



# How Academia Can Close the **ENGINEERING** **SKILLS GAP** IN THE AGE OF DIGITALIZATION

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# Educating Today's Engineering Students

## The Future of Engineering Education

How can schools best prepare today's engineering students for the real world?

The rapid evolution of products, technologies and entire industries has driven significant change in the skills companies seek in graduating engineers. As digitalization changes the way companies operate, the environments in which engineers work will also transform as technology plays an even greater role in an engineer's daily work. This dynamic environment creates demand for engineers with a broad, agile skillset. What should universities and colleges do to prepare graduating engineers?

This research shares a global perspective of what colleges and universities are doing to develop the engineering talent needed in the age of digitalization.



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# Executive Summary

## Requirements for New Engineers

Industry needs more engineering graduates. New engineers must be comfortable with cross discipline projects, a range of technology including digitalization, and horizontal organizations. Along with this deep skillset, industry wants engineers to be strong problem solvers with the aptitude to apply technology to solve problems. Previous Tech-Clarity research finds that industry believes schools could do better to meet these requirements.<sup>1</sup>

## Requirements for Learning Approaches

Much of this is due to the traditional lecture-based approach to education. By reshaping the curriculum to focus on project-based learning and partnering with industry thought leaders, there is tremendous opportunity to improve students' education.

## This Research

This research builds upon past Tech-Clarity research, *Close the Engineering Skills Gap* when over two hundred companies were surveyed to identify specific skills industry wants to see in graduating engineers.

For this new research, educators from around the world were interviewed to understand what schools are doing to better prepare their students. This report details different perspectives and shares advice to evolve the curriculum to meet today's needs.

The research explores how some schools have embraced digitalization, incorporated the latest technology trends, and leveraged industry partnerships. It also shares lessons learned as a result of the COVID-19 pandemic.

Schools should:

1. Offer long term realistic projects
2. Reshape the curriculum
3. Leverage software
4. Enhance learning with digital twins
5. Enrich learning with technology
6. Develop collaboration skills
7. Prepare for horizontal cross-functional teams
8. Build resumes and offer career insight
9. Partner with industry for technology thought leadership

These steps will help schools better prepare engineering students for industry, and recruit top talent in the future.



We cannot push information to students, students need to pull information they are convinced they need. Students are empowered with projects that force them to think about what they have to learn, with whom they should work, and what resources they need. Project-based learning teaches them how to get and apply information, so it is a winning approach for learning; and in turn, for students and employers. Furthermore, to keep projects relevant, universities and industry must work together.



## Dr. Şirin Tekinay

Dean, College of Engineering,  
**AMERICAN UNIVERSITY OF SHARJAH** Chair, **GLOBAL ENGINEERING DEANS COUNCIL**

# Meet Industry Needs

## The Demand for New Engineers

As technology evolves, products become smarter, and product complexity grows, more is expected of engineers. They must work across engineering disciplines to solve a variety of multi-disciplinary design problems while managing the dependencies of an increasing number of interconnected components.

Compounding the situation, industry is losing its most experienced and knowledgeable engineers to retirement. This is driving a desperate need for companies to expand their engineering talent with new engineering graduates. In fact, previous Tech-Clarity research finds that an overwhelming 80% of companies believe hiring the right engineers will be critical to their business success. On top of that, 98% say that if they can't, their company will experience a negative business impact.<sup>2</sup>

## Practical Experience Needed

The research finds that hiring managers look for students with in-depth project experience. They prefer to see experience that has involved interactions with multiple roles across complete lifecycle stages, in ways that simulate a corporate environment.<sup>3</sup> They also want to see good problem-solving skills, yet 46% said that schools do not prepare them for it.<sup>4</sup>

Also, 75% of companies reported they want new graduates to know how to apply software and technology to solve problems, not just the "picks and clicks" of the software. Yet, 81% feel students are either not prepared to use software to solve problems or they still need significant training.<sup>5</sup> Universities and colleges that can offer students experiences that develop these required skills will find their students in demand, boosting the school's reputation.



Most engineering problems involve a blend of engineering skills including electrical, mechanical, the environment, and more so skills must be broad.



### Dr.-Ing. Detlef Gerhard

Digital Engineering Chair / Mechanical Engineering  
**RUHR-UNIVERSITY BOCHUM**



Jobs for circuit design engineers have evolved significantly. PC Board Layout has become harder than generating the circuit schematic. Engineers used to be circuit designers or circuit board designers. Now they do both. Students need practical experience that's indicative of today's high-frequency circuits that only work if the PCB layout is completed to meet the laws of physics.



### Rick Hartley

Sr. Principal Engineer  
**RHARTLEY ENTERPRISES**

# Embrace Digitalization

## Industry Is Changing

While the skills engineers need are evolving, so are their environments. Tech-Clarity research finds that digitalization is fundamentally reshaping how companies operate. Digitalization is helping companies gain a competitive advantage, disrupting markets, and challenging the status quo. It drives new levels of innovation, agility, product performance, and quality.<sup>6</sup> Companies who ignore digitalization trends will likely struggle to remain competitive. Incidentally, 65% of surveyed manufacturers said digitalization was critical or very important to their business strategy.<sup>7</sup>

In fact, Accenture's CEO, Pierre Nanterme, stresses the urgency and impact, observing, "Digital is the main reason just over half of the companies on the Fortune 500 have disappeared since the year 2000."<sup>8</sup> This means that while industry is already suffering from a lack of skills, they also need the right engineering talent to support their digital transformation. To support digitalization in product development, companies need engineers with digital skills who understand the technology and how to apply it to solve problems and support business operations. Consequently, academic institutions should prepare students to work in the age of digital transformation.

## COVID-19 Accelerated Digitalization

Interestingly, the COVID-19 pandemic has accelerated digital transformation. In fact, Microsoft CEO Satya Nadella stated that they saw two years' worth of digital transformation in two months. This growth creates even greater urgency for schools to prepare students for digitalization.<sup>9</sup>



**Digitization** is the process of converting data into an electronic format.

**Digitalization** goes beyond simply digitizing data. It involves using digital technologies to support the flow of digital processes and data. Digitalization initiatives include digital twins, a digital thread, augmented/virtual reality (AR/VR), Internet of Things (IoT), Industry 4.0, and automation.

To support digitalization in product development, companies need engineers with digital skills who understand the technology and how to apply it to solve problems



# Viewpoints on Digitalization



“

Digitalization will be critical for the future. Companies that do not jump on the train will not be as efficient. They need to go through a digital transformation and change their corporate culture to be digital native. The change needs to happen at universities too.

”

## Prof. Dr. Andreas Deuter

Vice Dean - Production Engineering & Wood Technologies / Lab for Computer Science in Production

**OWL UNIVERSITY OF APPLIED SCIENCES AND ARTS**



“

Digitalization has already had an impact. We support a digital learning process that plays a major role in every engineering subject. We've been talking about the digitalization of products and processes for 15 years, and we'll probably be talking about it for another 15-20.

”

## Dr.-Ing. Detlef Gerhard

Digital Engineering Chair / Mechanical Engineering

**RUHR-UNIVERSITY BOCHUM**



“

Digitalization has changed how industry approaches product design. In turn, it's changed how we design our curriculum and educate students. Technology advancements allow students to simulate complicated equipment. They can observe phenomenon with 3D visualizations to study complex concepts. They can even turn innovative ideas into working prototypes via 3-D printing.

”

## Dr. John W. Weidner

Professor of Chemical Engineering  
Dean of Engineering and Applied Sciences

**UNIVERSITY OF CINCINNATI**

# Prepare for the New Corporate Culture



## Agile Businesses

Taking advantage of the efficiencies achieved through digitalization requires a business transformation that changes the organizational structure. McKinsey has found that in a study of 2500 business leaders, three-quarters of respondents rank organizational agility as a top or top-three priority.<sup>10</sup> They describe agile businesses as flat, made up of networked empowered teams, with technology seamlessly integrated with every aspect of the company. These digital organizations support a collaborative culture of highly skilled talent.<sup>11</sup>

## Horizontal Leadership

This transformation to digital organizations has given greater prominence to the practice of “horizontal leadership.”<sup>12</sup> Horizontal leadership shifts from a top-down hierarchy where executives make decisions to a flatter organization made up of empowered teams. This type of organization breaks down silos across groups and requires multi-skilled workers.<sup>13</sup> The structure is well-positioned to support a digital transformation. However, to be successful, both large enterprises and small companies will need strong horizontal leaders who can work across engineering disciplines and other departments such as manufacturing, procurement, and finance. Schools that can offer students experiences to develop horizontal leadership skills will prepare them to become future leaders.

# Opportunities for Improvement

## Challenges with Traditional Approaches

Traditionally, schools have focused on theory, assuming that with a solid theoretical understanding, students will have the foundation to develop the practical skills they need once they are in the workforce. However, considering how much industry has evolved and the requirements for new engineers, this traditional approach is no longer enough.

One challenge is that what's learned during traditional lecture-driven courses does not necessarily stay with students. Further, lectures do not teach students how to use that knowledge to solve problems. All the information they have memorized will not be useful unless they know how to apply it. Beyond that, when COVID-19 forced schools to rapidly transition to online formats, some professors reported dramatic drops in attendance. This indicates that students may find less value in the traditional lecture format, especially if it is not in person.

During lectures, it is also difficult to provide students with an industry perspective that will help them understand why certain concepts are important. However, while many professors have a strong academic background, not all have had a range of industry experiences they can share with students. One way to overcome this is to hire industry veterans who can position theory with real-world examples, such as many of the instructors who were interviewed for this research.

## Guest Speakers

Another way that adds context to lectures is to invite guest speakers. Outside industry thought leaders and subject matter experts can not only share their experiences, but they can also be a great resource to educate students on the latest industry advancements. Sometimes, it can be tough to recruit guest speakers if they travel or can't take time away from their day job.

On the flip side, the lack of travel during the pandemic created opportunities for online guest speakers. Online guest speakers create more opportunities for others to share their experience, provide examples of real-world problems they solved, and explain how to use technology to develop better products.

## Make It Stick

How do you develop problem-solving skills in students, without extending the time they are in school, in a way they will absorb it? Many schools incorporate real-world projects and competitions. Some of these may be part of the curriculum. Some may be part of extracurricular activities. Regardless of the method, students get exposed to the types of experiences that prepare them for the real world. They also remember what they've learned and, in a way that students find more enjoyable. As an example, McMaster's Pivot Program has shifted engineering education in this direction.



# Viewpoints on Education



“

We differentiate between durable learning and perishable learning. We find that if we just deliver content in a lecture, it's ingested, but it's perishable. When students learn through project-based programs, their skills become more durable, and they remember what they learned. The inexpensive model puts one instructor in front of a class of 180-200 students. We've done away with that, yet keep the cost down with sticky learning, durable learning.

”

**Dr. Ishwar K. Puri**  
Dean of Engineering  
**McMASTER UNIVERSITY**



“

The traditional, siloed approach, organized by mechanical, electrical, production engineering, etc. makes it difficult to take an interdisciplinary approach, but we are working toward it. We are working on a new initiative that involves developing a product (we called it a “learning carrier”) from design to production over a complete course. It incorporates 3D CAD, 3D printing, software development, and manufacturing planning, with processes managed by PLM software.

”

**Prof. Dr. Andreas Deuter**  
Vice Dean Production Engineering & Wood Technologies / Lab for Computer Science in Production  
**OWL UNIVERSITY OF APPLIED SCIENCES AND ARTS**



“

The bulk of the engineering education does not emphasize creativity. An artist can't become a great painter by reading a book. You have to paint, draw, and get critiqued. You don't become a great golfer by reading a book. You have to practice. Engineers must go through this too. The skills my students obtain by participating in competitions like the Mars Rover are so significant; the senior capstone project is like kindergarten in comparison.

”

**A. Harvey Bell, IV**  
Professor of Engineering Practice and Co-Director, Multidisciplinary Design  
**UNIVERSITY OF MICHIGAN**



“

Students value learning by doing. Connecting with a company with hands-on experiences is invaluable. Some university programs have extracurricular programs embedded in the curriculum, which students appreciate as interactive learning and team projects provide positive learning experiences. Diverse engineering teams of software, electrical, mechanical, and other disciplines can work together and teach each other basics of their disciplines.

”

### **Antonia Nănău**

Former President / 2020 Graduate  
**BOARD OF EUROPEAN STUDENTS  
OF TECHNOLOGY**



“

Effective engineering education means learning by doing. The pedagogical term for this is experiential learning, and at its core is cooperative education (i.e., co-op). This work-based approach to learning means our faculty and students understand how industry functions and companies remain at the forefront of technology. Through our Department of Engineering Education, we continue to innovate to develop the next generation of engineers.

”

### **Dr. John W. Weidner**

Professor of Chemical Engineering  
Dean of Engineering and Applied Sciences  
**UNIVERSITY OF CINCINNATI**



“

Projects that are part of students' lessons are usually formulated really well, and students just have to solve them. In the real world, engineers have to figure out what they need and how to solve it. They have to ask questions. When they work on a company-sponsored project, they learn to solve a real-world problem and get invaluable experience.

”

### **Dr.-Ing. Detlef Gerhard**

Digital Engineering Chair / Mechanical Engineering  
**RUHR-UNIVERSITY BOCHUM**

# Adapt to the Needs of the 2020s

## The Impact of COVID-19

While industry is in the process of adopting digitalization, schools have been slower to adapt. However, social distancing requirements due to the COVID-19 pandemic forced schools to quickly adopt digitalization technologies to connect students and professors so that learning could continue.

Interestingly, this experience has exposed students to what it is like working in the modern workplace. Design teams are often globally distributed, and they must work together virtually, using remote collaboration tools to connect. This is precisely the environment the pandemic forced upon schools. However, to simulate a true engineering environment, students need more than video conferencing. They need the full functionality of an engineering collaboration platform.

## Offer Richer Experiences

As a result of the pandemic, enrollment may suffer if schools cannot provide students with a richer experience. Faced with the high cost of tuition, some students may wonder if the price is

worth it, especially if classes are not in-person.

When interviewed about the impact of COVID-19, Audrey Labovitz, a high school graduate who was planning to attend Carnegie Mellon University for mechanical engineering, observed, “The value of college is often more about meeting people than learning things. Because with the internet now, I can learn anything without any help,” She adds said. “It would be helpful if I had professors, but if I really wanted to, I could learn most of it from YouTube.”<sup>14</sup>

Schools need to overcome this perception. By using a richer online platform that supports engineering work, and goes beyond offering lectures via video conference, schools can offer their students a much more engaging and educational experience. Plus, some vendor learning systems are the same systems used by professional engineers, which will help students develop skills they will need in their careers.



To simulate a true engineering environment, students need more than video conferencing. They need the full functionality of an engineering collaboration platform.



# Viewpoints on the Impact of the Pandemic



“

The pandemic has given us a good opportunity to speed up digitalization in education. We've had to learn a lot and we've been forced to consider how we can improve our online learning. This can be applied to future learning opportunities too.

”

## Dr. Chen Ming

Director of Industry 4.0 Learning Factory  
**TONGJI UNIVERSITY**



“

The pandemic has forced a credible, real-world experience because in the global world today, we operate in teams around the world. I view it as an opportunity to work as they would in the real world where design reviews are conducted remotely.

”

## A. Harvey Bell, IV

Professor of Engineering Practice and Co-Director, Multidisciplinary Design  
**UNIVERSITY OF MICHIGAN**



“

The outbreak has accelerated digitalization and virtualization beyond the speed we could have imagined.

”

## Dr. Şirin Tekinay

Dean, College of Engineering  
**AMERICAN UNIVERSITY OF SHARJAH** / Chair, GEDC

## Steps Schools Should Take

So how can schools adapt their curriculum to better prepare students for the 2020s? How should they incorporate digitalization? Are there lessons from the COVID-19 pandemic that can be applied to help students develop the skills required to succeed in the 2020s and beyond?

The remainder of this eBook shares advice to help schools close the engineering skills gap and better prepare students for their careers.

# 1. Offer Long Term, Realistic Projects

## Develop Foundational Skills

When defining a project-based curriculum, the first step should be to establish the goals. William Oakes, Director of the EPICS Program and Professor of Engineering Education at Purdue University, says, “The purpose of project work is not the project. The purpose is to lay foundational skills for our students to do great things later.” He stresses that while there is value in the project, the project itself should not be the main goal.<sup>15</sup> When scoping a project, consider the foundational skills students need to succeed in their careers and structure projects to expose students to experiences that will develop these skills.

## Partner with Industry

Offer students the most realistic experience possible by partnering with industry. Industry partners can provide a product problem or idea they would like to explore or perhaps sponsor a team in a collegiate competition. Industry software partners can also provide the platform to support and manage the project at a level of professionalism the client expects.

## Projects Should Be Multi-Discipline

Ideal projects should involve multiple engineering disciplines to mimic the reality of today’s engineering projects. While exposing

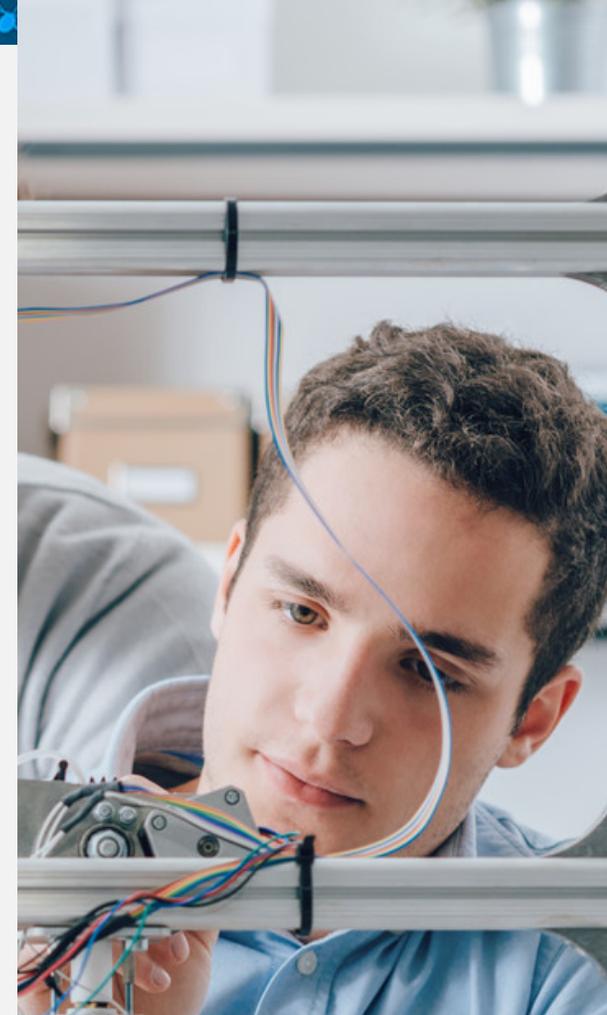
students to realistic multi-disciplinary problems is hard to replicate in a classroom, projects based on real-world challenges and problems create excellent opportunities for students to develop and practice the technical and soft skills required to succeed in their careers.

## Long-Term Projects

The scope of the projects is also critical. If it is too narrow, students won’t be challenged and will be less likely to develop the right skills. If it is too big, students will be overwhelmed.

While students can learn a lot during a semester-long project, the shorter time frame limits the opportunities. Long-term projects and competitions that last multiple years are closer to real-world engineering projects.

Some of the best lessons are those learned from mistakes, but only if there is enough time. With a long-term project, students can apply the lessons they learned. Also, the fear of failure often holds back innovation. If students have the freedom to experiment with trial and error, they can learn great lessons about innovating in a safe environment.



Offer students the most realistic experience possible by partnering with industry.



# Viewpoints on Projects



“

It is hard to develop teamwork skills over the course of a single semester. The best student teams exist over years. In this way, programs like the [Mars Rover Challenge](#), [Baja SAE](#), and [Solar Car Challenge](#) provide teams with invaluable teamwork skills. They extend from a student's first year to their senior year. Students learn how to work together, and older students can mentor the first years. Some projects even require teams to raise money and work within a budget, as they would in the real world.

”

## A. Harvey Bell, IV

Professor of Engineering Practice and Co-Director, Multidisciplinary Design  
**UNIVERSITY OF MICHIGAN**



“

A key aspect of experiential learning is project-based classroom assignments and student-run competitions. Students need to go beyond memorizing facts and understand concepts. They need to analyze complex problems and evaluate the merits of different solutions. For example, in the [Baja competition](#), students learn the importance of scheduling tasks, accurate drawings, machining tolerances, material variability, assembly challenges, and much more. They also develop critical communication and leadership skills that are hard to replicate in a lecture environment.

”

## Dr. John W. Weidner

Professor of Chemical Engineering  
of Engineering and Applied Sciences  
**UNIVERSITY OF CINCINNATI** Dean



“

We are strong believers in allowing students to fail, which is why we structure projects as year-long. When you are limited to a semester, but still have to hit learning outcomes, there isn't time to allow students to fail. Projects must also be multi-disciplinary so students learn critical skills and develop experience with systems integration.

”

## Gail Hohner

Director, Multidisciplinary Design  
**UNIVERSITY OF MICHIGAN**

## 2. Reshape the Curriculum



### **Restructure and Remove Content if Needed**

While project-based learning offers many opportunities, it also adds more material to the curriculum. To compensate, schools should reshape the curriculum and, in some cases, remove content that has become less relevant. This is a significant challenge as students still need a solid education in engineering fundamentals.

### **Evolve the Role of Professor**

With shifts in the curriculum, the role of the professor is changing. With less focus on lectures and defined problems with set answers, professors can spend more time mentoring and guiding students on their journey. With projects, students should have the authority to try out new ideas and figure out what will work, with the professor there for support. With a technology, such as Product Lifecycle Management (PLM), professors have visibility into student progress and can see how they defined requirements and the status of individual tasks so that the professor can provide feedback, much the way a manager would in industry.

Professors can also use their connections or take advantage of the school's relationships with industry and alumni to invite guest lecturers who can share their practical experience.

# Viewpoints on Curriculum



“

When we shifted to online, I was concerned about the effort for a 100- student class. However, with everything digitized on our learning platform, it has been effective to click on a student’s work and see what is ok, what isn’t, and if there are opportunities for the students to improve. I can give them specific feedback like, ‘everything looks good’ or ‘maybe think about this.’

”

## Prof. Dr. Andreas Deuter

Vice Dean - Production Engineering & Wood Technologies / Lab for Computer Science in Production

**OWL UNIVERSITY OF APPLIED SCIENCES AND ARTS**



“

For some of our programs at the University of Michigan, a faculty member meets with teams for two hours a week, and we offer mentoring. Industry project sponsors also meet with the team for an hour a week.

”

## Gail Hohner

Director, Multidisciplinary Design  
**UNIVERSITY OF MICHIGAN**



“

Rather than individual subjects that follow the traditional 3-4 credit class structure, we do five different projects that involve several subjects that are ten-credit-hour classes. These courses focus on real-world problems. We have a common engineering program during the first year where students learn coding, elements of robotics, engineering design concepts, and project skills like communication. Instructors are more like guides on the side as mentoring is required for learning.

”

## Dr. Ishwar K. Puri

Dean of Engineering  
**McMASTER UNIVERSITY**



“

All engineering students need to understand the laws of physics. What undergraduate students do not need is physics at the molecular level. Undergraduate students also do not need calculus. These topics are only useful at the graduate level for students going into research. Schools should not waste student's time on things they will not use. Hands-on, real-world type classes are more relevant.

”

**Rick Hartley**

Sr. Principal Engineer  
**RHARTLEY ENTERPRISES**



“

Technology develops at an exponential rate. We cannot add more time to get a degree, but it is hard to take anything out. We try to be more efficient with a blended curriculum.

”

**Dr.-Ing. Detlef Gerhard**

Digital Engineering Chair / Mechanical Engineering  
**RUHR-UNIVERSITY BOCHUM**



“

We have added a lot of new courses about new technology, especially digitalization. Because digital technology is so important, we should teach some traditional classes less so that we can use that time for new courses. For some courses, I suggest listing the software skills needed to take the class so that students can identify what they should learn on their own.

”

**Dr. Chen Ming**

Director of Industry 4.0 Learning Factory  
**TONGJI UNIVERSITY**

# 3. Leverage Software

## Use Software to Solve Problems

Software plays an incredibly critical role in today's engineering work. As mentioned earlier, previous Tech-Clarity research found that industry would like students to be better prepared to apply technology to solve problems. Using software during real-world projects is an excellent way to help students develop those skills.

## Focus on Upfront Processes

While the COVID-19 pandemic has limited physical lab experiments, it has created opportunities to focus on other aspects of design that require practical applications of software. For example, student teams can spend more time on upfront design tasks, embracing digitalization from the beginning. They can focus on requirements management, developing concepts, innovating and exploring new ideas, and optimizing the design. The right software tools will enable this.

## Consider Virtual Labs

Bill Oakes of Purdue recommends overcoming restrictions with physical labs by leveraging virtual labs instead. Students can use simulation to test designs; much the same way design engineers test in the real world.<sup>16</sup> In this way, students can learn the

value of spending more time upfront, early in the design cycle, getting the design right. They can experience the benefit of identifying problems early on and learning how to troubleshoot them in a virtual environment to avoid later downstream problems. All of this work exposes students to activities design engineers may be involved in during their careers.

## Use What Professionals Use

However, to be successful, students need professional software tools that offer full capabilities. Partnerships with software vendors will help, especially if the vendor provides learning resources to educate students on the software concepts to complement the professor's lessons. This gives students the background to help them apply their learning to their projects. Further, students, and their future employers, benefit if the software vendor provides commercial software training at no additional cost to students.



COVID-19 has created opportunities for students to spend more time on upfront design tasks such as requirements management, developing concepts, innovating and exploring new ideas, and optimizing the design.



# Viewpoints on Software



“

To prepare for the real world, students need the industrial version of the software, not a watered-down academic version. To learn how to apply the technology to solve problems, it should be the complete tool. If it is a cloud solution, you don't even need to worry about IT maintenance.

”

## A. Harvey Bell, IV

Professor of Engineering Practice and  
Co-Director, Multidisciplinary Design  
**UNIVERSITY OF MICHIGAN**



“

We use different packages to introduce students to what is possible. With PLM software, for instance, you want to give students a view of a platform, but make sure they understand the concepts so they can adapt to other platforms. The goal is to make sure they're using the software to solve problems.

”

## Dr. Ishwar K. Puri

Dean of Engineering  
**McMASTER UNIVERSITY**



“

We teach best practices for setting up models. Then we leave it up to students to learn more advanced functions by viewing videos provided by vendors or online training courses. We find this works well.

”

## Dr.-Ing. Detlef Gerhard

Digital Engineering Chair / Mechanical  
Engineering  
**RUHR-UNIVERSITY BOCHUM**

## 4. Enhance Learning with Digital Twins

### Bridge to Online Learning

Students learn best by doing. Consequently, lab experiences can significantly enhance the learning process, but experimentation is limited by the lab's hardware. However, with a digital twin, students can extend that learning.

### Digital Twin Definition

Definitions for a digital twin can vary. From an innovation perspective, Tech-Clarity defines a digital twin as a virtual model of a physical item. The most mature digital twin is connected to the physical item. The model represents a specific product, configuration, piece of equipment, plant, city, or other physical asset, with enough fidelity to predict, validate, and optimize performance and behavior. Digital twins are a key aspect of digitalization.

Digital twins, at the core, rely on a digital product model. A digital model defines a product in a way that can be interpreted programmatically and leveraged beyond the design tool that initially created it. It documents product designs and frees up the

information to be shared with other people, processes, and software applications to communicate better, collaborate, and coordinate designs across the organization and supply chain.

### Experience Greater Flexibility

By using a digital twin, students can see the impact of their changes in less time. Consequently, they can try out more ideas than would not be possible when working on physical equipment, advancing their learning even further. Digital twins can also reduce the lab budget since fewer physical components are needed.

Digital twins are another area schools have been slow to adopt, but when the COVID-19 pandemic made it impossible to conduct tests in physical labs, some professors experimented with digital twins and were surprised by the value.



A digital twin as a virtual model of a physical item. The model represents a specific product, configuration, piece of equipment, plant, city, or other physical asset, with enough fidelity to predict, validate, and optimize performance and behavior. Digital twins are a key aspect of digitalization.

# Viewpoints on Digital Twins



Students should know what a digital twin is. Part of my course involves working with a so-called SmartLight. During the pandemic, it wasn't possible to use a physical SmartLight, so we created a digital twin using our software platform instead. We found that we had a lot more flexibility. Previously, students were limited by the physical SmartLight. With the digital twin, they could make the SmartLight smaller or bigger or change how it moved, allowing them to explore a lot more options. Going forward, I will use digital twins more.



## Prof. Dr. Andreas Deuter

Vice Dean - Production Engineering & Wood Technologies / Lab for Computer Science in Production

**OWL UNIVERSITY OF APPLIED SCIENCES AND ARTS**



In our lab, if we relied on physical robots, due to the expense, the whole class would have to share one or two. However, by using a digital twin of the robot, students can experiment with their own robot. We can also easily change the robot to extend the learning experience further.



## Dr. Chen Ming

Director of Industry 4.0 Learning Factory  
**TONGJI UNIVERSITY**



# 5. Enrich Learning with Technology

## Personalize Teaching

Beyond teaching about technology, technology can also help professors provide students with a more personalized learning experience. When forced to rely more on technology during the pandemic, many professors found that it forced them to change how they teach. While it did limit interpersonal connections, for some, it revealed pleasant surprises that will improve their teaching in the future.

In a digital environment, Professors can also check on students in real-time and offer guidance as students progress, rather than waiting until the end when the assignment is complete. The quality of the learning will be higher and students should be less concerned they are wasting tuition money on material they could learn on YouTube.

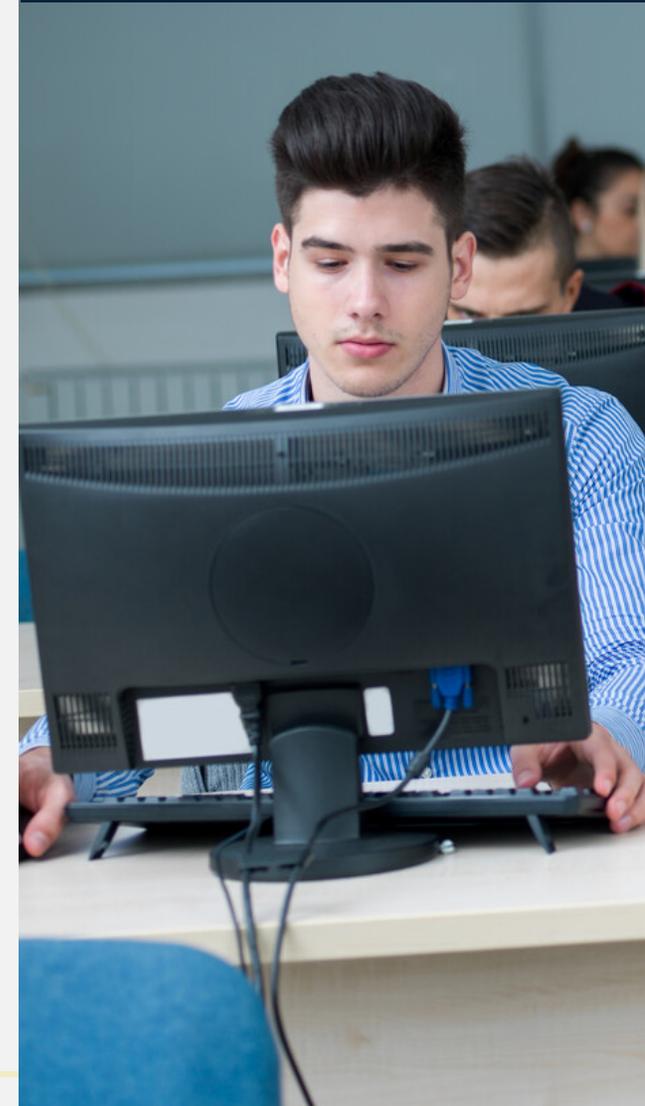
Today's students are digital natives. They are resourceful and grew up in a culture that relies on social media and expects feedback. This level of high-touch feedback adapts to the culture they are comfortable with.

## Use Technology to Teach Technology

A software vendor can enable this with an engineering platform that allows collaboration between professors and students. In fact, some universities use a Product Lifecycle Management (PLM) platform as a learning management system, which not only supports the curriculum, but also supports a realistic way for students to work. To ensure adoption, software vendors should also offer excellent support for students and professors so that they are comfortable with the platform.

Technology can also support a learner's journey with online courses or Massive Open Online Courses (MOOCs). This can support a hybrid approach between instructor-led courses and autodidactic learning. These courses can be especially valuable when students need to use software to complete a course, but there is not enough time to cover it during class.

In a digital environment, technology can enrich learning for students and teaching for educators.



# Viewpoints on Learning with Technology



“

Our efforts due to COVID-19 have elucidated how online enrichment materials can be developed rapidly and economically. Now that we have developed these modules, future students' learning, whether online or in physical classrooms, will be improved through blended learning. We have also learned how to engage students and ensure that they learn through shorter modules than the traditional long-form classroom lecture.

”

**Dr. Ishwar K. Puri**  
Dean of Engineering  
**McMASTER UNIVERSITY**



“

The pandemic has forced me to use a digital platform to support my classes. For me, as a teacher, I feel it has improved the learning experience. I get a much better idea of each student's progress. During a traditional class, you can walk around and get a limited impression of what students are doing. With the platform, I sit on my PC at home, check all their tasks, and get a much better impression of what each student understands. Then I can spend time in personal sessions with them. It is much better and I will incorporate many aspects of this approach into my future courses.

”

**Prof. Dr. Andreas Deuter**  
Vice Dean - Production Engineering & Wood Technologies / Lab for Computer Science in Production  
**OWL UNIVERSITY OF APPLIED SCIENCES AND ARTS**

## 6. Develop Collaboration Skills



The ability to collaborate using a single model, regardless of where team members are, is a skill students need today and in the future.



### Teamwork is Critical

While technical skills are critical, it is often soft skills that improve student success. These transferable skills can become invaluable throughout a student's career, no matter which path he or she takes. In fact, in many ways, they are even more valuable than technical skills since students will rely on these skills throughout their careers, while technical skills can become obsolete.

### Practice Local and Remote Collaboration

In industry, engineering teams will often consist of both local and remote team members, so students should be comfortable with multiple communication methods. During interviews, many professors discussed the challenges that COVID-19 created because remote learning made it harder to read body language and other non-verbal cues. This is also an important lesson for students.

Today's students already tend to be very adept at online communication, and with so much business conducted via email, this is a valuable skill. However, teamwork requires different styles of communication, verbal and written, and students should practice them. They should be comfortable adjusting their communication method based on the situation. Students should also understand how to use the proper tone, especially based on their audience, whether it is a team member, client, or professor.

### Complement Communication with Technology

The pandemic and remote learning forced students to stretch their communication skills in different ways, which should help them during their careers. Complementing this with the right technology and the ability to collaborate using a single model, regardless of where team members are, is a skill students need today and in the future. They can learn this now by using a comprehensive engineering software platform to support their work.

# Viewpoints on Collaboration



“

When a project fails, it's rarely because their analysis was wrong. It's because their team didn't gel. They couldn't manage themselves professionally, or they couldn't write clearly or express their ideas well. They fail on non-technical things.

”

## Gail Hohner

Director, Multidisciplinary Design  
**UNIVERSITY OF MICHIGAN**



“

Team projects develop competencies like leadership, teamwork, and communication skills. Communication skills should cover both verbal and written. Students are required to do write-ups on their projects, and they also must develop three-minute pitches.

”

## Dr. Ishwar K. Puri

Dean of Engineering  
**McMASTER UNIVERSITY**



“

No one gets fired because they didn't do an analysis. They get fired because they can't play with others. Coming out of high school, students haven't participated in a creative engineering process. Students need to learn to disagree respectfully while working in a creative environment. The best teams argue, but they are still good friends. Learning how to navigate disagreements is extremely important. Many student leaders feel that to be a leader, they need to carry all the rocks and absorb the pressure themselves, so they don't delegate. Then they realize this doesn't work, and they need an organizational structure.

”

## A. Harvey Bell, IV

Professor of Engineering Practice and  
Co-Director, Multidisciplinary Design  
**UNIVERSITY OF MICHIGAN**

## 7. Prepare for Cross-Functional Horizontal Teams

### Other Soft Skills Needed for Success

Innovation does not work in a vacuum. Engineers must be able to work with others, recognizing what they are good at and when they need to rely on others. They also need to be able to sell their ideas to team members as well as those outside engineering, including management and those in less technical roles. This is especially critical for entrepreneurs who need to put ideas into a business context to solicit funding. These soft skills are some of the most important to develop.

However, they are difficult to develop when sitting in a lecture. On the other hand, working in project teams will help students develop these skills.

### Prepare for Horizontal Organizations

Also, trends toward horizontal leadership will increase the need to work with various groups and skillsets. Not only should engineers have experience working with other engineers, but they should also be prepared to interact with manufacturing, marketing, procurement, the supply chain, and business executives. Engineers who are comfortable in this environment will have the foundation to become successful leaders.



Not only should engineers have experience working with other engineers, but they should also be prepared to interact with manufacturing, marketing, procurement, the supply chain, and business executives.

# Viewpoints on Cross-Functional Teams



“

One of the biggest learning challenges for multi-disciplinary teams is developing a comfort level with trusting information from others. It is very destabilizing for someone when they have to work with a team member from a different discipline and they do not personally have the expertise to know if that person did the right thing.

”

## Gail Hohner

Director, Multidisciplinary Design  
UNIVERSITY OF MICHIGAN



“

Engineers develop a sense of responsibility when they get involved with project teams. They learn how to work something out. Feedback on the project also helps them learn. They develop a range of skills such as teamwork, communication, project management, presentation skills, time management, and stress management.

”

## Antonia Nănău

Former President / 2020 Graduate  
**BOARD OF EUROPEAN STUDENTS  
OF TECHNOLOGY**



“

Engineering is a complicated profession that involves interacting with customers, regulators, suppliers, marketing, technicians, entrepreneurs, financial experts, and many others. An effective engineer does not have to be an expert in all these areas, nor could they, but they need to understand, appreciate, and lead diverse teams to accomplish a common goal. Our students practice this in the classroom, and apply it during their student competitions and co-op rotations.

”

## Dr. John W. Weidner

Professor of Chemical Engineering  
Dean of Engineering and Applied Sciences  
**UNIVERSITY OF CINCINNATI**

## 8. Build Resumes and Offer Career Insight



Industry certifications and Excellence Awards prove that students have mastered specific skills can also be a great way to boost a resume.

### **Provide Resume Experiences**

Real-world projects benefit students in many ways, helping them develop both technical and soft skills. Students can then build resumes about their practical experiences in ways that are more powerful than just listing classes they've completed. Their resumes can also include transferable skills that employers look for.

### **Help Students Figure Out Their Interests**

Real-world experiences, either through projects or internships, also provide students with valuable insights about their interests that will allow them to make better career decisions. For some, who are limited by travel, virtual internships offer an excellent opportunity for practical experience that can go on a resume.

### **Gain Credibility with Industry Certifications**

Industry certifications and Excellence Awards prove that students have mastered specific skills can also be a great way to boost a resume. This is especially true for newer technologies such as Machine Learning, Artificial Intelligence, and Additive Manufacturing.

# Viewpoints on Building a Resume



“

By participating in projects and competitions, students can build a portfolio of work they did in. This can even include how they have used software to solve problems. They can leverage this experience to sell themselves to future employers.

”

## A. Harvey Bell, IV

Professor of Engineering Practice and  
Co-Director, Multidisciplinary Design  
**UNIVERSITY OF MICHIGAN**



“

In some cases, industry certifications can help schools address gaps, especially in cutting edge technologies that industry is looking for, but have not been around long enough to become a formalized part of the curriculum.

”

## Dr. Chen Ming

Director of Industry 4.0 Learning  
Factory  
**TONGJI UNIVERSITY**



“

There is a lot of value in technology certifications, as all technologies are dynamic in nature and can't be taught through the regular curriculum. Certifications for niche technologies will make them more pertinent to industry, which will benefit students during industry hiring. Certifications in niche technologies will certainly assist in hiring decisions.

”

## Professor

Dean of Industry  
**TECHNOLOGY INSTITUTE IN INDIA**



“

We have been working to formulate and offer virtual internships, for instance: [www.gedc-virtual-internships.org](http://www.gedc-virtual-internships.org), which has been especially relevant during the COVID-19 pandemic.

”

### **Dr. Şirin Tekinay**

Dean, College of Engineering  
**AMERICAN UNIVERSITY OF SHARJAH** / Chair, **GEDC**



“

I think it is a great idea for colleges to offer certification opportunities to students. My experience has been that companies love to know what they are getting when they hire someone right out of school. Certifications tell prospective employers a great deal about an individual.

”

### **Rick Hartley**

Sr. Principal Engineer  
**RHARTLEY ENTERPRISES**



“

Programs that offer real-world experiences can help students identify what they want to do in their career, and what they don't want to do. Working closely with industry, they can also determine the type of corporate culture they like or don't like. The exposure can help them decide if they prefer a large or small company before they've even formally entered the workforce.

”

### **Gail Hohner**

Director, Multidisciplinary Design  
**UNIVERSITY OF MICHIGAN**

## 9. Partner with Industry for Technology Thought Leadership

### Technology Moves Fast

The pace of technology moves so fast; it is hard for schools to keep up. Plus, it is hard for schools to know how technology will be applied. Yet, industry expects students to have an understanding of new technology. While professors agree on the importance of these technologies, many schools have not yet adapted their curriculums to use them.

To overcome this, schools should partner with industry thought leaders to support educating students on new technology. This way, professors stay focused on their area of expertise while leveraging the knowledge of those more directly involved with the technology. This is especially true for new and evolving technologies such as artificial intelligence (AI), machine learning (ML), augmented and virtual reality (AR/VR), and additive manufacturing. Good partners will have a vision for how the technology will be used in industry, how engineers should leverage it, and can explain why it is important. Together educators and industry experts can also collaborate on curriculum development.

### Artificial Intelligence

ML and AI are important aspects of digitalization that will likely augment future

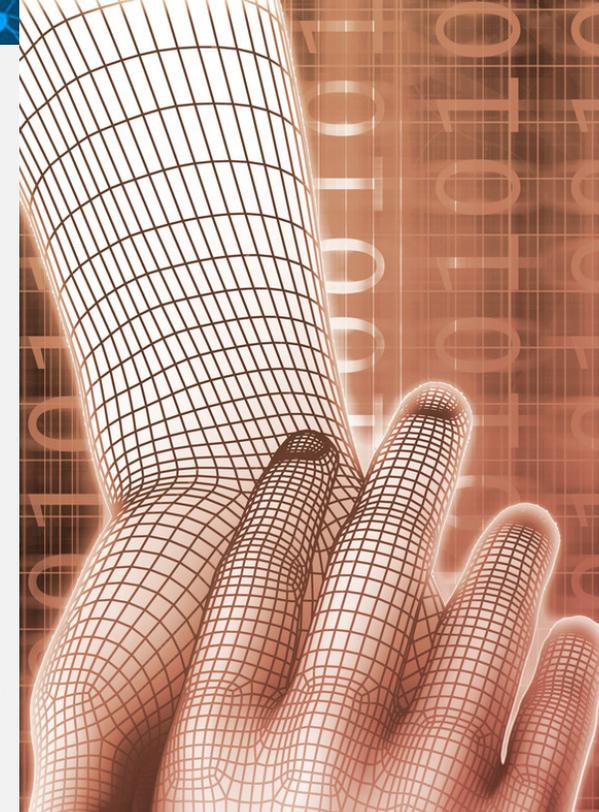
engineering work. These technologies are already used to automate tedious workflows and to support engineering decisions. New uses continue to grow, so students will benefit from the exposure to the technology.

### Augmented and Virtual Reality

AR/VR can provide real-life experiences to make a lesson more memorable so that it sticks. During a time when travel is limited, these technologies can help bring experiences to students. While visiting an overseas production environment may not be possible, even during normal times, with AR/VR, students can see a realistic view of how the concepts they are learning about work. Imagine the impression of “using” a CNC milling machine in the classroom, as students learn about the science behind machining. Professionally, AR and VR are already used as training aids, as well as to assist technicians during production and service and applications will likely grow.

### Additive Manufacturing

Tech-Clarity research finds that 89% of Top Performing companies will look at new ways to design to take advantage of 3D printing.<sup>17</sup> This will be an important technology for students to understand as it will have a fundamental impact on the future of design.



By partnering with industry thought leaders, professors stay focused on their area of expertise while leveraging the knowledge of those more directly involved with the technology.

# Viewpoints on Technology and Industry Partnerships



“

It is not easy to balance industry requirements, which constantly change, with the less flexible university educational system, while ensuring students graduate in four to six years. The best way to close the gaps is for companies to become active in research projects and participate in university lectures to share their specialized knowledge.

”

## **Dr.-Ing. Dieter Krause**

Professor of Product Development and Mechanical Engineering Design  
**HAMBURG UNIVERSITY OF TECHNOLOGY**



“

Machine learning and artificial intelligence will change the nature of students' jobs, but design engineering jobs will never go to robots. Students need to learn how to apply technology to design human-centric, need-based solutions. Technology will take care of repetitive tasks. As it evolves, the way we teach technology must also evolve. From the COV-19 pandemic, we know technological underpinnings need to transcend 2-dimensional interaction, so we are migrating to augmented, or virtual reality.

”

## **Dr. Şirin Tekinay**

Dean, College of Engineering  
**AMERICAN UNIVERSITY OF SHARJAH**  
Chair, **GLOBAL ENGINEERING DEANS COUNCIL**



“

Academia is slow to adapt to new technologies while industry is very fast. A company can mentor students in a competition to develop skills and close gaps. This way, students are more familiar with the technology the company uses so they will be more productive when they start working.

”

## **Antonia Nănău**

Former President / 2020 Graduate  
**BOARD OF EUROPEAN STUDENTS OF TECHNOLOGY**



“

To support software training, we hold workshops run by an industry partner. Students can show up for a hands-on training session. Students leave with at least the problem set up. Our partners send us their very best trainers. Our students respond better to a human being rather than help files. An alternative is to refer them to targeted videos of software classes.

”

**Gail Hohner**

Director, Multidisciplinary Design  
**UNIVERSITY OF MICHIGAN**



“

Universities are not yet geared up to cater to the requirements of Industry 4.0 challenges ahead and I predict the skill gap will only broaden. Industry partnerships are the only way to fill the gap. Rigorous, meaningful, and mutually trustworthy partnerships/ collaborations between industry and institutes are among the best ways to cater to the dynamic industry requirements.

”

**Professor**

Dean of Industry  
**A TECHNOLOGY INSTITUTE IN  
INDIA**



“

To integrate technology into the curriculum to teach students how to apply it to solve problems, professors should partner with an appropriate technology thought leader. For example, I know very little about Artificial Intelligence, but I do know the major. With a partner, together, we could offer a hybrid class where I teach the concepts supporting the major, and an AI expert could explain the technology. Students should start working with new technology and software as early as possible in their education so they can be used in later courses to solve problems.

”

**Dr. Chen Ming**

Director of Industry 4.0 Learning Factory  
**TONGJI UNIVERSITY**

# Conclusions

## Develop Students that Are in Demand

By adopting a project-based learning curriculum, schools can help students develop the practical skills industry is looking for when they make hiring decisions. Projects should be long-term and involve multiple engineering disciplines. They should also give students experience solving real-world problems and provide opportunities to leverage software to solve those problems. Virtual labs, digital twins, and simulation software all play an important role in problem solving and engineering decisions.

## Foster Soft Skills Too

Students should also have experience collaborating with engineers as well as groups outside of engineering such as manufacturing, finance, and marketing. This will give them experience to help them become successful horizontal leaders.

## Use Technology to Support Learning

Beyond learning how to use software to solve problems, engineering technology such as PLM bring the real-world into the classroom and help manage classroom projects and tasks, while giving professors visibility into exactly what each student is doing.

## Partner with Industry Thought Leaders to Stay Current

Technology moves at such a fast pace, it is nearly impossible for academia to keep up and adapt, yet industry wants students to be familiar with the latest technology. This is where industry partners can provide invaluable thought leadership. By getting involved in curriculum development, they can complement the expertise of the professor, while adding industry insight on the latest technologies. Further, industry certifications and awards from partners can provide future employers with validation that students are familiar with the latest technologies.



# Recommendations



## Recommendations and Next Steps

Based on this research and our experience, Tech-Clarity offers the following recommendations:

- Restructure academic programs to maximize project-based learning opportunities. This can be done as part of the regular curriculum or as extracurricular activities.
- Recognize the numerous benefits of project-based learning for both students and industry. Design programs to ensure that participants realize these benefits.
- Involve industry to provide real-world problems as well as mentorships and internships to ensure students have the opportunity to learn from their experiences and expertise.
- Projects need to develop problem-solving and collaboration skills, while exposing engineers to multi-discipline work
- Reshape the curriculum and remove content that is less valuable for today's engineers.
- Leverage industry-developed curriculum and content to improve learning and take advantage of the latest technological developments and thought leadership. Use technology to teach technology.
- Make software an essential part of projects to develop the skills students need to apply technology to solve problems.
- Integrate industry trends such as digitalization, machine learning, and artificial intelligence to expose students to the technologies that will impact how they design products.
- Bring in industry thought leaders and subject matter experts into the classroom.

# Acknowledgments



## Michelle Boucher

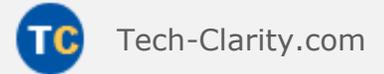
Vice President  
Tech-Clarity

### About the Author

Michelle Boucher is the Vice President of Research for Engineering Software for research firm Tech-Clarity. Michelle has spent over 20 years in various roles in engineering, marketing, management, and as an analyst.

Michelle graduated magna cum laude with an MBA from Babson College and earned a BS in Mechanical Engineering, with distinction, from Worcester Polytechnic Institute. She is an experienced researcher and author having benchmarked over 7000 product development professionals and published over 90 reports on product development best practices.

**Tech-Clarity** is an independent research firm dedicated to making the business value of technology clear. We analyze how companies improve innovation, product development, design, engineering, manufacturing, and service performance through the use of digital transformation, best practices, software technology, industrial automation, and IT services.



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