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Entlebuch
Switzerland

ISBN 978-3-319-09188-4 ISBN 978-3-319-09189-1 (eBook)
DOI 10.1007/978-3-319-09189-1

Library of Congress Control Number: 2014946184

Springer Cham Heidelberg New York Dordrecht London

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Science and Technology

To
Dr. Heinrich Steinmann
and
Prof. Dr. Tibor Vamos
for their leadership in Science and Technology

Foreword

Why to add a new book about the history and roles of Science and technology to the library filling volumes of the same subject?

The usual reason for writing and reading a new book on an old theme is the discovery of new circumstances, more original authors, different receptions in different ages, new projects, stories about the thinking of celebrated scientists as well as gossips.

Here we meet another difference. The main characteristic is the author himself and his unusual point of view.

The history and influence of science and technology is deeply related to philosophy, from the origins and to realization in everyday life, especially nowadays. Professor Dimitris Chorafas is the unique person for that. Having a deep traditional Greek education, he is at home at these historical origins which still influence the ways of scientific thinking.

The proof of this idea of historical metal continuity is an attractive thread of citations and related stories for everybody who is or was not familiar with that decisive heritage. The unbiased and never complete search for working models of the reality, the critical view of these theories lead us in an entertaining style from the ingenious questioning dialog method of Socrates to the cosmological and quantum theories of up to date physics.

Not less convincing is the same story from the antique ideals of brave and intellectually bold ethics, its validity in science, technology and not less in present finances.

The reader receives as illustrations of these abstracted ideas in deep analyses of system science applications, e.g. in decision support for alternatives in energy production. Chorafas main field has been engineering but he worked extensively in finance as an advisor to major banking and investing corporations. He published his experience in best seller books which reflect always deep analyses of the subjects and are written in an easily understandable, enjoying style which explains the complex problems. A modern philosophical observer on the Socratic route to handle our reality.

This is the reason why this book rendered for me and surely for all the readers the view of an economist, a rather different aspect as we are accustomed in our presentations of high pitch knowledge and earth-bound discussions about budgets.

The argumentation is based on factual experience with project evaluation, e.g. about energy systems; a focus of strategic planning, product development, system optimization, futurologism.

The other unique generalization refers to the developments and continuities of science and technology, their mutual interrelations, ways of thinking and values related to strive for novelty and preserving ethical values. These are the exciting aspects of a person, who followed this process during a long and changing professional activity and observing all these from different towers of knowledge. Are these as alien as we think based on our prejudices or are they able to extent our perspectives from this not so far standing process of human progress?

I can recommend this book to everybody interested in the twins, science and technology, due to its very unusual but highly realistic views for those who are actors and jurors of the main line of human achievement.

Budapest, Hungary Prof. Em. Tibor Vamos

Preface

A widely prevalent myth is that books are inanimate, ineffective, nearly futile objects belonging to the shades and quiet environment of libraries, monasteries, and other retreats from the real world. Contrary to this misinterpretation and misunderstanding, books can be dynamic and vital elements of culture. They can be full of ideas and experience, capable of changing the direction of events.

From fiction to drama, philosophy, science, technology, finance, models of thought, poetry, and essays, books have been cornerstones to the evolution of society. They are the means to spread wider (often contradictory) concepts underpinning the march of civilization, and they have gone way beyond supposedly static objects to dynamic entities able to make immense contributions.

Much to their credit, books have been instrumental in promoting *thinking*, which is important inasmuch as thinking must be part of everybody's education. Thomas Watson, Sr., one of the most resourceful businessmen, used the logo THINK almost at par with that of his company, IBM. And on August 31, 1837, in his Cambridge lecture Ralph Emerson said: "If one is a true scientist, then he is one who THINKS."

Niels Bohr, the nuclear physicist, was teasing his peers and his students by telling them: "You are not thinking, you are only being logical." Great scientists and technologists have always appreciated that thinking means doubting and experimenting. Because it is based on thinking, scientific experimentation is the mother of research and of the applications to which technology is being put.

Science is the process of creating new knowledge, not just interpreting the old in an ever greater but uncertain detail. Scientists make progress by distinguishing between what they regard as meaningful and what they consider as being secondary or unimportant. The meaningful is dynamic; typically, the less important is static.

Technology amplifies and applies to daily life products and processes based on the breakthroughs of science. Technologists who are worth their salt know that the work they do is in full evolution. *If* they fail to steadily develop their skills, their tools, and their methods, *then* they will only be as good as their last design and at the risk of becoming obsolete.

Whether we talk of new products, novel processes, or advanced systems, the deliverables of scientists and technologists who look at their work through the prism of a narrow discipline are necessarily restricted. In a complex society like ours we have to broaden—and to do so our focus we must espouse interdisciplinary approaches, effectively using our critical spirit and being able to see the difference between a project that goes nowhere and one that actually works.

Because it is a salient problem and a most challenging issue to our society at the present time, power production has been chosen as a case in point in technological development. The discussion of possible alternatives in energy sources, the advantages but also costs and obstacles confronted by each of them, confirm the view that technology must be in touch with common citizens to satisfy their needs and answer their fears about the future. This has been classically philosophy's remit, but it is no less true that philosophy, science, and technology correlate.

* * *

The theme of Chap. 1 is natural philosophy, a term which preceded that of science all the way from antiquity to Isaac Newton's time, and it is still in use. To appreciate the intellectual effort that has been invested over the centuries, the text describes the parallel evolution of philosophical ideas and scientific thought, prior to making a distinction between basic and applied research. This is followed by examples of work on the very small (molecules) and the very large (astrophysics). Lasers are taken as a case study on development, followed by work that targets improvements in the quality of life.

Chapter 2 turns back to the fundamentals by concentrating on philosophy and the work of thinkers which led, since antiquity, to the evolution of science's first principle. What is generally considered as having been a speculative natural philosophy was based on observation, intuition, and reason, which can be found at the roots of every science. In ancient Greece, two schools confronted one another in terms of what philosophy is or should be:

- The Sophists regarded philosophy as education and training on how to do things.

This has been the practical side of natural philosophy exemplified by the work and teachings of Protagoras and (to a lesser extent by Pythagoras), whose deeds are discussed in Chap. 2.

- Socrates looked at philosophy as a process of acquiring knowledge of the nature of things.

This was quite a different approach than that of the sophists. The questioning method underpinning the Socratic Method can be seen as the spinal cord of present-day basic research—a reason why the text explains it in detail (in connection to the education necessary to promote the work of scientists and technologists).

To Socrates and the followers of his method, the successful pursuit of any occupation demanded the mastery of a particular knowledge, skill, or technique. Politicians, generals, other philosophers, poets, and craftsmen came under the scrutiny of questioning. To his dismay the ancient Greek philosopher had discovered that except craftsmen none of them knew the meaning of the words he used.

Research in the physical sciences is addressed in Chap. 3, starting with the concept and practice of scientific experimentation which can be looked at as a direct descendant of the Socratic Method. The best thinkers of antiquity devoted a good deal of interest to the heart of matter, but the effort to provide proofs more or less eluded them. It has taken huge investments in present-day scientific laboratories and thousands of man-years of investigation to reveal some of the secrets of the physical world through documented evidence.

Scientific investigation, as well as the development of new products have been significantly assisted through mathematical analysis, models, and simulation which is the subject of Chap. 4. The text places emphasis not only on simulated environments but also, and most importantly, on flawed computer-based and other models—and on the need that the hypotheses we make, the algorithms we develop and use, as well as (postmortem) the forecasts and other insights that they provide are put to test.

The subject of Chap. 5 is education for science and technology—starting with the most important theme of them all: Learning how to learn. Cornerstone to this are the goals that we wish to reach, which essentially means the use of knowledge. The experimental work of Louis Pasteur, the renowned biologist, on symmetries and asymmetries is taken as an example. Learning how to learn must start at the early student years, because it is difficult to change attitudes later on. At the end of the day, the best way to judge the quality of learning, for reasons of selection and promotion, is through deliverables.

Chapter 6 introduces to the reader the concept and practice of technology related to but distinct from science. Technology has a direct impact on everyday life and biomedical engineering is taken as a positive example. Because technology and society correlate, more so than science and society, it is quite important to properly evaluate both the upside and the downside of technological developments. Even projects that are daring and correct in terms of engineering may have adverse effects. The Aswan Dam has been chosen as a case study.

Chapters 7–9 share the themes associated to energy production. This has been a deliberate choice because energy is the moving gear of the civilization and the technology in which we live. Every source of energy has its advantages and its perils; pollution is one of the latter. The critical question is how to balance the advantages against the costs—not just the financial costs but also the relative destruction of the environment that accompanies each solution of energy extraction and consumption.

Chapter 7 provides the reader with a general appreciation of technological challenges connected to energy supplies. However, understanding the sources of energy is important but not enough. There is no better way to come to conclusions, in a factual and documented way, than to examine each source of energy individually and then compare the obtained results. Chapter 8 does so with coal, gas, biofuels, shale gas and oil, solar energy, and wind power as the main issues.

The remit of Chap. 9 is the challenges presented by nuclear energy production, in terms of their own merits (or demerits) and in comparison to the alternative sources of energy discussed in Chap. 8. This presentation starts with an introduction to nuclear power, followed by case studies in France, where nuclear power represents about 80 % of electricity production; Germany, where for political reasons the government veered away from nuclear power production; and Japan, where nuclear power experienced an unprecedented catastrophe. Other important subjects included in Chap. 9 are the lifecycle of nuclear plants and challenges posed by their decommissioning.

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I am indebted to a long list of knowledgeable people, and of organizations, for their contribution to the research, which made this book feasible. Also, to several experts for constructive criticism during the preparation of the manuscript. Dr. Heinrich Steinmann, Prof. Dr. Tibor Vamos, Prof. Dr. Vijay Dhir, and Eva Maria Binder have, as always, made a significant contribution.

Let me take this opportunity to thank Andrew Doyle for suggesting this project, Gabriella Anderson and Tanja Jaeger for seeing it all the way to publication, and Kiruthika Poomalai for the editing work.

Valmer and Entlebuch, July 2014 Dimitris N. Chorafas

Contents

Chapter 1
Science

1.1 Natural Philosophy

The word *science* does not date back to antiquity. It has been coined relatively recently though its concepts, theories, and rules have been classically part of philosophy. In 1660, when the Royal Society, the world's first academy of scientific discipline, was founded in London, the subject to which it addressed itself was referred to as *natural philosophy*.

Isaac Newton titled his famous book: "*Mathematical Principles of Natural Philosophy*." Other terms, too, have developed over time or even changed their meaning. The *humanism* of the Renaissance was originally a technical term applied to studies centered on grammar and rhetoric—as contrasted to logic and natural philosophy of the *scholastics*, who were the early day scientists.

Like natural philosophy, science aims at creating new knowledge; it is not just interpreting the old in an ever greater but uncertain detail of discoveries already made. In addition, it contributes to progress by distinguishing between what it regards as meaningful, which is by and large dynamic, and what it classifies as secondary or unimportant, which is typically (albeit not always) static.

The key function of science is to challenge the "obvious" through research, investigation, and experimentation. This requires a method for carrying out planned experiments, recording observations, analyzing data, and developing mathematical algorithms based on the analysis being made. A key scientific tool is enquiring after, and contesting, the properties of the subject undergoing investigation that have been deduced from experiments.

The spirit of investigation and process of experimentation are two foremost tools of science. As Galileo Galilei, the famous scientist, stated to his accusers: "One well-documented experiment is enough to knock down a hundred thousand probable arguments" (Galileo Galilei, Opere VII, 148).[1]

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[1] Antonio Zichichi "*Galilei Divin Uomo*," Il Saggiatore, Milano, 2001.

D.N. Chorafas, *Science and Technology*, DOI 10.1007/978-3-319-09189-1_1

To the opinion of Max Planck, the German physicist, the basis of science does not lie in the nature of things. A certain dose of abstractness must be admitted at the beginning. It is most useful and productive to stipulate a causal, real outer world (see also Chap. 3 on cause and effect). Causality extends to history and psychology. We must, indeed, have determinism to lay any claim as science, and we should be guided by our feeling of personal freedom.[2]

Planck agreed with Einstein that work on science was far from a finished theory. Quoting from thoughts and statements included in his biography, Planck said that "To some extent (the aforementioned principle) is unsatisfactory but on the other hand it is proper and gratifying, for we will never come to an end, and it would be terrible if we did ... In science, rest is stagnation, rest is death."[3]

Through its experimental function, science is building knowledge, demolishing theories, and developing new ones which, in their turn, will be challenged through new scientific ideas, theories, facts, and experiments. The mission of scientists is to analyze and systematize experimental results extending the frontiers of knowledge till the hand of time demolishes existing concepts opening the field for new ones—the challengers.

In her book "How the Laws of Physics Lie,"[4] published at Oxford in 1983, Nancy Cartwright advances the thesis that science does not describe a profound physical reality. It only advances phenomenal models, valid only in a limited space or conditions. While modeling is indeed an important scientific domain (Chap. 4), this is too narrow a view of science because it tends to leave out three all-important fields:

- Investigation
- Experimentation, and
- The link between science and philosophy.

It also pays no attention to the role of chance in scientific thinking and investigation. Chance is omnipresent: From hitting on an idea (see in Sect. 1.5 laser's development) to making a discovery, but as Louis Pasteur, the great scientist, has said: In the domain of science, chance favors only the prepared mind.

What Pasteur essentially stated in 11 powerful words is that chance event(s) can influence an outcome; therefore, they are all important provided our spirit is able to understand their message and capitalize on it. This requires plenty of training (Chap. 5) and a more sophisticated approach to developing and demolishing scientific theories that might have been necessary otherwise.

Thomas Bayes was an eighteenth century British philosopher. Blaise Pascal was Frenchman. Both were mathematicians and are considered to be early workers on probability theory. The two did not quite agree on how real life should be

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[2] J.L. Heilbron "*The Dilemmas of an Upright Man. Max Planck and the Fortunes of German Science,*" Harvard University Press, Cambridge, 2000.

[3] Idem.

[4] Nancy Cartwright "*How the Laws of Physics Lie,*" Oxford University Press, USA, 1983.

observed. Pascal's concepts were relatively simple and therefore wider understood. He looked at each throw of the dice as independent of the previous one. By contrast, Bayes allowed for the accumulation of experiences that led to the concept of conditional probability: IF…THEN.

Past experiences were to be incorporated into a statistical model in the form of prior assumptions that could vary with circumstances. Bayesian theory maintained that by failure to do so the artifact being developed could be subject to serious mistakes. (At about 500 BC, Confucius, the Chinese philosopher, had expressed this concept in different terms: *If* you wish to know about tomorrow, *then* study the past.)

Scientific ideas and theories supporting them are sometimes invented, forgotten, and reinvented. *Chaos theory* provides an example. Feigenbaum is widely credited as being its inventor, but in reality, the man who laid the foundation of chaos theory has been Jules-Henri Poincaré (1854–1912). He is also famous for his saying: "What is chance for the ignorant is not chance for the scientist. Chance is only the measure of our ignorance."

The reference to the natural philosophy of Galileo, Newton, Bayes, Pascal, and Poincaré, as well as the brilliant scientific ideas they brought forward, is important for still another reason. Science is not omniscience. Scientists know what they learned in school or found by way of research or observed through their daily experience. But not all scientists continue to develop their notions and their skills.

- The acquisition of greater sophistication requires steady effort.
- Most researchers are only as good as their last experiment, and
- When it comes to making important decisions scientists may not possess the competence that is needed.

In addition, like business and all other forms of human enterprise, scientific principles are best applied by people who are both generalists and specialists, amateurs and experts, merchants of dry facts and purveyors of considered conclusions. Scientists who, like Einstein, take a global encompassing view are most valuable. While the views of specialists who see through the prisms of a narrow discipline are necessarily restricted, their contribution too, may be highly significant.

Having said this, when our mission is to broaden the focus of a scientific discipline, we must turn to the interdisciplinary fellow, the generalist, who can use his or her critical faculties to bring together knowledge from different fields. By contrast, a vast array of events related to experimentation requires digging deeper into one field—the one that is the object of the experiment.

1.2 Evolution of Scientific Thought

Robert Oppenheimer, the physicist, has taken the broader possible, flexible, and much more realistic view of science—more so than any of his colleagues. This is a comprehensive and adaptable frame of reference provided by a brilliant brain. Using good sense, Oppenheimer compared the edifice of science to the development of a town.