> Technological Sciences

Discovery – Development – Responsibility

acatech IMPULSE – SUMMARY

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NATIONAL ACADEMY OF SCIENCE AND ENGINEERING

People have been creating technology since time immemorial. However, what sets modern engineers apart from their historical predecessors is that from the 18th century on they began to apply the scientific method to their work, giving it an objective, verifiable and widely reproducible basis. Of course, engineers were not the only ones to do this. Alongside scientists, humanities scholars, economists, managers and physicians, they made their own unique contribution to recognize the world with scientific means by subjecting everything they did to scientific criteria in order to enhance reliability and increase productivity.

What are the technological sciences?

The technological sciences form a genuine group of scientific disciplines with a distinct focus and different goals, methods and institutions to other sciences. The focus of the technological sciences is technology, in the sense of artificial, purposeful objects and processes that possess both tangible and intangible elements. The technological sciences involve the study of technology in terms of its structure and function, its impact on the environment and society and the social and cultural context in which it is developed and used. They thus look at the entire life cycle of a given technology, from design and manufacture through to utilisation and disposal or recycling.

The goal of the technological sciences is to generate knowledge about the laws, structure and rules of technology with a view to using this knowledge in technological applications. The technological sciences employ a diverse but targeted array of methodologies ranging from the rational and systematic to the intuitive and heuristic. However, it is fair to say that the technological sciences tend to focus on what is actually feasible rather than what is merely conceivable. The technological sciences are not confined to the analysis of technology, they also develop ways of combining existing technologies to create something new. They anticipate future applications of technological know-how and their interactions with the environment, meaning that environmental, economic, cultural and social factors are all embedded in technological science models. The technological sciences have a place both within and outside higher education institutions. Ultimately, they encompass all the scientifically-based knowledge that we possess about the production and utilisation of technology, its cognitive and practical requirements and its impact on the environment, the economy and the society.

The technological sciences may be summed up by the following sentence:

The technological sciences establish the cognitive presuppositions for technological innovation and the application of technological know-how and provide us with a basis for considering the impact and repercussions of technology.

The most important intellectual tools that are specifically needed to apply the scientific method to technology are abstraction and modelling. Technology should always be subjected to experiments and tests if at all possible. However, there comes a point where the size and complexity of the system as a whole means that it is no longer feasible to test it in a laboratory prior to installation. When physical testing cannot be carried out (this may also be for financial, safety or ethical reasons), its role may be taken over by modelling and subsequent simulation.

The concrete nature of technology and the abstract nature of scientific thought are mutually complementary. Abstraction establishes a link between what is as yet undiscovered and what has already

At a glance

- The technological sciences establish the cognitive presuppositions for technological innovation and the application of technological know-how and provide us with a basis for considering the impact and repercussions of technology.
- The technological sciences form a genuine group of scientific disciplines.
- Scientists, and in particular engineers, have a special duty to ensure the success and safety of our technological world.

been discovered and scientifically investigated. In the technological sciences, abstraction thus fosters pragmatic problem-solving among professional engineers. Modelling enables theoretical and empirical estimation of how innovations will behave in practice. Modelling allows systems' key behaviours to be identified, assessed and controlled through appropriate design.

Technological science models should be comprehensive and possess a high degree of complexity in order to ensure that their results are sufficiently reliable to be used in practice. At the same time, the nature of the technological sciences and technology in general is such that it will never be possible for everything to be based entirely on hard facts and it will always be necessary to make assumptions at some point or other. This means that the information derived from models will inevitably be prone to a certain degree of uncertainty. Indeed, the unavoidable use of incomplete stochastic models is one of the greatest practical challenges facing engineers today.

This interaction of experience and creativity, systematisation and research makes modelling in the area of technological sciences to a kind of art. Targeted abstraction is indispensable for successful modelling. It is in this part of the design process that creativity has an especially important role to play.

Responsibility in the technological sciences and technology

There is always a degree of ambivalence attached to any technology. Those responsible for planning and implementing engineering projects are constantly confronted with the challenge of producing something that can perform the relevant task without unavoidable and harmful side effects. Since the ostensibly simple requirement of achieving utility without harmful consequences is something that can rarely be achieved in practice, it is substituted by a difficult balance between utility and harmfulness based on the criteria established by society. This in turn requires an ongoing dialogue with society regarding the goals and consequences of technology. Changes in and especially reappraisals of resource availability, together with reappraisals of how vulnerable the available resources actually are, mean that there is a constant demand for technological innovations. Similarly, changing social needs that are constantly growing as technology opens up more and more new horizons require a continuous stream of novel technological solutions.

There can be no doubt at all that the application of the scientific method to technology was largely responsible for the proliferation of creative designs and improved reliability of technological products and processes that has occurred in the recent past. Indeed, the science of technology is the most potent tool that today's engineers have at their disposal. Nevertheless, whatever we might do, it will never be a perfect science and mistakes will inevitably be made. It is essential never to lose sight of this fact when designing technology. It is the fundamental responsibility of all scientists, particularly engineers, to keep testing and retesting the scientific data derived from technology. Engineers have a special duty to ensure the success and safety of our technological world, despite technology's implicit imperfections. At the same time, they have a duty as professionals to inform society when there are doubts or persistent uncertainties and to be prompt in raising any issues that require immediate input from society or that may do so in the future as a result of potential new technologies. As such, engineers and technology science experts are not just responsible for producing optimally functioning, user-friendly technologies that use natural resources both economically and sustainably. They also have a duty to present us with all the conceivable and feasible alternatives for how our high-tech world might look in the future. Technology science experts and engineers need to keep the future open for us.

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