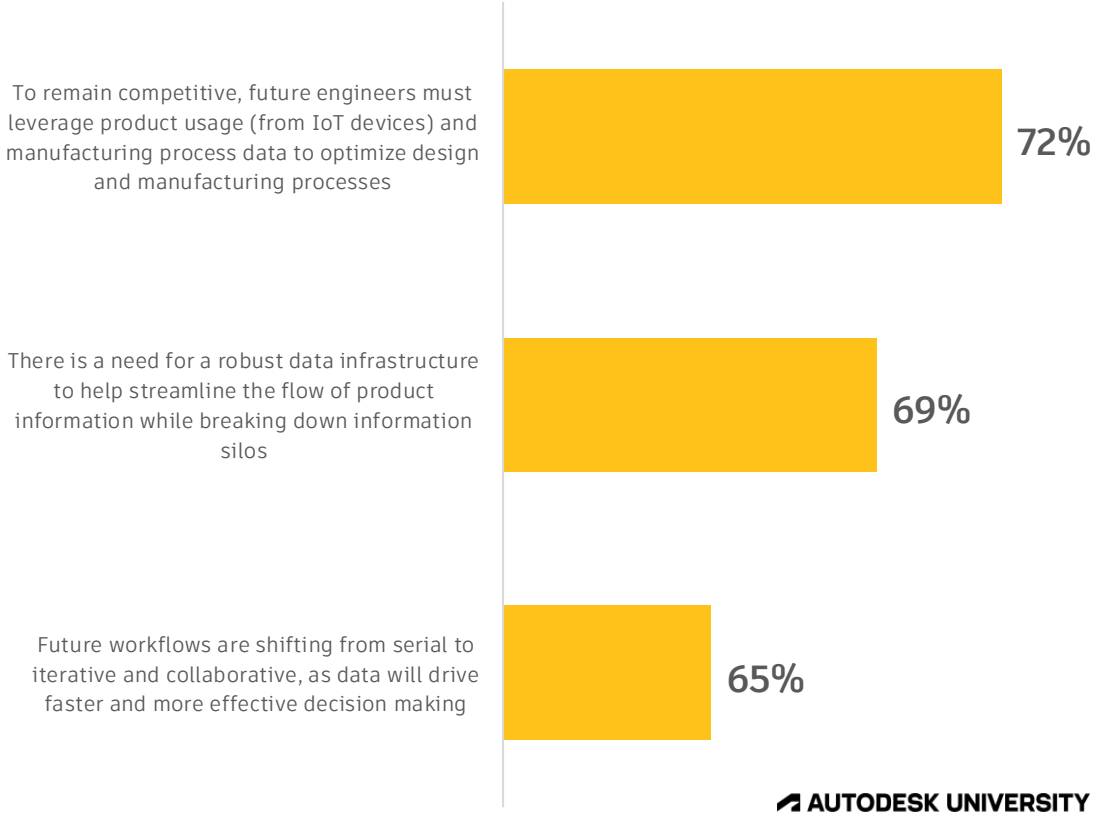
Increase collaboration will require the need for better communication and group problem-solving as new workflows converge.

Cloud collaboration platforms that break down geographic barriers and bring teams together in new ways will enable all job functions to collaborate more efficiently.

Please rate your level of agreement with the following statement with regard to the future of manufacturing.

Attitudes about Advanced Manufacturing and Utilization of Data

(% Strongly, Somewhat Agree)
Base: 324 (All Respondents)



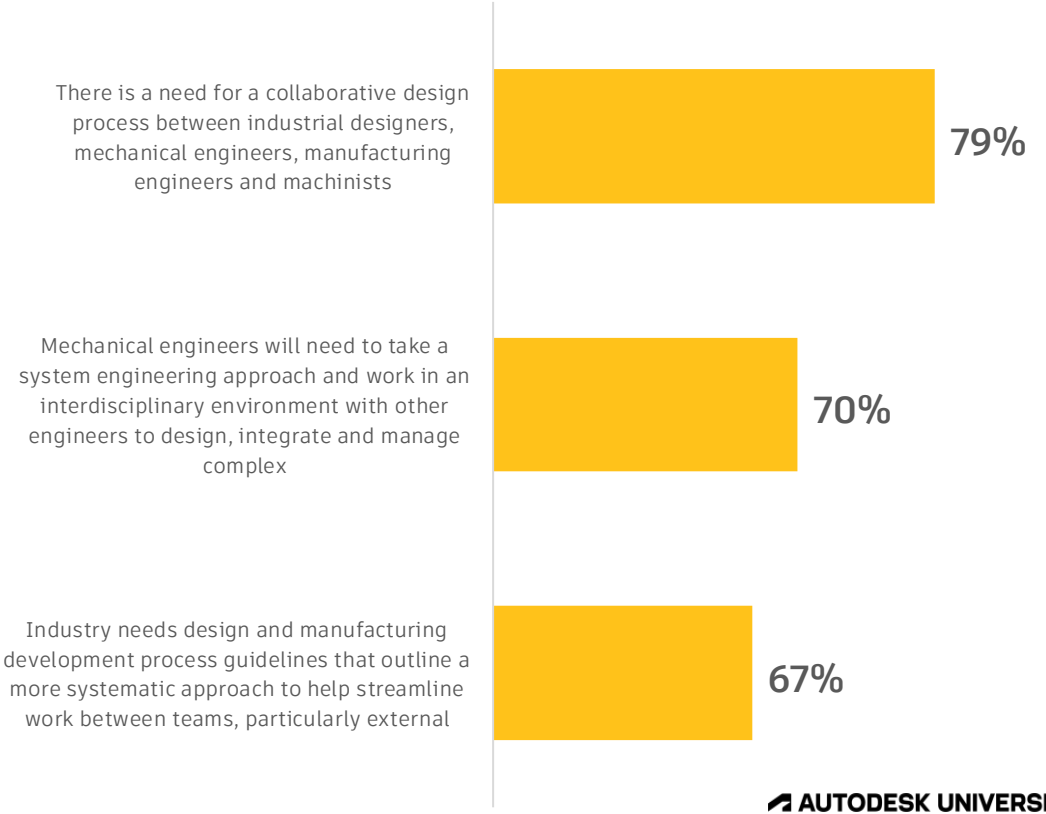
There is widespread agreement about the need for greater interdisciplinary collaboration among engineers, as well as with machinists and other external parties - in large part because of the fundamental need to adopt a system level approach to product development.

Using a system-level approach, firms will be able to develop advanced manufacturing strategies and technology adoption plans that will deliver the connected, collaborative, and continuous manufacturing workflows and workforce needed to achieve their business goals and outcomes.

Please rate your level of agreement with the following statement with regard to the future of manufacturing.

Attitudes about Advanced Manufacturing, Design and Collaboration

(% Strongly, Somewhat Agree)
Base: 324 (All Respondents)



AUTODESK UNIVERSITY

Evolving Roles

The Mechanical Engineer

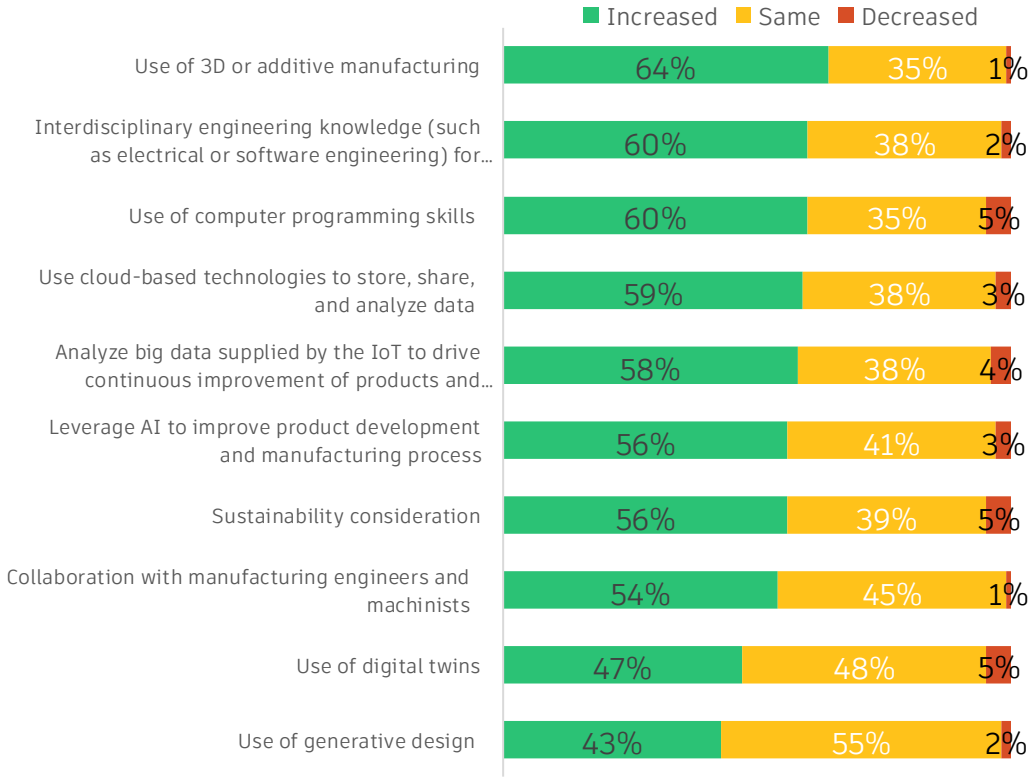
Mechanical Engineering – Changing Priorities

Base: 171 Mechanical and Manufacturing Engineers

In the coming decade, the role of the mechanical engineer will likely shift, with job functions and skills such as additive manufacturing, programming, data analytics and use of cloud technologies coming to the fore.

Mechanical engineers will play key roles in developing better products that are designed for manufacturability and are leaner, smarter, and more sustainable.

Required mechanical engineering skills will expand beyond their traditional scope to include the abilities to design with electronics and to design for product modularity that will extend the product lifecycle



Over the next 5 to 10 years, how will the work of mechanical engineers change, if at all?

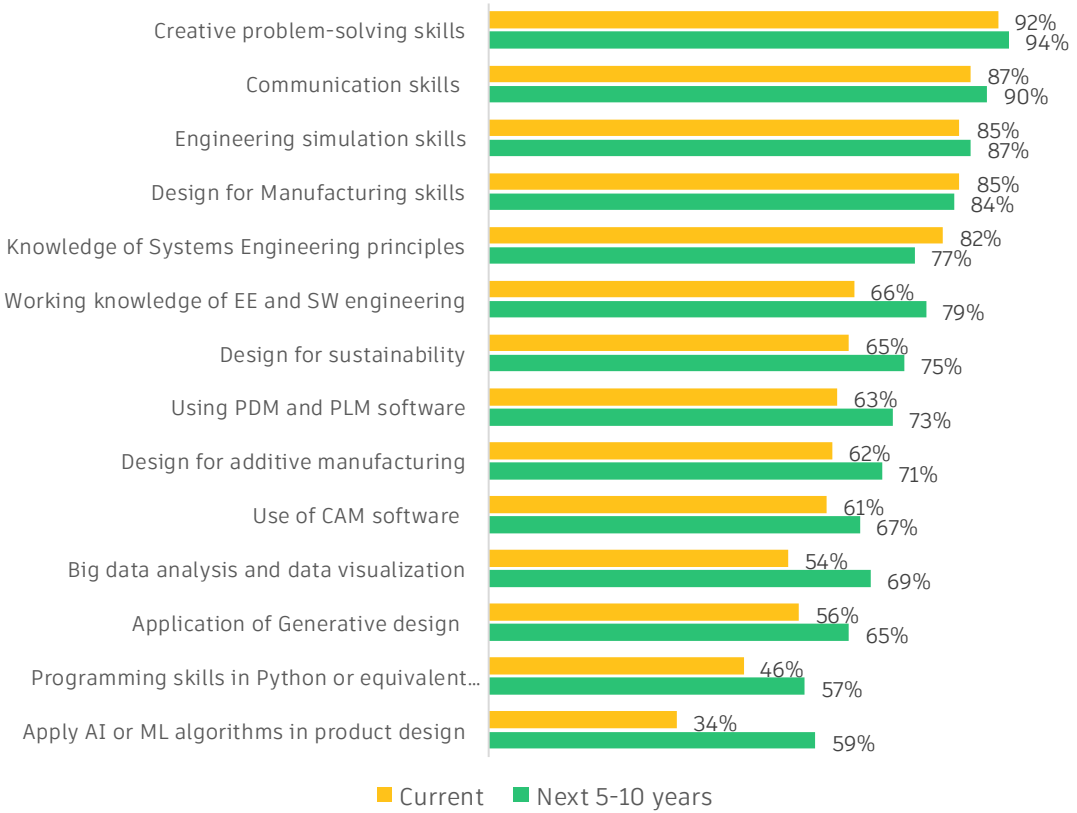
The increased deployment of Industry 4.0 technologies will completely change the skill set requirements for not only those entering the profession but also those currently in the workforce.

Mechanical engineers will continue to acquire, nurture and practice “soft” skills such as problem solving and communication skills.

Over the next 5 to 10 years, how will the work of mechanical engineers change, if at all?

Mechanical Engineering – Required Skill Sets

Base: 171 Mechanical and Manufacturing Engineers



The Mechanical Engineer of the Future

Today

Mechanical engineers today are primarily responsible for the research, planning, design, development, testing, and continuous improvement and redesign of new and existing products, machines, and tools

Most mechanical engineers have at least a bachelor's degree (83%), although some have associate degrees (7%) or no degree (5%)

Future Hard Skills

- Generative design
  AI/ML for product development
- Design for Manufacturing (DfM), including knowledge of the subsequent manufacturing processes (for engineers involved in the design phase)
- Knowledge of coding
- 3D modeling/design with a focus on aesthetics
- Data analytics and visualization
- Prototyping
- Engineering simulation and digital twin simulation

Future Soft and Interdisciplinary Skills

- Creative problem-solving
- Collaboration as individuals/teams
- Communications (written/verbal)
- Experience with systems engineering
- Knowledge of electrical and software engineering
- A focus on sustainability

AUTODESK UNIVERSITY

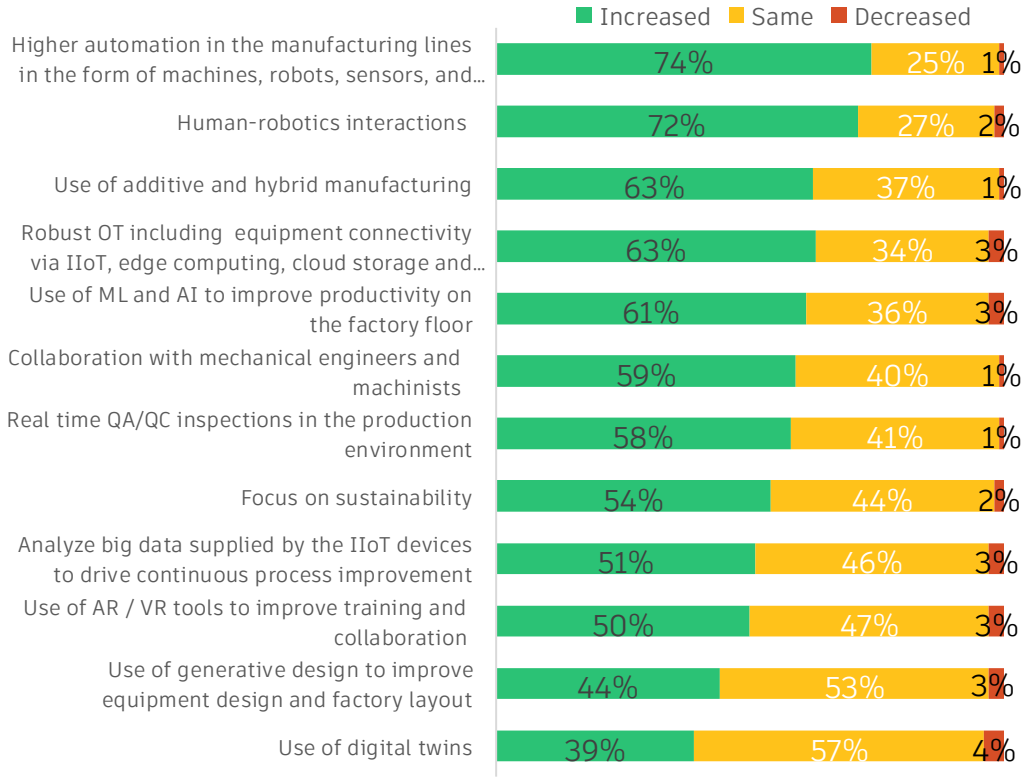
Evolving Roles

The Manufacturing Engineer

Manufacturing Engineering – Changing Priorities

Base: 171 Mechanical and Manufacturing Engineers

The working lives of manufacturing engineers will also undergo dramatic shifts in the next decade due to increased automation (particularly AI/ML enablement), human-friendly robotics, more widespread use of additive manufacturing and more robust interactivity throughout factories large and small.

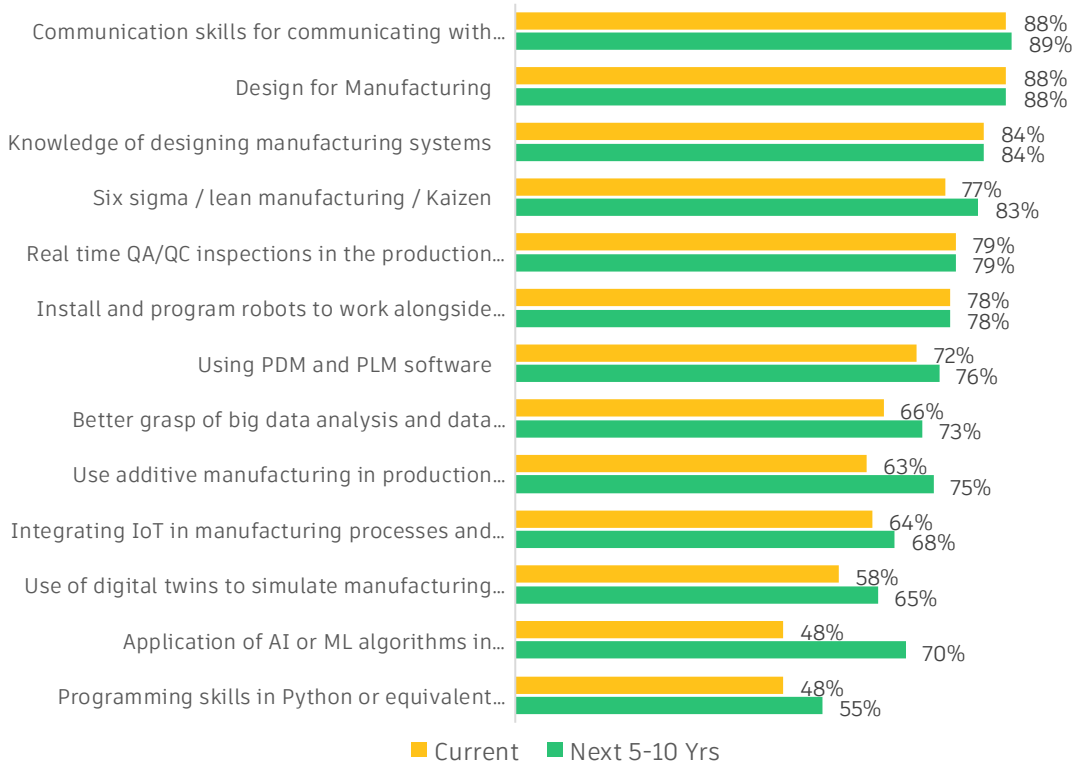


Over the next 5 to 10 years, how will the work of manufacturing engineers change, if at all?

Manufacturing Engineering – Required Skill Sets

Base: 171 Mechanical and Manufacturing Engineers

Similar to mechanical engineers, tomorrow's manufacturing engineers will continue to need enhanced communication skills and will be expected to master how to incorporating 3D printing into production processes as well as utilizing AI/ML, digital twins and data analytics output to improve throughput and efficiencies.



Currently, how important is it that manufacturing engineers have the following skills today?

Over the next 5 to 10 years, how important will it be that manufacturing engineers have the following skills?

The Manufacturing Engineer of the Future

Today

Manufacturing engineers today typically design, implement, and improve manufacturing processes and systems.

Most of them have a bachelor's degree (76%), while a significant number hold an associate degree (16%) and others a high school diploma (4%).

Future Hard Skills

- Design for Manufacturing
- AI/ML for factory floor productivity
- Robotics/cobotics
- CAD/CAM software and programming
- Additive and hybrid manufacturing
- Data analytics
- OT, including cloud storage, edge computing, cybersecurity, MES/ERP platforms, and the Internet of Things (IoT)
- CNC machining
- AR/VR

Future Soft and Interdisciplinary Skills

- Creative problem-solving
- Collaboration as individuals/teams
- Communications (written/verbal)
- Mechanical engineering fundamentals
- Factory line automation from machines, robots, sensors, and actuators
- A focus on sustainability

AUTODESK UNIVERSITY

Evolving Roles

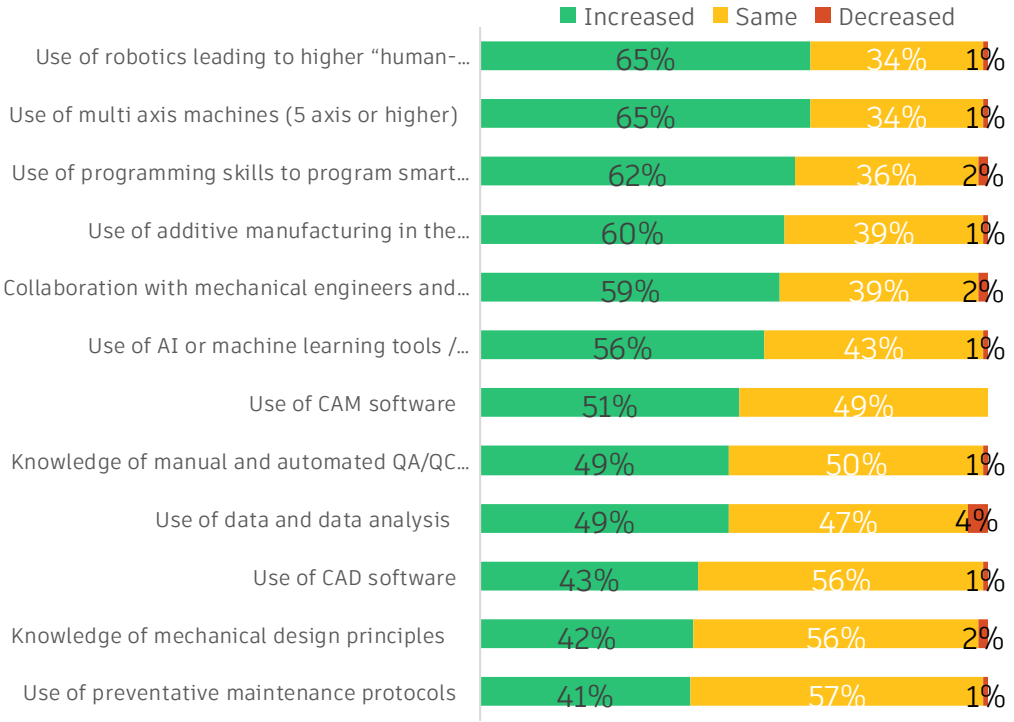
The CNC Machinist

CNC machinist's roles are likely to be the most changed of the three.

The factory environments in which CNC machinists of the future will work will increase in complexity (e.g., cobotics, 3D printers, AI/ML and multi axis machines) and require far more skill dexterity (such as programming) and productive collaboration with engineering teams.

CNC Machinists – Changing Priorities

Base: 222 Industry Professionals



Over the next 5 to 10 years, how will the work of CNC machinists or programmers change, if at all?

CNC machinists' roles will take the biggest step forward among the three positions as their role is significantly enhanced by Industry 4.0 technologies.

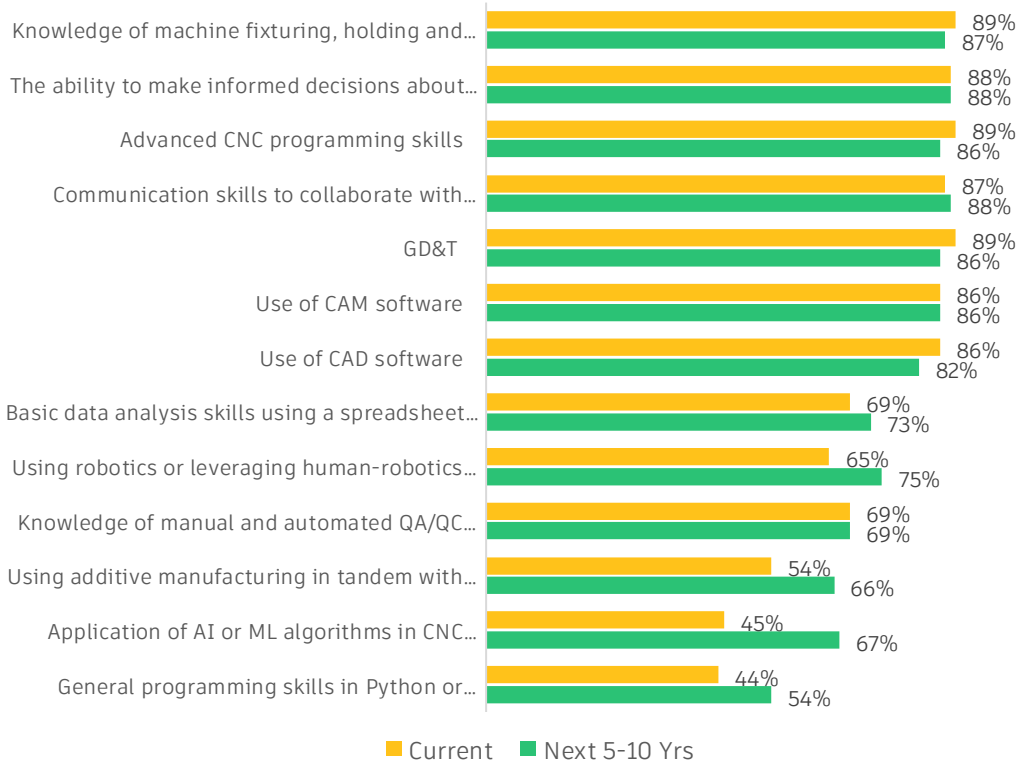
Their positions will expand and shift to include managing and programming robots (autonomous machines that perform tasks without human control) and cobots (artificially intelligent robots that perform tasks in collaboration with humans), as well as analyzing real-time production output, shop-floor inspection, and participating in quality assurance (QA) and quality control (QC)

To help foster these changes, tomorrow's CNC machinists must become more familiar with these new and emerging technologies compared to their current skill sets – while at the same time not neglect their knowledge of fixturing, holding, kinematics and GT&T.

Over the next 5 to 10 years, how will the work of CNC machinists or programmers change, if at all?

CNC Machinists – Required Skill Sets

Base: 222 Industry Professionals



The CNC Machinist of the Future

Today

CNC machinists today are responsible for producing precision components using machining equipment and tools, as well as equipment setup, operation, repair and maintenance.

These professionals have a high school diploma or equivalent (36%), post-secondary certificates (33%), or some college credits without a degree (17%)

Future Hard Skills

- AI/ML for production
- Predictive/preventative maintenance
- Additive and hybrid manufacturing
- Robotics/cobotics interaction, programming, and/or maintenance
- CAD/CAM software and programming
- Five-axis or higher machines

Future Soft and Interdisciplinary Skills

- Creative problem-solving
- Collaboration as individuals/teams
- Communications (written/verbal)
- Working with engineers on product development
- Working with QA and QC teams

There’s just one problem: The workforce isn’t ready

There is a **divide** between education programs and the manufacturing workforce requirements of the future.

Many of the skills needed aren’t yet being taught in education institutions.

Both industry and academia will need to adapt their approaches to reframe their roles as well as foster closer collaboration.

The role industry can play

- Industry can contribute to growing the skills of the manufacturing workforce of the future through **internships** and **co-op programs**, **robust internal training** and development, embracing and reinforcing the need for manufacturing workers to engage in **continual education**, and partnering with and supporting education institutions (particularly community colleges) by serving on advisory boards and as faculty members.

- Cross-pollination and exposure to and interaction with different disciplines and teams via frequent job and project rotation and as well as indigenous training solutions, should be promoted.

- Engineering college faculty appreciate active involvement from industry executives (as well as industry's financial support), and engineering schools will continue to recruit faculty with demonstrable industry experience.

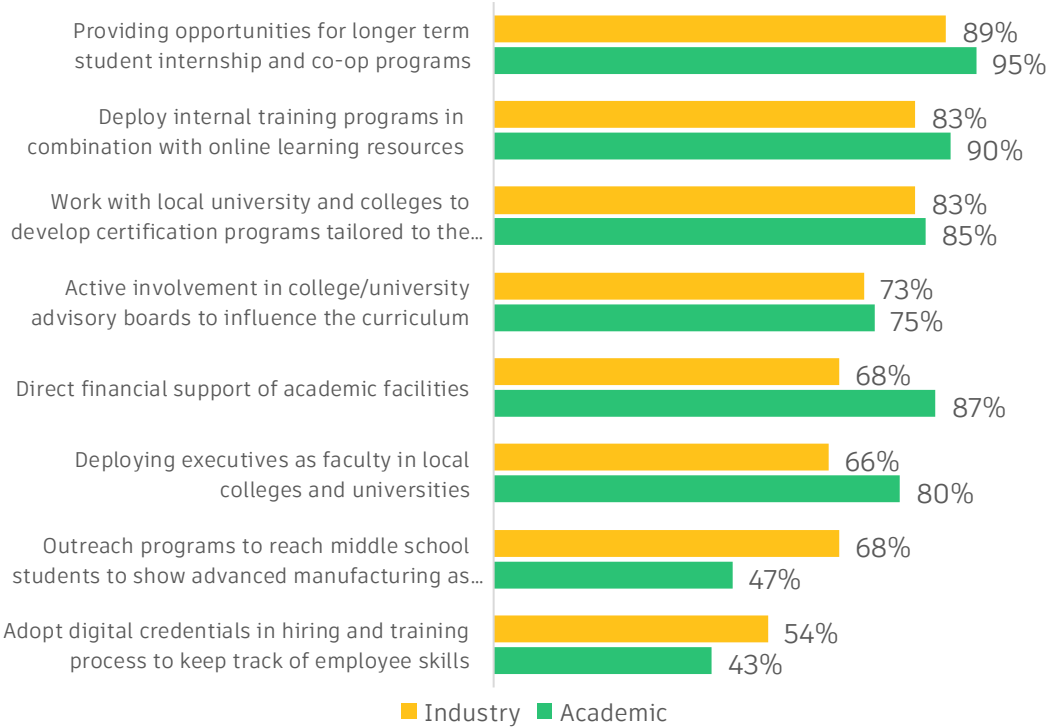
Academic courses would be enhanced with **cross-pollination** from industry executives
(as well as financial support).

Industry sees promise in reaching out to secondary school students (and even younger) to promote and invite them to consider a career in advanced manufacturing.

Over the next 5 to 10 years, to prepare engineering and machinist professionals for the demands of advanced manufacturing, how effective will the following strategies be that private industry can undertake?

Most Effective Strategic Initiatives By Industry To Develop the Manufacturing Workforce of the Future

Base: 222 Industry and 102 Academic Professionals



The role academia and educators can play

- Engineering academics are starting to rethink engineering education from the ground up. They know they must incorporate more practical, **“hands on”** learning opportunities for their students to fully grasp design-for-manufacturing knowledge and skills.

- As a means to break down silos and encourage greater collaboration, engineering pedagogy will be need to become **more interdisciplinary** and leverage new technologies that will become commonplace in industry.

- Academic institutions can lean toward **certifications** and inclusion of subjects that promote critical thinking and communication, but engineering degrees will continue to be critical.

- The expansion of future-proof content such as Design for Manufacture (DfM) in programs will be key to equipping students with the skills needed to enter the workplace of the future.

- Building links to top engineering firms and utilizing their

Both industry and academics see value in deepened DfM content in programs together with a renewed emphasis on hands-on, project-based learning.

Educators are leaning toward certifications or technical education with more inclusion of subjects that promote critical thinking and communication.

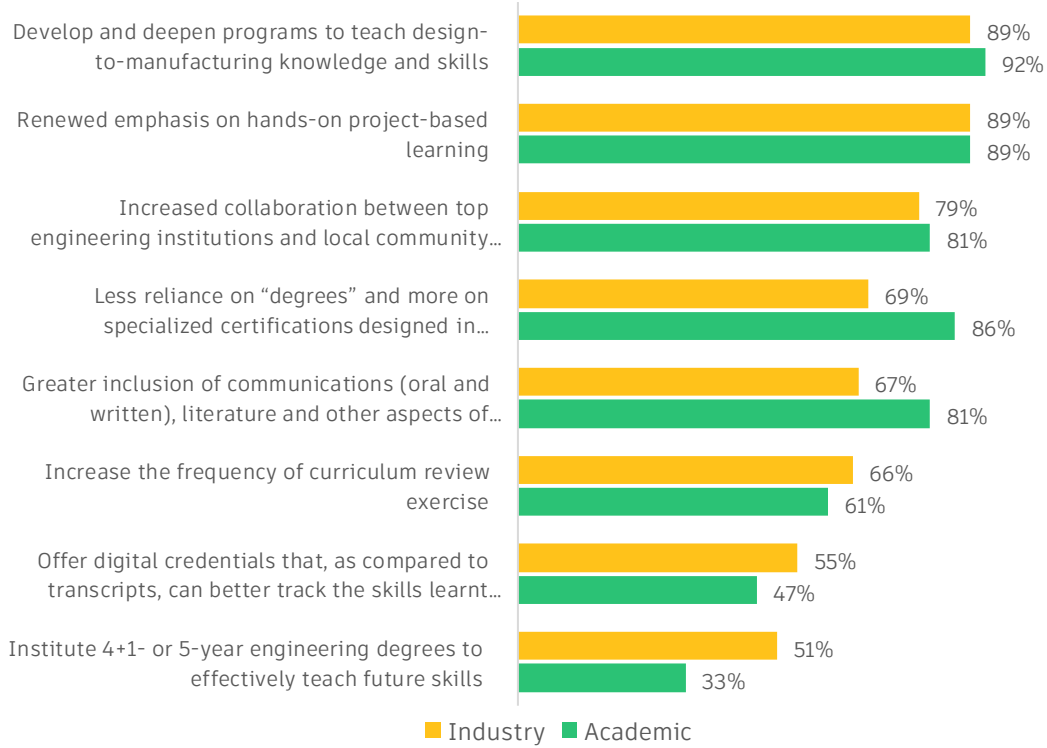
Industry engineers suggest that engineering programs add another year to teach the skills needed for advanced manufacturing.

Industry and academia also broadly agree that curricula should be reviewed more frequently.

Over the next five to 10 years, to prepare engineering and machinist professionals for the demands of advanced manufacturing, how effective will the following strategies be that academic institutions can undertake?

Most Effective Strategic Initiatives By Academia To Develop the Manufacturing Workforce of the Future

Base: 222 Industry and 102 Academic Professionals



AUTODESK UNIVERSITY

What changes can we make now?

Transforming together

Industry 3.0 Today

Legacy CAD/legacy CAM

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

Siloed workflows and teams

Digital transformation

Adopt the foundational and enabling technologies to support and facilitate new workflows and business processes.

Workflow transformation

Reimagine workflows, roles and skills to leverage the technical capabilities delivered in the digital transformation.

Business transformation

Apply new technologies, workflows and roles to achieve better business outcomes.

Industry 4.0 Tomorrow

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

Key steps for academia and educators

Step 1 Reimagine training from the bottom up to align with the digital transformation of current and future workflows. Look for opportunities to replace theory-based knowledge with applied learning.

Step 2 Engage industry and technology partners like Autodesk to establish an industry/academia relationship to stay current on industry trends, developments, and required skills to prepare students for the workforce.

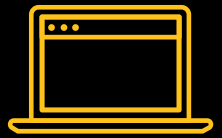
Step 3 Realign current curriculum and/or create new curricula or programs to teach advanced manufacturing subjects and skills-requested by industry-that will support the new workflows and business processes.

Step 4 Maintain an open dialog with industry and regularly review curriculum and programs to ensure industry alignment.

You can begin using the tools and resources below

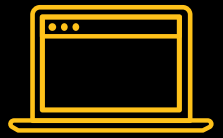
Autodesk Education Community

autodesk.com/education



Autodesk Learn Lab

blogs.autodesk.com/learn-lab/



Autodesk Learning and Certification

autodesk.com/certification/

Additional Resources

For Industry 4.0 to succeed, manufacturing education must transform

Transforming Manufacturing Education campaign landing page

Future of Manufacturing white paper

Transforming Manufacturing Education e-book hosted on Redshift

Research inspired ALP workshop sign-up page

Educator Resource Center for CAM

Educator Resource Center for CAD