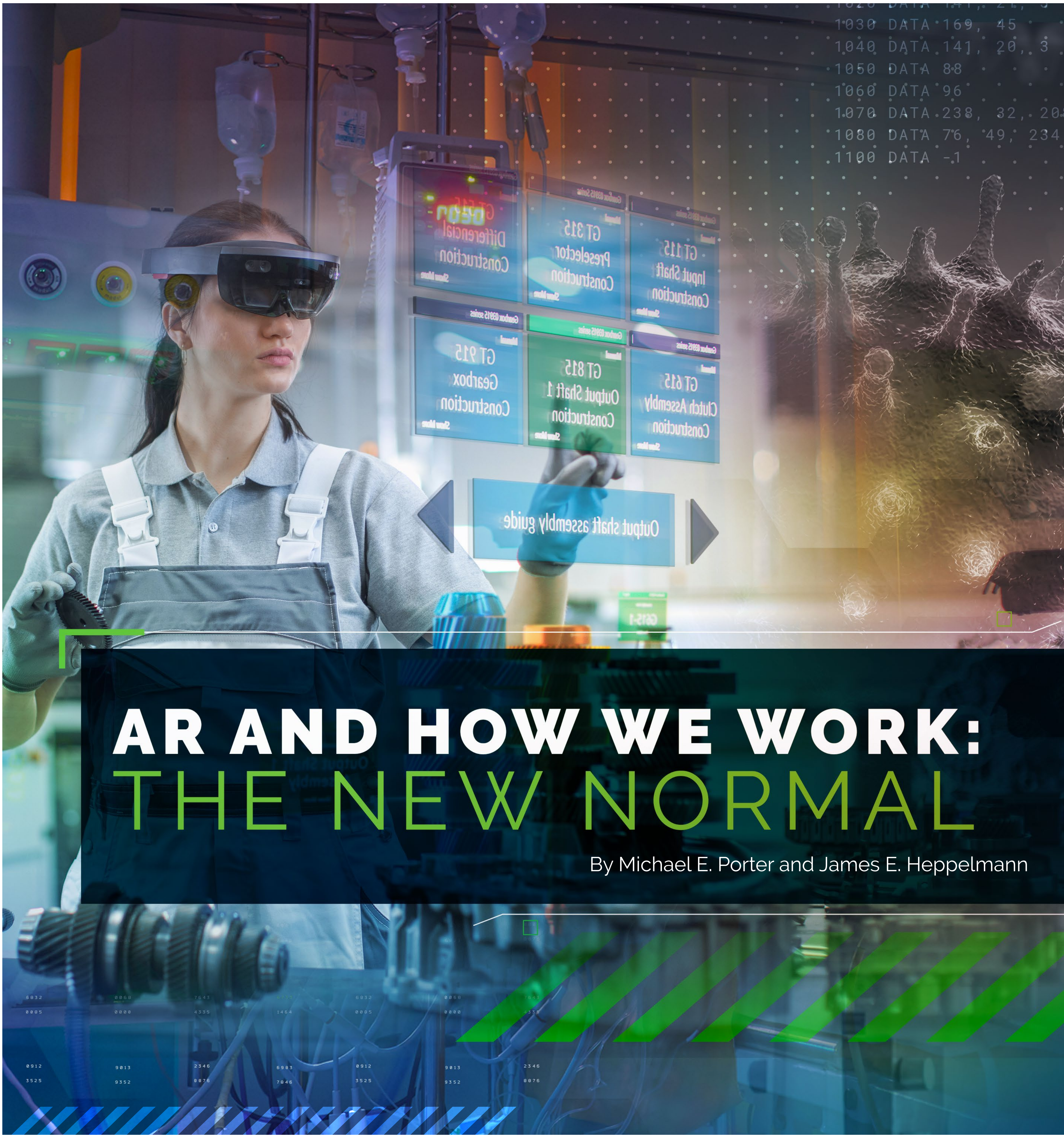
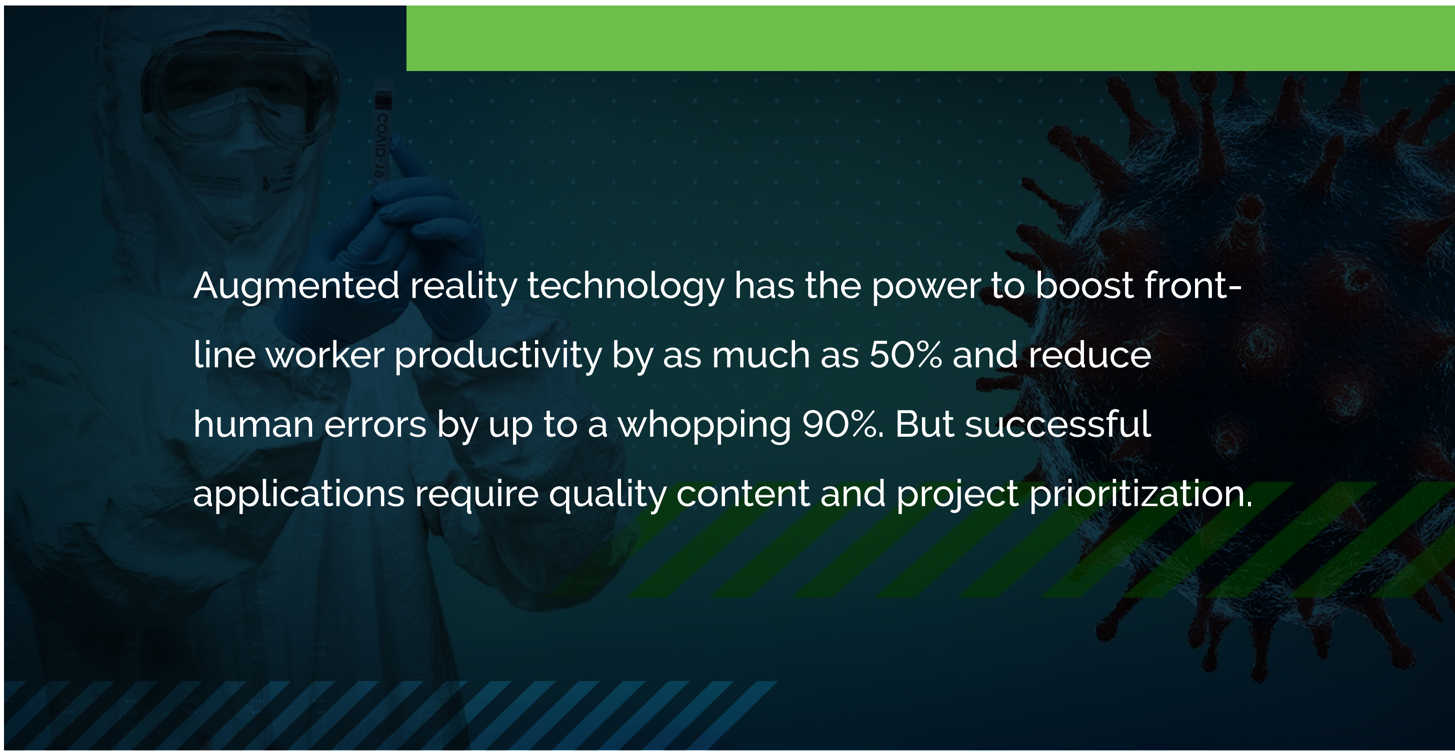
WHITE PAPER



AR AND HOW WE WORK: THE NEW NORMAL

By Michael E. Porter and James E. Heppelmann

MANUFACTURING LEADERSHIP COUNCIL
NATIONAL ASSOCIATION OF MANUFACTURERS



Augmented reality technology has the power to boost front-line worker productivity by as much as 50% and reduce human errors by up to a whopping 90%. But successful applications require quality content and project prioritization.

The coronavirus crisis of 2020 is changing the way we work, perhaps forever. Travel bans, lockdowns, and social distancing policies disrupted business around the world, forcing companies to find new ways to work. The trend toward a more distributed, mobile, and agile workforce was already unmistakable, but the crisis has dramatically accelerated this shift for workers who can thrive in the virtual world. But perhaps the bigger news coming out of the crisis is that the larger front-line workforce operating in the physical world participated for the first time in digital transformation in a meaningful way.

Knowledge workers in roles such as management, finance, marketing, scheduling, or product development trade in information that is readily captured in digital files and databases. Their work is easily exchanged via emails. Virtual meetings to collaborate with peers around the globe are a few clicks away. Where the work is digital, worker location doesn't really matter. So when knowledge workers around the globe were forced into a massive work-from-home experiment with almost no planning, the results proved better than we ever thought possible. Not only did productive work continue, but additional time and cost savings were realized from reduced commuting and business travel.

These compelling results make it clear that the work-from-home Genie probably won't go back into the bottle, even when the crisis passes. For knowledge workers, this way of working will become part of the "new normal" because of its inherent advantages. But what about front-line workers?

The Difference With Front Line Work

Not all workers spend their day behind a desk using IT tools to engage the virtual world on their computers. Approximately 75% of the global workforce consists of front-line workers, whose job is done out in the real world beyond the office, and involves physical work.

> AR enables front-line worker solutions that parallel the well-established digital technologies that came to the rescue for knowledge workers.

While knowledge workers transitioned easily to work-from-home, the larger force of front-line workers cannot do their work from home. In fields like retail and hospitality, many were furloughed because their businesses were closed, sometimes by mandate. But work at factories, farms, repair shops, distribution centers, and other types of physical worksites was deemed essential to the economy. The Brookings Institution estimates that between 49 and 62 million front-line workers in the US alone were asked to continue reporting to work.

Front-line workers need knowledge too in order to do their work. But rather than electronic files and video calls, it traditionally comes in the form of paper documentation, training classes, over-the-shoulder mentoring, and face-to-face troubleshooting. None of these modalities work that well in the best of circumstances. But they have been seriously impaired in the era of many working at home, travel bans, and social distancing. In addition to potential exposure to health risks, the coronavirus exacerbated an already serious problem for many companies, which is an increasing shortage of trained front-line workers.

Bringing Digital Technology to the Front Line

Office productivity tools like Microsoft Office help knowledge workers capture and share information, and videoconferencing tools like Zoom or WebEx work great for collaboration when there is a knowledge worker using a computer on each end of the information exchange. But how do you facilitate collaborate between an expert knowledge worker such as a manufacturing engineer and a front-line worker such as an assembly worker out in the factory? This traditionally involved the engineer travelling to the factory, but suddenly that was not possible. Also, how do you facilitate collaboration between two front-line workers where one is a veteran technician who needs to explain a laboratory process to a new-hire technician? This used to involve mentoring or "job shadowing", but social distancing makes that difficult.

The answer to how to enable collaboration and knowledge transfer with front-line workers is augmented reality (AR), a digital communication technology that can support and significantly enhance the productivity of physical work throughout the economy. We have discussed the concept and impact of AR technologies in our earlier Harvard Business Review article titled "A Manager's Guide to Augmented Reality". In the simplest terms, AR allows relevant and actual digital information to be transmitted and displayed in context in the physical world. This creates a powerful force for productivity improvement in a series of areas.

AR: Zoom for Front-Line Workers

AR enables front-line worker solutions that parallel the well-established digital technologies that came to the rescue for knowledge workers. Instead of a Zoom video conferencing call, however, AR technology allows remote experts to see the physical world in video and annotate physical objects during the call. Rather than publishing a PDF document or a Web page, AR can map instructional content directly onto the 3D physical environment in which work will take place. Instead of a YouTube how-to video on a computer screen, AR offers a solution that captures the best front-line expert performing a task with a wearable device that captures every step, and creates an interactive and step-by-step guide mapped onto the work environment for other workers to follow using a wearable device.

The critical difference in each AR solution is its power to deliver needed digital content and expert guidance into the context of the physical environment, where front-line work is done. This substantially reduces the cognitive distance getting in the way of the worker translating the information from digital to the real world, increasing worker productivity and reducing errors.1

Expert Collaboration and Remote Support

AR is a powerful real-time collaboration tool between a remote expert and the front-line worker who needs input. The front-line worker can use an AR app on a standard mobile phone or tablet to request help from an expert at another work site, at a corporate office, or even at home. The remote expert can see, and digitally annotate, the on-site worker's physical work environment using their finger or a mouse, with those annotations remaining attached to the physical objects involved even as the worker moves.

AR does for front-line workers what video conferencing does for knowledge workers – it allows expertise to be shared electronically. But unlike video conferencing, which is solely digital and on flat screens, AR has one foot in the digital world and the other foot in the physical world – effectively serving as a bridge between them. This application of AR is akin to sportscaster John Madden's famous "chalk talks," where he diagrammed an NFL football play on the TV screen for viewers. With AR, a real-time chalk talk by an expert is overlaid onto a remote work environment.

//AR MARKUPS OVERLAID ON A VIDEO CALL.

This factory worker is being guided through a machinery troubleshooting process using AR markups by a remote expert overlaid on the worker's physical objects and environment during a video call.

The use of AR technology for collaboration and remote support of front-line workers has soared, enabling experts to be much more productive in helping to debug problems and resolve production issues remotely. For example, the use of AR video calls has allowed Toyota to save time and money by helping experts eliminate an average of four trips per month to production plants, because they can now oversee plant modification tasks and monitor local worker safety remotely. Using an AR-powered tool, employees and subcontractors are able to tackle complex or unfamiliar challenges with the help of an expert where and when they need it.

> "AR has allowed Toyota to save time and money by helping experts eliminate an average of four trips per month to production plants."

Worker Training and Learning

AR is also a breakthrough technology for training front-line workers, and enables next-generation instructional content such as training materials and step-by-step or standard operating procedures (SOP) for work. AR can deliver pre-prepared training content (and avoid real-time collaboration and remote support) mapping the content directly onto the 3D physical environment in which the work will take place. This results in a step-function improvement in comprehension and retention versus traditional PDF or Web-based documents that explain procedures on pages and via text in a more abstract 2D form. AR creates a 3D web, where instructional content is delivered via a 3D experience that mirrors an object or workspace, rather than on the traditional flat web page.

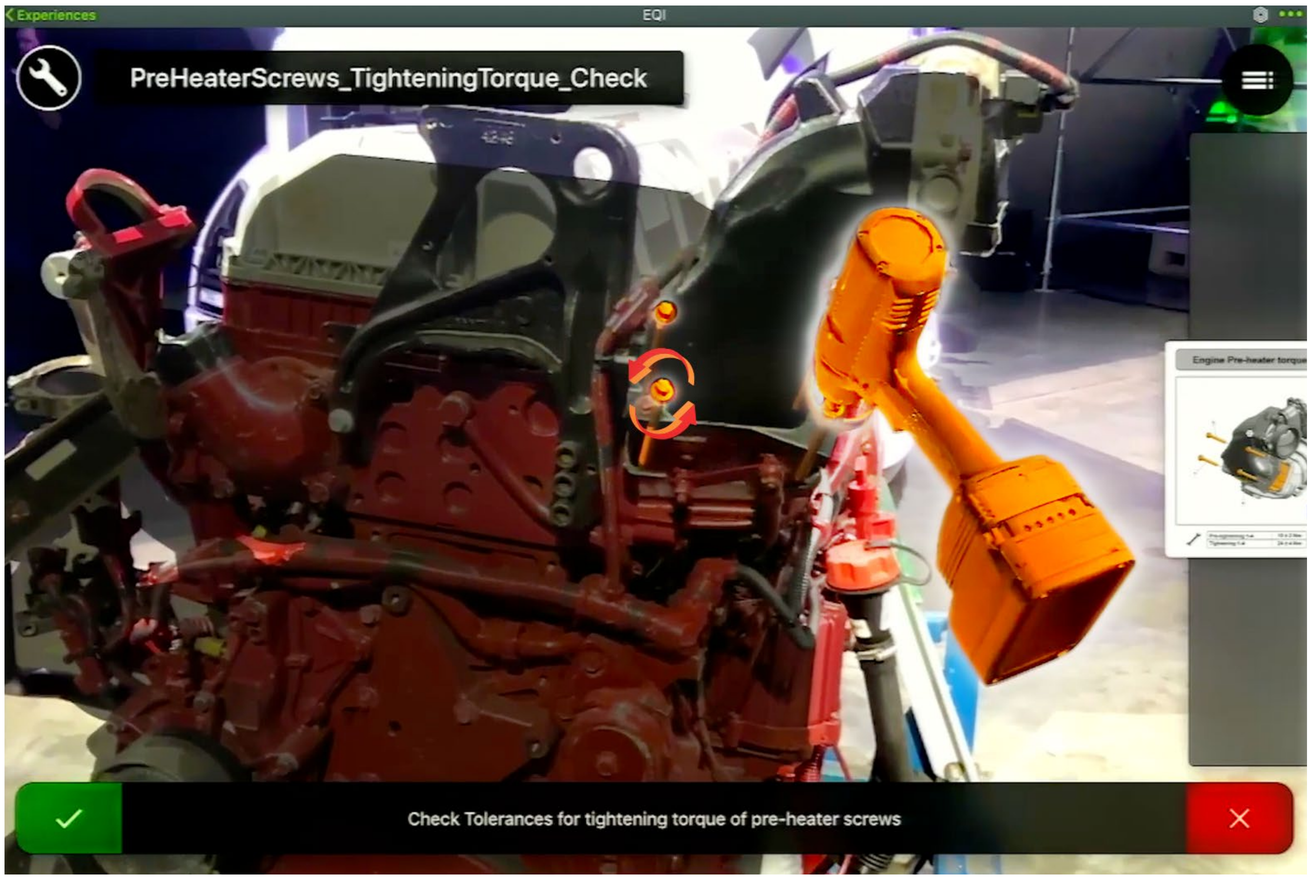
Industrial machinery in the physical world is decorated with an AR digital display showing status and key operating parameters of oil system, gearbox, air system, and main motor.

To access the instructions, a front-line worker launches a web browser app on smart glasses, a smart phone, or a tablet. AI-based computer vision technology identifies the real-world objects or workspaces using the AR device's video camera, and delivers the relevant content to the front-line worker onto the appropriate object or workspace in the worker's physical environment. The AR device can see the real world the way the worker does, while projecting digital information onto that world to guide a worker in performing a certain task, like a repair procedure.

A striking example is Volvo's implementation of AR work instructions to dramatically improve the productivity and accuracy of final quality checks on newly manufactured engines. The AR application provides visual guidance on where the Quality Assurance inspector should stand relative to the engine, what part of the engine she should look at first and next, and so on. The AR app shows what the inspector should expect to see to compare it to the actual parts. This is repeated for each step in the quality control process, capturing records of any non-conformances. This example also illustrates the major productivity impact of AR. The training time of Volvo QA inspectors has been reduced by 60%, or about three weeks per inspector. By decorating physical objects and locations with digital information in the actual work environment, the cognitive distance problem that stands in the way of all training—trying to absorb information in abstract 2D paper form and translate it to the real world—is avoided. AR is rapidly emerging as a powerful tool for accelerating how front-line workers learn, and conduct their work at substantially higher productivity.

> "Volvo's implementation of AR work instructions has reduced the training time for QA inspectors by 60%."

A worker is also guided to where the next procedure in the quality control sequence should best take place relative to the engine and where to hold the tablet, while their attention is drawn to use a tool to confirm the proper torque has been applied to these critical fasteners.



Capturing and Optimizing Human Work

In addition to enabling collaboration, training, and mentoring across distance and time, AR technology solves two other important problems many companies face with front-line workers. First, how to capture the deep expertise of retiring workers as they depart, or to take advantage of workers who are unable to travel. Second, how to enable all workers to perform a given process in the same way as the best, most experienced worker. As best practices evolve, AR can digitize process improvement and disseminate it to all workers to bring the whole team of workers along.

Central to AR's value proposition, then, is its ability to capture, digitize, and store human expertise and work processes, which can be delivered later either for training as described above, optimized, or at the time and location of need to a worker operating in the front-line work environment.

AR wearable headsets are not only tools to deliver digital AR content to the physical work environment, but also powerful tools to efficiently capture and digitize human work processes and expertise. Experienced technicians and engineers use a wearable device to capture a task, or perform the SOP as they carry it out. This has replaced Frederick Taylor's stopwatches in measuring physical work. The content is then turned into a step-by-step guide with instructions for other workers to follow, through the same type of wearable device.

Using AR to capture and replay work processes is a huge conceptual leap beyond YouTube how-to videos. The digital knowledge of retired experts can be used not just to capture their own work, but to digitally shadow and coach new hires during their training. Comprehension of expert content by the recipient is dramatically greater when AR maps the interactive digital content directly onto the actual work environment.

//AR PLAYBACK OF A PREVIOUSLY CAPTURED WORK PROCESS

A new worker watches visual content captured from an expert showing what operations she should perform at this machine, with relevant tips anchored in the physical environment and each step in the procedure.

A good example of work capture and exchange is Smiths Medical, a medical device manufacturer participating in the "Ventilator Challenge UK" to manufacture scarce ventilators in response to the COVID crisis. Smiths used AR to capture its front-line manufacturing process knowledge and procedures for ventilator production, and delivers those guided step-by-step instructions to production workers at GKN, an automotive and aerospace manufacturer. By capturing and distributing Smiths's expert knowledge, the company is able to digitally guide workers from other companies and industries, with no medical device expertise, in making the same ventilators. There are many similar examples of companies which turned to AR during this emergency and were impressed by its utility.

The Emerging Platform for Front-Line Work

These uses of AR are major productivity drivers, in good times and bad. According to the Manufacturing Leadership Council's 2020 Factories of the Future survey, gathered before the COVID-19 crisis, 48% of manufacturing companies had already adopted or planned to use AR in the next two years. During the crisis, thousands of additional companies utilized AR as a critical technology to enable their ongoing operations irrespective of travel restrictions and social distancing. Capturing and digitizing the expertise of experienced workers also establishes the foundation for optimizing the physical work processes of front-line workers. Case studies suggest that AR can dramatically reduce worker training time by 50%, increase worker productivity by 30-50%, and reduce human errors by 60-90%.

The coronavirus crisis has brought to light how technology can enable a distributed and mobile knowledge workforce to actually improve productivity as the nature of their work changes. AR provides front-line worker solutions that parallel the well-established digital technologies that have come to the rescue for knowledge workers. In a world where a remote workforce is the new normal, AR is a technology whose time has come.

Footnotes

[1] Cognitive distance is the gap between the form in which information is presented, and the context in which it is applied. Greater cognitive distance increases the "cognitive load," or mental capacity, required to interpret the information, hold it in the working memory, and translate it into implications in the physical environment.

Considerations for Deploying Augmented Reality

While advancements in AR technology and adoption are accelerating quickly, three common challenges could derail an AR initiative as it gets underway. It's therefore important to keep these in mind from the outset:

- PRIORITIZATION: AR is a broadly applicable technology. Dozens of opportunities exist across the value chain, from engineering, to marketing and sales, manufacturing, and field service, which requires disciplined use case prioritization to maximize business value capture. Start by defining measurable challenges that have financial consequences for your organization, documenting the as-is state to quantify the opportunity and later measure ROI, and then prioritize the AR use cases that best achieve that business value.
- HARDWARE: Different use cases call for different devices, so each AR solution should be designed with a device type in mind to ensure a good user experience. Start by deciding whether head-mounted or hand-held is best suited for your use case. While a standard mobile phone or tablet work well for many use cases today, hands-free operation will require head-mounted devices from Microsoft, RealWear, Vuzix, or others. While that technology is improving quickly, companies should develop an AR strategy that is compatible with many devices, to avoid getting locked-in.
- CONTENT: AR solutions are only as good as the quality of the content and data that companies use. Getting access to the data or creating new content, and combining it in a meaningful way, can be challenging. Leading companies today reuse 3D content from CAD systems and leverage data from IoT systems to accelerate this process. Companies would also benefit from a digital thread— a single source of data truth by real-time synchronization of systems —to link interrelated data across all the processes, products, and people in the value chain.

//ABOUT THE AUTHORS

James E. Heppelmann

President & CEO at PTC

James (Jim) Heppelmann is the president and CEO of PTC. During Mr. Heppelmann's leadership tenure, PTC has assembled the industry's leading software solutions that enable global manufacturers to accelerate product and service innovation, improve operational efficiency, and increase workforce productivity. Mr. Heppelmann was named one of 7 IoT Leaders to Watch in 2017 by Hewlett Packard Enterprise and has previously been recognized as IoT CEO of the Year by PostScapes, Technology CEO of the Year by the Massachusetts Technology Leadership Council, and received the CAD Society Leadership Award. He also serves on PTC's Board of Directors.

Michael E. Porter

Economist, Researcher, Author, Advisor, Speaker and Teacher

Michael E. Porter is an economist, researcher, author, advisor, speaker and teacher. Throughout his lifetime career at Harvard Business School, he has brought economic theory and strategy concepts to bear on many of the most challenging problems facing corporations, economies and societies, including market competition and company strategy, economic development, the environment and healthcare. Michael's approach is based on understanding the overall economics and structure of complex systems, in contrast to particular elements or parts. Michael graduated from Princeton University and holds an M.B.A. from Harvard Business School and a Ph.D. from Harvard's Department of Economics.