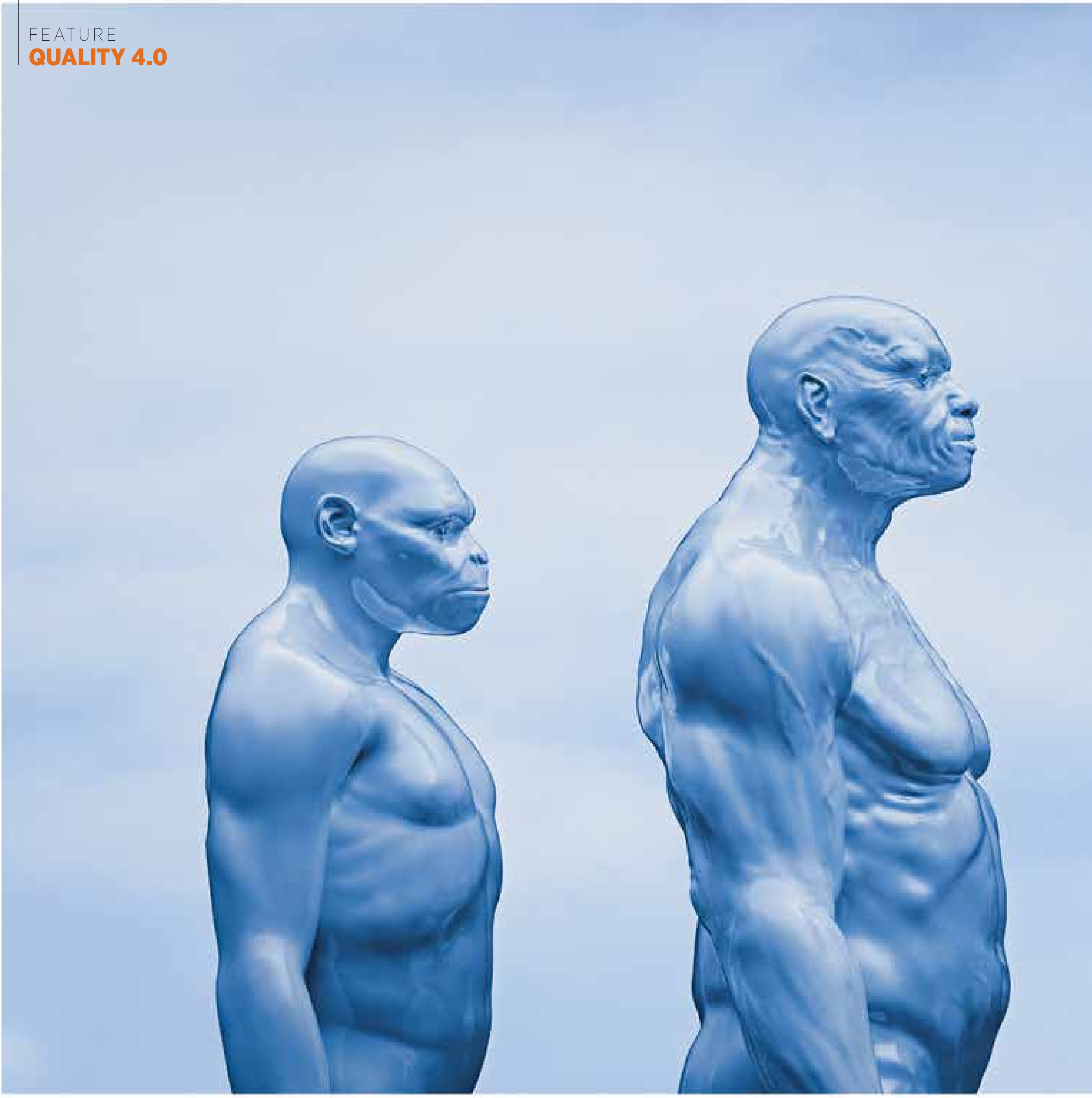

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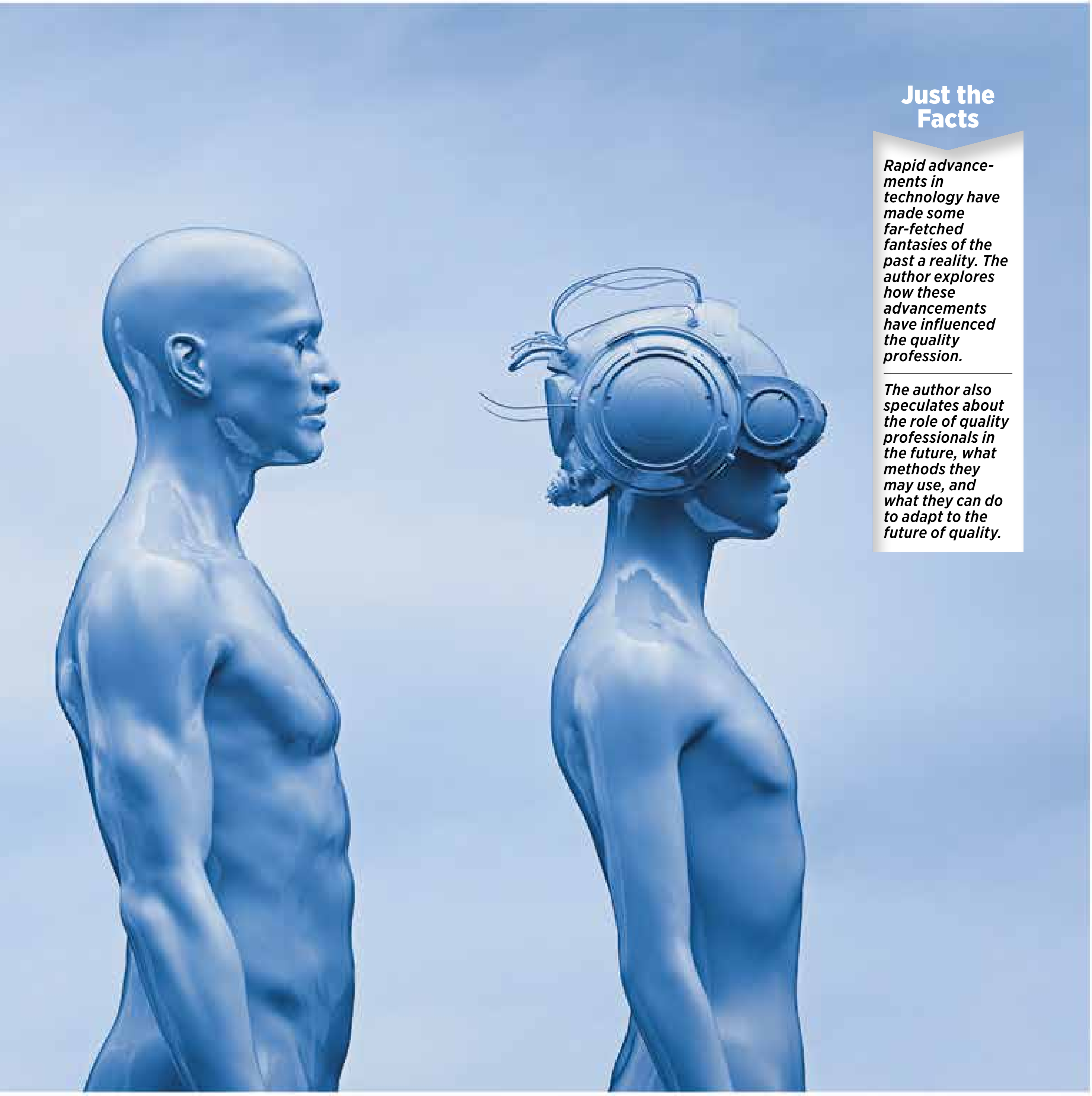


Just the Facts

Rapid advancements in technology have made some far-fetched fantasies of the past a reality. The author explores how these advancements have influenced the quality profession.

The author also speculates about the role of quality professionals in the future, what methods they may use, and what they can do to adapt to the future of quality.

QUALITY 4.0

How the new age of quality came to be and what it might look like in 20 years

by Gregory H. Watson

In recent years, the phrase "Quality 4.0" has come into our vocabulary. It derives from the German industrialization program called Industry 4.0 and evaluates the role of quality in an age of increasing digitization and automation of work.

In 1998, *Quality Progress* published the cover article, "Digital Hammers and Electronic Nails—Tools of the Next Generation,"[1] which forecasted how quality would evolve over the next two decades in response to the growing availability of digital technology. It predicted that quality functions and analyses would become automated and inquired, "How will the role of quality professionals change in that emerging environment?"[2]

At the time, the internet was creating new ways of doing business, and the article described a future in which information—like food and consumer electronics—would be a freely traded commodity.

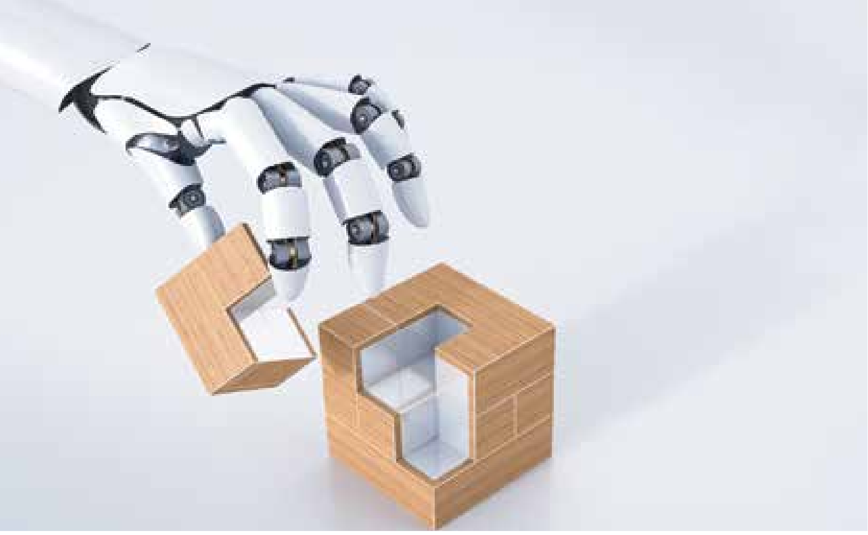
That day has arrived, and those technology trends have evolved into our current realities. How can we cope with the challenges associated with this new environment, and how should we adapt to prepare for a future that will continue to evolve?

Reflecting on the past

The digital environment forecasted in "Digital Hammers and Electronic Nails" focused on two key drivers:

1. Telecommunications technology and the internet.
2. Personal computing, networks and thought machines.

There has been evolutionary growth in the size of computing power since the transistor was first developed in the late 1940s. Moore's Law for Technological Progression is used to describe this growth as a "doubling function" of power in computing every two years.



These technologies did indeed drive much of the change that occurred over the past two decades. However, enterprise computing, integrated multimedia, cloud computing and artificial intelligence (AI)-enabled technology also contributed to the current state.

Today, the simple act of making an airplane flight reservation can generate many megabytes of data, which are connected to past experiences and a travel profile so that "thinking machines" can propose your next potential journey with some degree of accuracy. Purchasing a book or selecting an internet movie proposes a list of similar recommendations. Making a restaurant reservation online can result in receipt of a discount offer from another restaurant attempting to influence your choices.

The technology powerhouse firms in 1998 included Nokia Mobile Phones, Motorola and Compaq Computer—all of which have since been dismantled and their remnants restructured into different entities. Major technology players of today—such as Amazon, Google and Apple—had insignificant presences in those earlier markets. Amazon sold books online; Google had a web browser engine; and Apple produced graphical computers.

Since then, these firms reinvented themselves, taking advantage of the evolving technology trends, and they have emerged as global technical powerhouses. As a result, many organizations have scrambled to transition from analog to digital technologies, converting their predominantly human-based environments to machine-based platforms.

What happened to the work of quality professionals over these past two decades? It too has shifted substantially as we have adopted new approaches. For example:

- Improved statistical software has influenced quality analytics and supported the Six Sigma movement.
- The extensive availability of data related to customer complaints and interactions at touchpoints makes it possible to understand preference trends and react to quality issues almost in real time.
- More sophisticated statistical methods and computer software are integrated to enhance causal structure investigations to solve performance

TABLE 1

Aligned view of changes in industry and quality approaches

Period	Summary description	Quality	Summary description
Industry 1.0—Prior to 1890	+ **Humans harness water and steam power to build industrial infrastructure.** + **Crude machines gain productivity over independent craft work.** + **Increased output is achieved using mechanical advantages.** + **Work focuses on performing tasks faster and more consistently.** + **Transportation/moving goods occurs more frequently.**	**Quality 1.0**	+ **Quality is assured through measurement and inspection.** + **Production volume is emphasized rather than quality.** + **Inspection does not focus on cost reduction, eliminating wastes, or loss and inefficiency.** + **Work conditions are not important; maximizing worker productivity takes precedence.**
Industry 2.0—1890 to 1940	+ **Electricity powers industrial machines.** + **Performance capability gains occur through application of new mechanisms.** + **Scale of automation becomes broader as motor size can be varied to fit specific circumstances.**	**Quality 2.0**	+ **Maximizing productivity continues to be the primary focus.** + **Adherence to standards that reflect the minimally acceptable quality level is prevalent.** + **Financial quality is measured based on scrap and rework.** + **Labor performance is used to measure productivity.**
Industry 3.0—1940 to 1995	+ **Computer power provided to workers to increase productivity.** + **Use of information and communication technology drives improvements.** + **Human participation in workplaces declines.** + **Stand-alone robotic systems replace manual work.**	**Quality 3.0**	+ **Quality is a business imperative.** + **Meeting customer requirements (customer satisfaction) is emphasized.** + **Continual improvement is applied.** + **Gains in productivity occur by stabilizing highly efficient processes, standardizing work and involving all workers in the activities that create quality.** + **Standardization activities (ISO 9001) and achieving business excellence through organizationwide assessment (such as the *Baldrige Criteria for Performance Excellence*) emerge.**
Anticipated changes that will occur during Industry 4.0—1995 to present	+ **Integrated cyber-physical interfaces automate working environments.** + **Automated processes deal with end-to-end systems.** + **Humans serve only in positions where human judgment cannot be automated and human interactions cannot be simulated.** + **Machines learn to learn (artificial intelligence).**	**Quality 4.0**	+ **Digitization is used to optimize signal feedback and process adjustment, and adaptive learning supports self-induced system corrections.** + **Quality shifts its control-oriented focus from the process operators to the process designers.** + **Machines learn how to self-regulate and manage their own productivity and quality.** + **Human performance is essential; the emphasis shifts from production to system design and integration with the business system.**

problems. By reducing reliance on professional statisticians, this development also has driven the broad acceptance of Six Sigma across all organizational functions and dimensions of society.

Understanding the effects

The current predominant technology trends related to the digitization of society are big data and AI. Big data have evolved as the world becomes more connected and software applications begin to record more user interactions as a result of "links" (LinkedIn) and "likes" (Facebook), which allow cross-referencing of individual choices regarding consumer preferences.

Amazon has been most visible in applying these methods to its online purchasing model, which has evolved from a home shopping network to a worldwide portal for goods and services. Even political elections have been influenced by the ability to access and manipulate massive databases. AI has been combined with big data to make search engines more efficient by using pattern recognition and rule-based logic derived from the choices people make, and used to gain deeper insights to derive personal preferences.

The growth of big data is not surprising. There has been evolutionary growth in the size of computing power since the transistor was developed in the late 1940s. Moore's Law for Technological Progression is used to describe this growth as a "doubling function" of power in computing every two years.[3]

This powerful computing technology now is available to almost everyone through transformational changes, such as mobile phones becoming mobile computing platforms. Access to complete information is available at our fingertips wherever we can connect to the internet, which is almost everywhere. In the first decade of this century, the transition to digital technology became so complete that it can be considered ubiquitous.

Industry 4.0 is built on the framework that internet connectivity through wireless telecommunications permits integration of diverse types of devices (such as home appliances, automobiles, industrial platforms and merchandise markets) for business or personal purposes. Digital signals now are influencing almost every aspect of our lives, as demonstrated by:

+ Performing diagnostics on remote elevators.
+ Restaurant food delivery by courier.
+ Establishing environmental settings before arriving home.
+ Starting and warming cars remotely on cold winter days.
+ Doctors receiving secondary opinions on medical test data from off-site colleagues.
+ Surgeons receiving advice from "master doctors," who are highly specialized in a procedure or a particular diagnostic field.

How does this affect the quality profession? One visible trend is the rise of a new related job: data scientists. Data scientists use data management tools and software to explore affinities among measurements from massive online databases (often stored in the cloud) by using predictive analytics. These evaluations support organizational decision making based on predicted outcomes, which provides insights, not possibilities, for the future. Clearly, technology has enabled the widespread application of statistical thinking.

But what is the implication of this shift in technology access for the quality profession? Generally, academic research is the primary source of new approaches to industrial engineering and statistics. Now, the curricula for those fields incorporates systems-thinking and data science for industrial engineering and statistics students, respectively. Sometimes, these areas are established as independent fields of study.

There is a growing need for organizations to divide their data analytics resources into two compartments—developing strategic insights and market positions (data science) and managing daily routine operations (quality). This arrangement challenges the perception of the value of quality management and raises questions regarding the importance of "little data analysis," which focuses on real-time, data-based investigations of problems' causalities and ensuring consistent quality is produced by a stable process.

Many of the control mechanisms in this daily management system can be enabled through robotics or other types of automation that use sensor systems, data monitors or telemetry. These systems are supported by AI systems that feed corrective action signals through an adaptive feedback mechanism for changing production system settings.

The evolution of quality

Why do we still need quality professionals? Did the quality profession become perceived as unimportant because digitized technology can replace it? What can we do to change this perception and reshape our profession in the coming two decades? How can we convince decision makers that automated little data analytics do not replace quality professionals and big data?

Joseph Juran declared in his important "Last Word" speech that the 21st century would be the "century of quality!"[4] We must act to ensure the truth of his prediction.

Collaborative analytics will give equal credence to the technological aspects of the production system and the human aspects of the administrative system.

Let's begin by clarifying the roots of how quality professionals think and work. We'll compare the histories of industry and quality to understand how our principles, methods and tools have matured over time. Quality 4.0 will be shown to be the appropriate companion to Industry 4.0. As in previous developmental periods, this relationship between industrial advances and quality developments is interactive and it operationalizes these changes using an aligned approach, which is described briefly in Table 1 (p. 27).

Here are some key considerations to bring the maturing of industry and quality into context:

+ Quality 1.0 dates back thousands of years and describes the earliest roots of the quality profession.
+ The idea of Quality 2.0 emerged from the Industrial Revolution. This period often is referred to as Taylorism, as described by Fredrick W. Taylor in his 1911 book, *Principles of Scientific Management*.[5]
+ Quality 3.0 evolved from the time of Taylor to the end of the 20th century and was stimulated by Walter A. Shewhart's interpretation of the advancements in physics discovered during his lifetime. He pragmatically applied them to the production environment in his 1931 book, *Economic Control of Quality of Manufactured Product*,[6] which became the cornerstone of Quality 3.0. This period represents the analog equivalent of the current digital transformation.
+ Quality executives now must cope with the reinvention of research and development practices. Quality thinking must be incorporated into the design of holistic business systems that support productive operations. Furthermore, the reformation of quality competence among professional staff members must prepare them for full participation in this digitally enabled management age.

Insights about the future

The emerging path forward for the quality community must extrapolate these lessons. What will be the job of the quality professional in 20 years, and what methods will be employed then? The following three conjectures are based on observations of the current state:

1. The emphasis will shift from the operationally oriented task of creating and executing a quality strategy to more holistically applying quality as a strategy across the entire organization. Quality thinking will equal financial thinking in organizations' operational management systems, as demonstrated by and documented as the Toyota Management System, which goes beyond the well-known Toyota Production System.[7]
2. The distinction between quality professionals and data scientists will be replaced by a new approach that might be called "collaborative analytics." It will merge all continual improvement activities into an integrated, cross-functional, organization-wide method driven by a structured, scientific approach to problem investigation, diagnosis and remediation.

   Additionally, collaborative analytics will give equal credence to the technological aspects of the production system and the human aspects of the administrative system. Research regarding such a system has been underway since 2014 by the International Academy for Quality.[8]
3. The tools of data analytics will mature to incorporate a new way of conducting exploratory data analysis. This will combine big data methods for identifying interesting rational subgroups (or, as W. Edwards Deming described, an enumerative approach) with little data methods for determining potential causes and detailed patterns that might exist in historical data sets—what Deming called an analytic approach.[9]

   Many new analytical methods will be associated with this change. James Duarte, for example, has proposed seven analysis tools that can be used for data probing and other methods to use data more efficiently.[10]

Another technique might be labeled "passive design of experiments," where statistical computing systems analyze natural interrelationships among multiple factors in a large data set.

Focusing on the future

Perhaps the rate of change has been too fast for us to comprehend what will occur in the next two decades. Information storage is doubling every two years, mirroring technological advances. These two factors increase information access and processing speed, and their combined effect is multiplicative.

The quality community now faces the same circumstances. Although a specific path may not be totally predictable at this point, there are known factors that improve our forecasting ability. Most importantly, we must develop a strategic approach that organizations can implement to sustain success while we focus on enhancing our methods and toolkits.

We will thrive, rather than merely survive, if we learn how to gain greater insights from collected data and design quality systems that fit our organizations specifically, rather than copying and pasting approaches from the past. These are essential elements for us to master to embrace and leverage these turbulent times of digital transformation. QP

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REFERENCES

1. Gregory H. Watson, "Digital Hammers and Electronic Nails: Tools of the Next Generation," *Quality Progress*, July 1998, pp 21-26.
2. Ibid.
3. Gordon E. Moore, "Cramming Components Onto Integrated Circuits," *Electronics Magazine*, Vol. 38, No. 8, 1965, pp. 82-85.
4. Brad Stratton, "A Few Words About the Last Word," *Quality Progress*, October 1993, pp. 63-65.
5. Frederick Winslow Taylor, *The Principles of Scientific Management*, Dover Publications, 1911.
6. Walter A. Shewhart, *The Economic Control of Quality of Manufactured Product*, Van Nostrand, 1931.
7. Toshio Horikiri, "The Toyota Management System," proceedings of the fifth Productivity Summit in Sochi, Russia, April 2017.
8. Gregory H. Watson and Lars Sörqvist, *IAQ Report: Engineering the Process of Continual Improvement*, International Academy for Quality, 2017.
9. W. Edwards Deming, "On Probability as a Basis for Action," *The American Statistician*, Vol 29, No. 4, 1975, pp. 146-162.
10. James Duarte, "21st Century Quality, Reliability and Six Sigma," proceedings of the ASQ European Quality Conference in Berlin, Germany, November 2017.

Gregory H. Watson is a past president of the International Academy for Quality (IAQ) and ASQ. He has been elected an honorary member of IAQ and a fellow of ASQ. He also has received the IAQ's Founders Medal, the Deming Medal from the Union of Japanese Scientists and Engineers, the Borel Medal from the European Organization for Quality, the Feigenbaum Medal from the Asia Pacific Quality Organization and ASQ's Distinguished Service Medal.