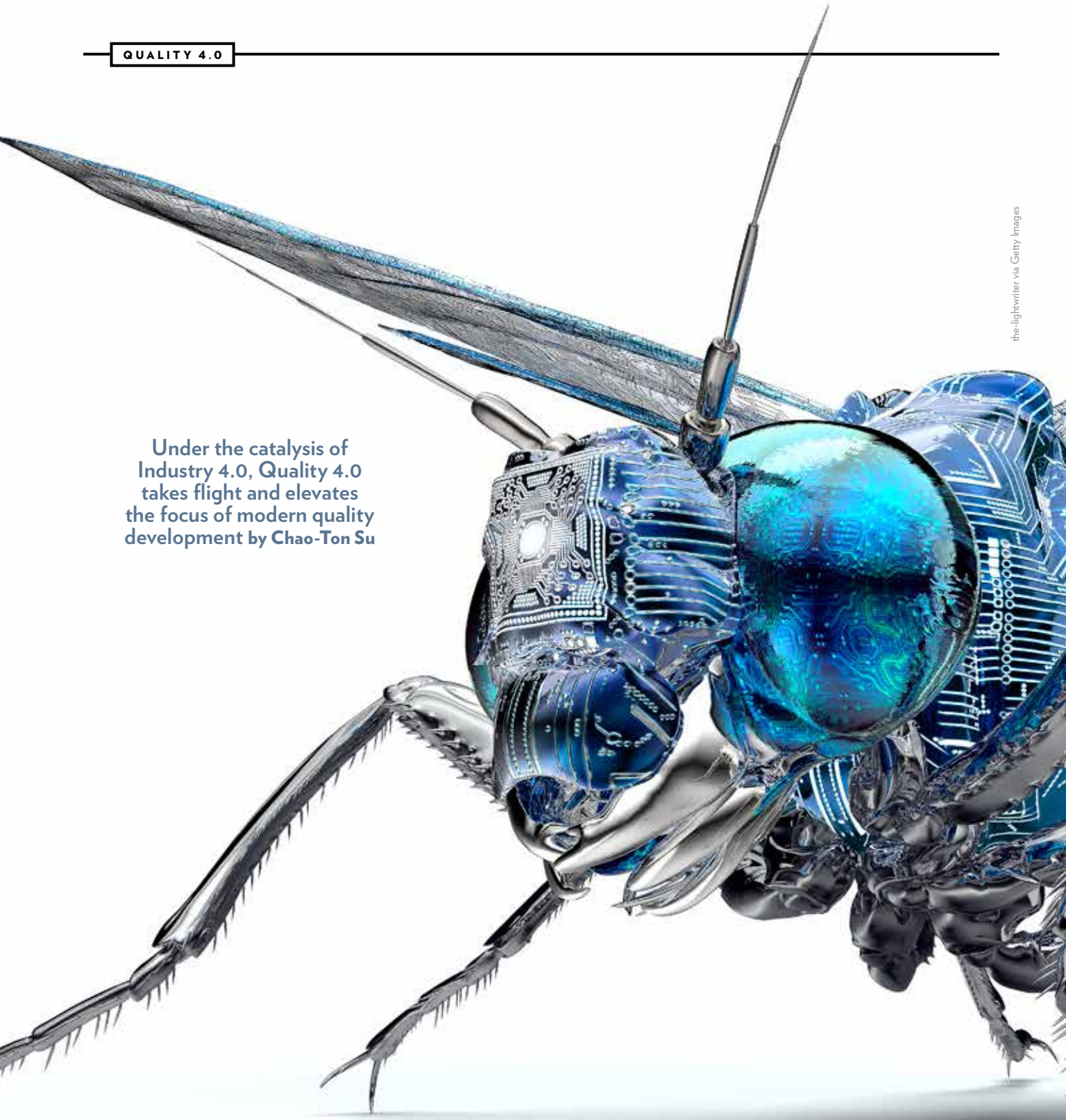

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Under the catalysis of Industry 4.0, Quality 4.0 takes flight and elevates the focus of modern quality development by **Chao-Ton Su**

UPLIFT AND

ADVANCE

JUST THE FACTS

From a macro perspective, Quality 4.0's main focus is digital transformation. It involves strategic change driven by customer and business needs. From a micro perspective, Quality 4.0 is aimed at using existing quality control methods and Industry 4.0 technology to assist organizations in quality improvement and innovation.

Under the catalysis of Industry 4.0 technology, Quality 4.0 has taken shape and become the focus of modern quality development.

More quality professionals must learn and understand new technology related to Industry 4.0 and consider how this new technology can be used to add value to the workplace and for customers.

Over the past 10 years, Industry 4.0 has engendered substantial change to the manufacturing practices of various industries. In turn, these changes have further affected the implementation of quality management activities. Since 2004, for example, Google searches for "quality engineering" have dropped by 70%, whereas interest in "data analytics" has increased by 20 times.[1] Current quality professionals must learn and understand recent technology related to Industry 4.0 and consider how this new technology can be used to add value to the workplace and for customers.

Quality evolution

Quality-related practices have undergone several changes throughout history—from inspection and quality control to quality management and, eventually, to quality design. Currently, the most well-known quality activities are ISO 9000, total quality management, Six Sigma and the Baldrige Performance Excellence Program. How to systematically integrate these quality activities to prevent and solve quality problems is still an important direction for organizations to implement quality management.

In all quality management activities, the central purpose is quality improvement. For quality improvement to occur, quality problems must be solved. The key aspects of problem solving are identifying the problem, breaking down the problem, collecting and analyzing data, and interpreting the results of the analysis. In the past few decades, many quality practitioners have applied this type of data-driven logic to solve quality problems.

The techniques commonly used to achieve quality improvement included statistical methods, quality tools and the Toyota Production System, or lean thinking. As technology advanced, organizations began to use data mining, big data and Industry 4.0 to improve quality, and the era of Quality 4.0 began. The relationship between industrial progress and quality development is presented in Table 1.

Industry 4.0 can be used to help us increase intelligence and solve quality problems. Industry 4.0 is an important helper of Quality 4.0.

The term "Industry 4.0" first appeared in 2011 at the Hannover Messe, a trade fair for industrial automation. The time at which the term "Quality 4.0" was first used is unknown. ASQ, however, has held five Quality 4.0 seminars since 2017. ASQ describes Quality 4.0 as "bringing together Industry 4.0's advanced digital technologies with quality excellence to drive substantial performance and effectiveness improvements."[2] Quality 4.0 is unique, and several aspects of the system distinguish it from others of its kind.

What does Quality 4.0 mean?

From a macro perspective, Quality 4.0's main focus is digital transformation. It involves strategic change driven by customer and business needs. Digital technology has been identified as having the potential to promote new business models and new sources of value, thus creating a new quality management system.

The extent to which existing systems and processes must change is still unclear. According to some literature, factors such as the strategic use of technology, value creation, structural change and financial considerations may contribute to the decision-making process.[3,4]

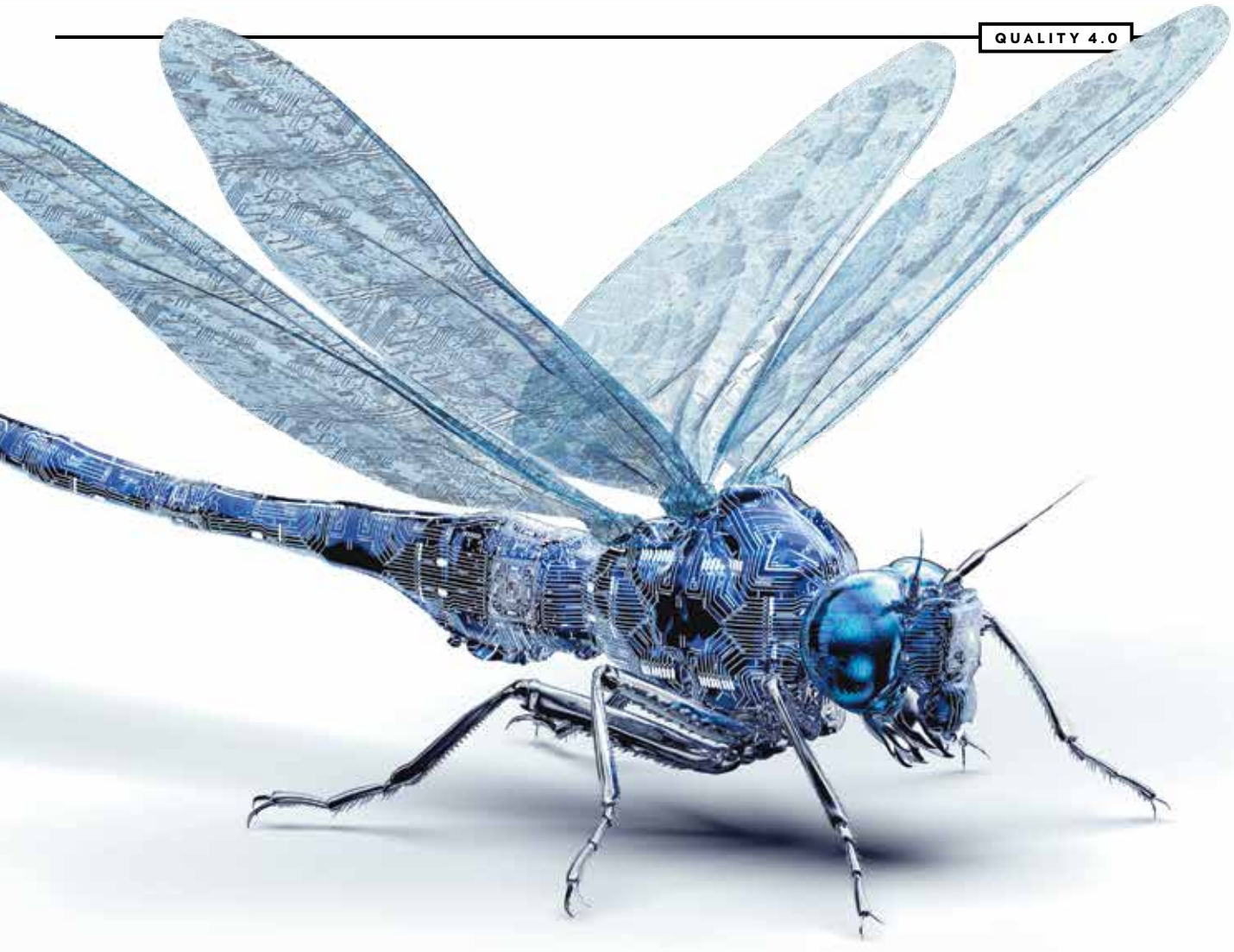

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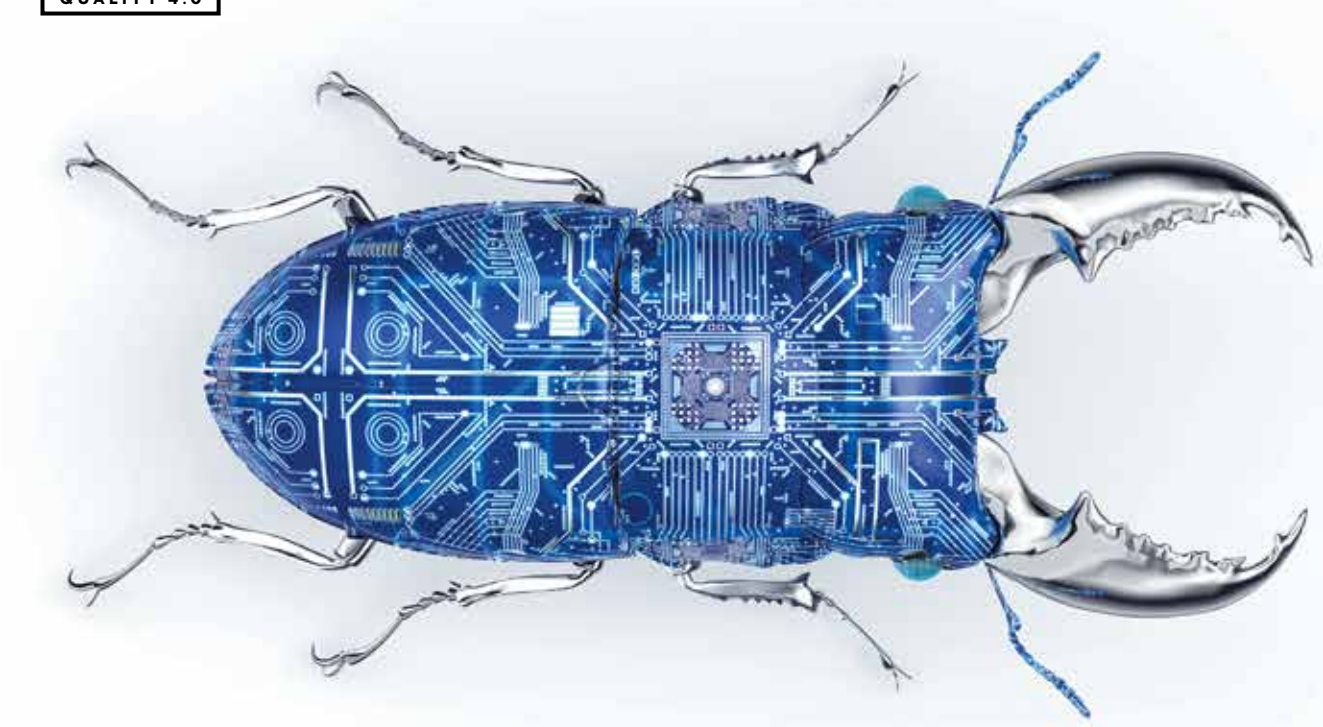
TABLE 1

Relationship between industrial progress and quality development

Industry	Summary	Quality	Summary
Industry 1.0	Use steam or waterpower as driving power to realize factory mechanization.	Quality 1.0	Ensure quality through measurement and inspection.
Industry 2.0	Use electricity to provide power and support for mass production using assembly line.	Quality 2.0	Comply with standards and minimize the cost of defective products and rework.
Industry 3.0	Use computers and industrial automation to execute modern production.	Quality 3.0	Pursue customer-oriented total quality management, with the main activities including ISO 9000, total quality Management, Six Sigma and Baldrige Performance Excellence Program.
Industry 4.0	Taking the cyberphysical system as the core, introduce concepts such as the Internet of Things, cloud computing, big data analysis and smart factories.	Quality 4.0	Continuing the practice of Quality 3.0, emphasizing digital transformation and using Industry 4.0 technology to assist organizations with quality improvement and innovation.



From a micro perspective, Quality 4.0 is aimed at using existing quality control methods and Industry 4.0 technology to assist organizations with quality improvement and innovation. Sensors can be installed in equipment, materials, semi-finished products and finished products, for example, to collect the necessary data. Sensors or IT can be used to monitor processes and obtain real-time visible quality indicators. Automatic inspection can be implemented to replace manual inspection or sampling inspection.

Hsueh-Ping Lu and Chao-Ton Su[5] proposed an approach entailing the use of a conditional generative adversarial network to eliminate moiré patterns from defect images. They developed a transfer learning ensemble model that aggregates multiple convolutional neural networks based on a denoising network for defect classification in a limited training data set taken from a high-mix, low-volume and short life-cycle production environment. Through a real case study, they illustrated that their proposed method can provide relatively high accuracy for *mura* defect classification.

In general practice, the accuracy of decision making and forecasting systems can be improved through big data analysis, such as understanding the performance of different suppliers, comprehending customer habits, predicting customer needs and improving the speed of customer service and support.

Philosophies

Quality 4.0 introduces the concepts and technologies of Industry 4.0 into an organization, and it enables effective quality management. The core concepts are:

- Quality 4.0 is cross-functional.
- Quality 4.0 integrates data, processes, products and people, enabling them to cooperate to improve efficiency and quality, and thus improve customer satisfaction.
- Quality 4.0 is aimed at enhancing human intelligence and improving the speed and quality of decision making.
- Quality 4.0 improves transparency, traceability and auditability.
- Quality 4.0 requires education and training, particularly in digital technology.
- The cost of poor quality is composed of prevention, appraisal, internal failure and external failure costs. Quality 4.0 is intended to reduce appraisal and failure costs to zero to increase profits considerably.
- Quality 4.0 leads to higher-quality products at a lower cost to enhance competitiveness.
- Quality 4.0 does not seek to replace traditional quality management practices but to improve upon them.
- Implementing Quality 4.0 is like introducing improvements and innovations into the organization, which requires a joint effort from relevant personnel in an organization.

Important skills

In general, a Quality 4.0 engineer must possess:

1. Soft skills, including communication skills, problem-solving abilities and change management skills. The engineer also must be a team player.
2. Technical skills, including data science-related skills.

Tools frequently used in Quality 4.0 include math and statistics, artificial intelligence, big data and enabling technology. Among these, big data plays an important role in Quality 4.0. Big data exerts three key influences on quality improvement:[6]

Although evidence regarding the successful implementation of Quality 4.0 is currently limited, hopefully more organizations implement Quality 4.0 to enrich the knowledge system of quality engineering.

1. Big data accurately evaluates the voice of the customer and helps organizations identify customers' purchases and motivations, thereby allowing organizations to determine customer needs and providing opportunities for quality improvement.
2. Big data can be collected from anywhere. It challenges and encourages organizations to apply advanced technologies to analyze large quantities of structured and unstructured data.
3. Big data enables forecasting. Through big data forecasting, processes and product performance can be improved, which affords effective risk management. The most crucial aspect of applying Industry 4.0 technology to quality improvement is understanding how big data or data science can be used to achieve quality improvement and innovation.

An ideal Quality 4.0 manager should have a systematic perspective, cross-disciplinary skills and the soft and technical skills mentioned earlier.

Industry 4.0 is part of Quality 4.0

In the environment of Industry 4.0, quality management personnel can obtain substantial real-time data from multiple sources. These data are used to make decisions to meet customer needs. Industry 4.0 can be used to help us increase intelligence and solve quality problems. Industry 4.0 is an important helper of Quality 4.0.

To improve the organization's operational management, organizations must understand customer needs, design products based on such needs, purchase materials, manufacture products, ship products that meet those needs and provide customer service. In Quality 4.0, traditional statistical methods and quality tools are used to assist in these processes.

Alternatively, network communication technology can be incorporated fully into the production process and business operations to improve the degree of virtual and real integration, as well as the application of the data between products, equipment and enterprises (smart factory). This improves efficiency and quality, which improves customer satisfaction. Accordingly, Industry 4.0 is an integral aspect of Quality 4.0.

Future of quality

Under the catalysis of Industry 4.0 technology, Quality 4.0 has taken shape and has become the focus of modern quality development. Applying Quality 4.0 is not limited to technology. It is an effective method for overall quality management. Quality 4.0 requires participation from all employees of an organization, including senior management, IT, marketing and quality professionals.

Although evidence regarding the successful implementation of Quality 4.0 is currently limited, hopefully more organizations implement Quality 4.0 to enrich the knowledge system of quality engineering. **QP**

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