

Chapter 2

Problem-Solving Revisited

“There is no problem that cannot be solved with a glass of brandy.”

E. Hemingway

2.1 The Role of Philosophy in IPS

Philosophers have the reputation of intellectuals for whom an ability to uncork a wine is the apotheosis of practicality. Nevertheless, I am among those who believe that philosophy has numerous practical benefits. *Inter alia*, philosophy is an ideal subject for learning thinking skills. In this chapter, we will see how IPS can benefit considerably by integrating the argumentative and conceptual focus of philosophy with the rigor and effectiveness of the scientific approach. By integration, of course, is not meant the unification of the different sciences. IPS requires neither the development of common laws for all disciplines nor a common ontology. Yet it implies a set of shared skills and thinking style that make it possible to synthesize diverse knowledge sources from different disciplines and direct them toward the solution of the in situ problem.

2.1.1 *Factual and Conceptual Features*

It has been said that life is problem-solving. It has even been said that, “The primary question about life after death is not whether it is a fact, but even if it is, what problems that really solves.”¹ Leaving afterlife problem-solving for another time and space, let us focus on present life concerns. Problem-solving is a human activity traditionally characterized as a form of thinking, a complex intellectual function, or a higher-order cognitive process that may require the modulation and control of basic or advanced skills (Goldstein and Levin 1987). The various IPS aspects have been studied in

¹ This statement is attributed to Ludwig Wittgenstein.

different fields, such as mathematics, logic, computer science, cognitive analysis, philosophy, sociology, and psychology. There was a time when the search for simplification and mathematical certainty was the dominant feature of a problem-solving approach, thus seriously limiting the domain of sciences (Morowitz 2002). In the real-world, a problem may represent a complex multidisciplinary situation, in which case its solution does not have a clear-cut and obvious meaning. This raises the profound question: What should be the main characteristics of a substantive solution to an in situ problem? Most investigators would agree that the answer to this question depends on one's worldview, conception of reality, ultimate presuppositions (conceptual and methodological), and tools (analytical, computational, and experimental). In this respect, the answer is linked to deeper issues of self-actualization, identity, and purpose that were discussed in Chapter 1.

The philosopher Rom Harré (2002) brings to our attention the crucial distinction between *factual* presumptions (i.e., concerning matters of fact and empirical evidence) and *conceptual* presumptions (concerning the meaning of concepts and the relations between them). With his careful analysis, Harré puts his finger on an important point. Every evidential base (observation, measurement, etc.) underlies a set of conceptual presumptions. The former relies on the latter, in the sense that the conceptual presumptions used to describe the evidence should be free of inconsistencies and contradictions (Section 1.7). This is valid for the same entity as well as for different entities that are related to each other within the boundaries of a specified system. Not only must the evidence obtained about a physical attribute fit the conceptual presumptions underlying this attribute but also the same evidence must not be in conflict with the conceptual presumptions underlying other physically and epistemically related attributes of the system. This important point is not fully appreciated in studies that transcend many fields, such as environmental exposure and health-risk assessment (Section 9.4). In the following, I will describe the science-philosophy affair and its practical value in the IPS setting.

2.1.2 Synthesis of Philosophical and Scientific Perspectives

Scientific IPS benefits significantly from the consideration of philosophical perspectives concerning the matter under investigation. History of science shows that mature disciplines are characterized by the close tie between science and philosophy (Frank 2004). This is true for physics and the fast advancing field of neuroscience as well. Werner Heisenberg discussed philosophy's vital role in the development of quantum physics in his celebrated volume *Physics and Philosophy* (Heisenberg 1958). Despite quantum theory's tremendous success, physicists are unsure about how it should be interpreted; they also realize that they cannot go forward unless they adopt an interpretation that is based on a sound philosophical position. In a similar vein, the neuroscientist Maxwell Bennett (2007: 163) expressed his strong conviction that: "I believe that every first-rate cognitive neuroscience laboratory now needs a very good critical, analytical philosopher."

Very important is philosophy's contribution to the solution of major existential problems linked to the potentially harmful consequences of scientific and technological developments. Modern science and technology have made it possible for certain individuals or small groups to cause – intentionally or unintentionally – the greatest imaginable damage to human civilization at a global scale. The intentional case refers to individuals or groups with a sociopolitical agenda to inflict large-scale destruction (e.g., biological attacks by a group of terrorists against a big city), whereas the unintentional case refers to major accidents (e.g., a nuclear explosion due to human error or miscalculation). The synthesis of philosophical and scientific perspectives can reconsider key concepts and presumptions, develop an adequate problem framework, and generate sustainable solutions that account for the multithematic features (technological, ethical, financial, etc.) of the problem. Given the ethical issues associated with the use of science, the collaboration between philosophy and science could be our only hope to resolve a potential crisis that can threaten the survival of our civilization.

Since science involves human practices that are based on certain presumptions, the role of philosophy is to bring these presumptions to critical scrutiny. As Wittgenstein used to say, "Philosophy unites the knots in our thinking that we have, in a senseless way, put there." This is an issue that amply demonstrates the high *practical* value of philosophy in IPS. An increasing number of people recognize that the failures of many scientific and engineering projects are, in large part, due to the inadequate presumptions taken for granted by the project investigators and the lack of any critical scrutiny of their conceptual and methodological underpinnings. As is well known, philosophy can be also useful in the context of the *demarcation* problem, i.e. the question of how to distinguish between science and pseudoscience. Moreover, owing to its nature, philosophical inquiry can help scientific IPS lay bare some questions about the phenomenon of interest that may have been hidden by the solutions. As far as Epibramatics is concerned, the gist of the whole science–philosophy business may be summarized as follows: Philosophy is able to contribute to what on its face might otherwise appear to be an entire scientific issue, by helping to test and reshape intuition, frame the right questions, and gain a better understanding of key concepts that are driving the solution of the problem of interest. On the other hand, when necessary the philosophy's despair about certain deep issues of human inquiry (such as the possibility of knowledge) is balanced by science's spirit of intellectual optimism.

2.2 Historical Perspectives: From Heraclitus to Kuhn

Given the multidisciplinary character of most contemporary real-world problems, rational agents are obliged to seek novel ways of conceiving, formulating, and subsequently solving the problems in an integrative manner. Under the circumstances, philosophical investigation (a form of conceptual analysis) and scientific inquiry (including quantitative and action-based analysis) are complementary and made for each other. If philosophical experience is of any help, here we review some relevant perspectives developed over time. These are what the views of some

major philosophers on IPS *might* have been according to their teachings. All possibilities are present, since these perspectives may be in complete agreement, properly complementary, or even contradict each other.

2.2.1 *Heraclitus' River*

Heraclitus (540–480 BC) believed that the only thing one can be sure of is that things are not going to stay the same and that everything is continually in flux. The universe changes according to a plan, with which the truly aware agent should cooperate. He used to say that, “One can never step into the same river twice.” He also had offered an insight about randomness when he asserted that the *κόσμος* (kosmos, universe) that appears ordered and harmonious, is in fact a random product. Heraclitus’ relevant quote was: “The fairest description of universe is but a randomly scattered dust-heap.”

In a nutshell, what this all implies for IPS is that the perception of what constitutes an adequate solution changes with time and the varying multithematic context within which the solution is conceived. Otherwise said, a solution is not a fixed objective entity but rather a mental construct that exists in peoples’ minds, and as such, it is influenced by a number of changing factors (environment, experience, and worldview). Hence, according to Heraclitus, a starting point of IPS should be the realization that the solution of an in situ problem is no more stable and fixed than the unstable environment in which it exists and evolves.

2.2.2 *Parmenides Apology*

Parmenides (c. 515–after 450 BC) made a conscious attempt to reconcile the world of appearance (of mortals, of *δόξα*) with the world of truth (of Gods), by explaining aspects of the former as a delusion due to erring mortals (Heidegger 1998). This monumental attempt, which is known as the *Parmenidean apology* (Popper 1998), admits that there is more than meets the eye in the world of appearance. Parmenidean apology exerted major influences on various aspects of human inquiry. One influential case of Parmenidean apology is the subjectivist interpretation of *probability theory*, which makes probability a consequence of human ignorance. The Parmenidean apology of *spatiotemporal analysis* is that because human agents are part of the world system we study and cannot place ourselves outside our four-dimensional environment (three spatial dimensions plus time), we cannot obtain an objective view of space–time. The Parmenidean apology of *thermodynamics* is that we are not fully informed – we are not Maxwell demons, but erring mortals. And last but not least, the Parmenidean apology of *modern physics* is that the observer or “the subject” necessarily invades the world of objective physics and subjectivizes it (in terms of the observer’s apparatus).

Also, Parmenides emphasized the *unity* principle, according to which, matters of knowledge need to be internally harmonious within a complete whole before

they can be judged as reliable. This is what in modern IPS terms is called “consistency.” Scientific reasoning is the capacity to reason and connect items of information, and draw from them new conclusions, therefore extending our knowledge and understanding. As long as knowledge is a fluid thing, a problem–solution can be a “truth-in-the-making” at best. In sciences, the two worlds of Parmenides became the way of reason (*rationalism*) and the way of the senses (*empiricism*). A problem–solution should adequately integrate these two ways of thinking. The relevance of the Parmenidean apology to real-world IPS is multifold: The solution often encounters situations in which the Parmenidean apology offers meaningful and fruitful interpretations, and it results from a thought process seeking maximum knowledge and viewing reason and senses in a unified context.

2.2.3 Socrates’ *Maieutic*

Socrates (469–399 BC) focused his philosophical investigations on humankind and was the first one to propose using *reason* to decide *moral* questions. The two cornerstones of Socrates’ approach were: the methodical and purposeful questioning of the various elements of the issue at hand (e.g., the values, motivations, and perceptions linked to the issue), and the way the understanding of “truth” affects one’s behavior. Socrates’ approach was to “interrogate” his subjects in a way that prompted them to derive their own conclusions about the matter – a dialectic approach that became known as “maieutic” (*Μαιευτική*; Paniagua 1989). In a sense, Socratic’s approach is a negative process of hypothesis elimination in that better hypotheses are found by steadily identifying and eliminating those that lead to contradictions.

In light of Socrates’ approach, the IPS process would be broken down into a series of questions, the answers to which gradually distill the ultimate solution. In other words, deriving a solution to a real-world problem requires a relentless questioning of everything related to the problem in order to obtain a deeper understanding of the relevant values, motivations, and perceptions, and then suggesting combinations of models (physical, biological, sociological, and mathematical), which, acting in synergy, can help answer these questions. This viewpoint has been reconsidered these days by some researchers (e.g., Glass and Hall 2008), although not necessarily in exactly the same spirit as proposed by Socrates. The objective is not simply to solve an individual problem in some established yet mechanistic sense, but hopefully to improve one’s way of thinking and value system, and, on that basis, one’s integrative approach to problem-solving.

2.2.4 Plato’s *Forms and Value Invariance*

Plato (427–347 BC) was the first to propose a theory of knowledge. In the view of many scholars, Plato offered an ingenious compromise between Heraclitus’ flux

and Parmenides' being, associating the former with the empirical and the latter with the intellectual. He viewed reality as a two-part affair, a changing part experienced through our senses and an unchanging or invariant part accessed only through our mental reflections. *Invariance* is one of Plato's ideas that plays a major role in modern physics. According to Paul Dirac (1947: vii), "the important things in the world appear as the invariants." Einstein later regretted that he called his work "Relativity theory" instead of *Invariantentheorie* (Nozick 2001: 78). In his famous allegory of the "Cave and the Divided Line," which is probably the most influential passage in Western philosophy ever written, Plato considered the world of the ephemeral (the shadows on the wall; a superficial world which, in itself, cannot be trusted to show us "the truth"), and the eternal world of *Forms* (that cast the shadows). Almost 2,500 years later, Plato's perspective is adopted in modern physics. According to Jonah Lehrer (Lehrer 2008: 18): "It turned out that Plato's pure forms – those unseen things that gave rise to everything else – were made out of subatomic particles, a surreal collection of electrons, neutrinos, gluons, and quarks of all directions ... We build an \$8 billion underground microscope [Large Hadron Collider] ... We gather specs of near nothingness and then smash them together to re-create the very origins of the universe. We look at those shadows on the wall and can infer the forms that cast them." On the other hand, Plato would probably disagree with Jean Baudrillard's claim that photography has led to "the death of reality." Instead, Plato would view photographs as belonging to the world of the ephemeral, in the sense that they are images of the true reality, which is the world of Forms.

Plato's insight is aware of the critical link between Heraclitus' flux and Parmenides' unity and suggests that a problem–solution should be always viewed not as the ultimate truth but rather as an attempt to infer the (unknowable) reality from the recorded knowledge sources using sound reasoning. A useful IPS approach must have elements of conceptual truth that are invariant to ephemeral changes in its empirical characteristics. That is, to understand a problem, one may need to know the transformations it is invariant under. Nozick (2001), e.g., considers applications of the invariance concept in the solution of problems in a variety of scientific disciplines.

2.2.5 Aristotle's Philosophy of Depths

Aristotle (384–322 BC) promoted a different view than Plato about what can be known. *Φίλτατος ο Πλάτων, φιλτάτη δε η αλήθεια*² he once said, in an effort to distinguish his views from those of his teacher. Aristotle's own teaching dramatized, for the first time, a major split between those (like Plato) who see "reality" as being beyond direct human experience and those (like Aristotle) who see the only

² Dear is Plato, but dearest the truth.

ground for philosophy the world as we can experience it with our senses. According to an intriguing interpretation of Raphael's famous 1511 painting *The School of Athens*, Plato is pointing upward, arguing for his upward-oriented philosophy of heights, whereas Aristotle stands besides him extending his hand over the ground, in an attempt to defend his down-to-earth philosophy of depths.

Aristotle's associated four different causes to a solution: *material* cause, i.e., what the solution represents physically (a quantity, a process, etc.); *efficient* cause, i.e., how the solution is obtained (by means of analogical, taxonomic, or mathematical reasoning); *formal* cause, i.e., the "essence" of the solution (captured in terms of shape, pattern, etc.); and *final* cause, i.e., a goal, purpose, or intention associated with the solution (e.g., maximizing one's intellectual satisfaction, wealth, or pleasure). The last cause is sometimes referred to as a *teleological* feature of the solution and plays a special role in Epibramatics. In addition, Aristotle promoted the view that a solution to a real-world problem should have a function and offer a sustainable benefit over time. That is, a solution *is* what it *does* for its user. A new development here is that a good IPS approach should balance Plato's intangible values with Aristotle's functional benefit.

2.2.6 Descartes' *Cogito, Ergo Sum*

Consensu omnium, René Descartes (1596–1650) brought philosophy into its modern era where the primacy of knowledge is explicitly acknowledged. In this respect, famous is Descartes' motto: *Cogito, ergo sum* (I think, therefore I am). According to Descartes, mental states and empirical findings are distinct and separate (this became known as the "mind–body dualism"). From Descartes onward, physical sciences have relied on the *reductionist* approach of a posteriori causation (cause precedes the effect), whereas a priori causation in the Aristotelian sense was considered unacceptable (Descartes 1641; Plotkin 1993).³

According to Descartes, when one is engaged with the solution of a new problem that presents several unknowns, one needs to use established rules as a practical guide but, also, be prepared that the shattering new insights will compel one to develop a fresh approach. This means that an IPS approach must identify the connection with its user's thoughts and innate ideas, and thereafter be the product of a purely rational (reductionistic) process. During this process, nonmaterial mental states could influence a material problem–solution. How this can be done, without invoking supernatural explanations, remains controversial to this day.

³ Although the teleological explanation has gained ground in modern biological thinking (Lennox, 2000).

2.2.7 *Spinoza's Omni Determinatio Est Negatio*

Baruch Spinoza was one of the most important rationalists of seventeenth century Europe. Spinoza supported the superiority of human reason to the senses, he distinctively opposed Descartes' mind–body dualism, and he came to the conclusion that reason and senses are not separate, being a single identity. Spinoza was a determinist who held that absolutely everything that happens occurs through the operation of necessity (Spinoza's famous motto was, *Omni determinatio est negatio*; that is, all determination is negation). Therefore, human agents should seek to understand the necessary and eternal order of the world, in order to understand both their place in the world and what they ought to do in this world. Spinoza's philosophical system is considered by many thinkers as the purest example of rationalism.

According to Spinoza's line of thinking, how human agents think rationally about problem-solving, and what its empirical manifestation actually is, should be viewed as an integrated whole rather than as two separate entities. "Man is part of Nature," Spinoza famously wrote, "and must follow its laws." That in theory a meaningful IPS approach must satisfy some general principles of reasoning and in practice be consistent with empirical facts should be considered as a *unified entity*. This unification is a central element of Spinoza's philosophy. Therefore, when a theoretical problem–solution is unsatisfactory, it is probably because it is improperly related to the totality of the agent's experience.

2.2.8 *Locke's Tabula Rasa*

John Locke (1632–1710) was probably the first of the British empiricists, and he is considered one of the most influential of Enlightenment thinkers. For Locke, there are two kinds of sense-qualities of a bodily thing: Primary qualities that are quantitative and spatiotemporal (e.g., size, texture, and motion), and secondary qualities that are qualitative and nonspatiotemporal (e.g., color, sound, and taste). Unlike Galileo and Descartes who considered the secondary properties to be subjective (in the mind of the observer), Locke held all qualities to be objective (part of the world). Also, contrary to the Cartesian philosophy, Locke believed that humans are born without innate ideas, i.e., they are born with minds like blank slates (*tabula rasa*). All knowledge is derived from experience through the action of the physical world upon an agent's senses. The theory of *tabula rasa* is not substantiated by scientific findings. Similarly, the idea that both the primary and the secondary qualities of a thing are objective is incorrect, since agents are unaware of the primary qualities except through the medium of the secondary qualities; if the secondary are unreliable (being largely subjective), there is no reason to believe in the actuality of the primary qualities.

To satisfy the Lockean viewpoint, a problem–solution should primarily fit empirical findings ("let the data speak for themselves"), often independent of thought

processes. As the readers know, this is a highly controversial viewpoint (the matter arises in various parts of this book). Empiricism dismisses the Cartesian view that a solution should result from a rational process that accounts for the agent's thoughts and motivations. In a similar way, empiricism contradicts Spinoza's unification of thought process and empirical manifestation. The result is an agglomeration of conflicting theories. Nevertheless, much of mainstream statistics is basically Lockean, producing purely data-driven solutions that often do not escape the fatal confounding of sense knowledge with intellectual knowledge.

2.2.9 *Hume's Skepticism*

Without being as extreme as Locke, the Scottish philosopher David Hume (1711–1776) favored a *skeptical* approach to human inquiry according to which knowledge is restricted to what can be experienced. Unlike Locke, Hume argued that one could form beliefs about matters that are beyond one's experience by using one's imagination, but he was skeptical about claims to knowledge on this basis. A key element of Hume's approach is that he doubted human claims to knowledge by effectively involving psychological considerations into the process. His philosophical question whether inductive reasoning can lead to truth became known as *Hume's problem of induction*.

Hume's skepticism essentially implies that a problem–solution can only be a *probable* one. Accordingly, the solution is based on perceptual knowledge (that comes via direct or indirect experience), and as such, the knowledge is subjective and incomplete. The solution process is inductive, starting with a set of specific empirical findings and developing generalizations that are not certain. An inductive solution fits as closely as possible the data available and produces results (e.g., interpolated and extrapolated attribute values at unobservable points) that are uncertain to a larger or a smaller degree. However, the main justification of induction is that it is expected to work in the future because it has worked in the past, which makes the justification perilously circular. On the other hand, when properly combined with complementary types of reasoning, induction can be a valuable IPS tool under conditions of uncertainty (Section 5.2.1).

2.2.10 *Kant's Synthesis*

Immanuel Kant (1724–1804) explicitly distinguished between the *noumenal* world (world of things in themselves), which remains unknown to us, and the *phenomenal* world (world of appearances), about which we can know certain things.⁴ This is the

⁴The readers may notice the close resemblance with the two worlds of Parmenides.

meaning of Kant's *Ding an sich*; after all, the real-world is infinite complex, whereas a mind is finite. Despite its finiteness, the role of mind is thus critical, since it shapes, categorizes, and organizes the experiences that constitute the phenomenal world (raw data that come from our senses). Kant famously said that, "Our intellect does not draw its laws from nature, but imposes its laws upon Nature." Kant considered as a good solution to a real-world problem that which is the synthesis of the rational and empirical thinking modes. For him, experience without theory is blind, and theory without experience is mere intellectual play. This synthesis was another major step forward that blended in a compelling way what can be thought (inside our brains) and what can be experienced (by means of our senses and tools). And in this way, Kant's work contributed decisively in the resolution of the historical split between Plato's and Aristotle's philosophies concerning what can be known.

Kant's synthesis accounts for the limits of knowledge: IPS is determined by what we are capable of knowing on the basis of the limited means available to us for gathering, assimilating, and using diverse data sources. Hence, a solution to a real-world problem is more about the way our minds work than it is about the way reality really is. Intuition and concepts constitute the elements of all human knowledge, so that neither concepts without an intuition in some way corresponding to them, nor intuition without concepts, can yield knowledge. The solution is determined by the subject (observer) and is not merely an inherent quality of the object (the observed).

2.2.11 *Hegel's Dialectics*

Georg Wilhelm Hegel (1770–1831) believed that any given phenomenon (thesis) contains within itself contradictory aspects (antithesis) that require a movement toward resolution (synthesis). Progress in understanding reality occurs according to a process that has this *dialectical* form. Hence, knowledge is a dynamic culture and not a pre-existing and timeless thing waiting to be discovered.

Hegel's philosophical reference frame implies that an IPS is the outcome of a dialectical process of change that has both an underlying structure and an ultimate goal. In German, this state is called *Geist* (a term that includes a sense of "consciousness" and "spirit"). The thus obtained problem–solution is context-dependent and emanates from the agent's consciousness, which itself is continually changing and developing new concepts and perspectives about important aspects of the real-world. For some Hegelians, the ultimate goal of the dialectical process is a state of understanding and self-fulfillment (which is similar to the Parmenidean *νοεῖν*). In modern IPS, the dialectical goal could be the maximization of a suitable quantity (utility) associated with the problem at hand. It should be mentioned in passing that Hegel's dialectical approach to IPS is similar to Socrates' questioning approach, in the sense that they both involve the possibility of conflict and tension between the opposing views and theses considered.

2.2.12 *Darwin's Evolutionary Adaptation*

For Charles Darwin (1809–1882), *adaptation* is a basic macrofeature of an organism (anatomical structure, physiological pattern, or behavioral trait) formed by a long *evolutionary* process of natural selection and interaction with the organism's environment in a manner that improves its expected chances of survival and reproduction. Otherwise said, Darwin approached philosophical problems through natural history.

The adaptation concept plays a central role in Darwin's evolutionary philosophy, and also has important consequences in IPS, since the brain's ability to acquire, appraise, and synthesize knowledge possesses an adaptational sense. For *evolutionary epistemology* (Section 3.2.1), knowledge development is the outcome of variation and selection processes involving potential knowledge sources. In evolutionary epistemology, a typical pattern of scientific inquiry includes multiple hypotheses generation by various means (variation) and subsequent elimination of those hypotheses that are considered inadequate (selection). In a similar manner, a problem–solution should be adequately adapted to the problem's specific contextual environment, and those potential solutions that fail to do so should be eliminated. For example, an initial solution obtained from core knowledge should be adapted in the light of the case-specific data that become available at a certain stage of the solution process.

2.2.13 *Wittgenstein's Living Practice*

For Ludwig Wittgenstein (1889–1951), philosophy can only address the part of the world that we can perceive by virtue of our senses. His intellectual construct focused on the connections between perception, thought, language, and expression – with the most important element being the centrality of *language*. He demonstrated the many ways in which human language functions in the real-world and distinguished it from the purified (purely logical) language in which the various shades of meaning and subtleties have been eliminated. For Wittgenstein, there is a vital connection between one's *use* of language (what one does with it, when and where one writes/says what one writes/says)⁵ and the *meaning* of the words and symbols one uses. In a sense, language works because it presents a picture of reality. A picture represents something that is or could have been the case had the world turned out differently. Meaning is more than about picturing reality; it is about the different ways language is used and the various ways in which it works.

Since a problem and its solution are expressed in linguistic terms (words, symbols, signs, and concepts are employed to describe phenomena and relations), questions may arise concerning the meaning of these terms and their role in connecting mental and natural states involved in IPS. To discuss the deepest issues

⁵ Which, in a sense, is related to Aristotle's notion of functionality.

of a real-world problem, we need to use a language with all its richness and ability to embrace metaphors and multiplicity and even tolerate paradox. In this sense, the language we use is not a determinate system specified in precise logical terms only, but a *living practice* that can be employed in a number of contexts for a variety of different purposes. Since the solution often depends on the way the problem is described, in many cases the real issue is not that one does not know the solution, but rather that one does not understand the problem. Hence, the problem–solution has not a single meaning, but rather several meanings derived from the different ways in which the solution is expressed linguistically, understood, and used in real-world situations. One should not limit progress by assuming that the solution of a problem necessarily means one thing; rather a solution’s meaning is the combination of all its uses and values.

2.2.14 Popper’s Constructive Criticism

Sir Karl Raimund Popper (1902–1994) has maintained that one simply cannot observe a natural process without first having some theoretical notion of its significance. Popper’s open society functions on the basis of educated skepticism, whereas his famous *falsification* concept (Section 1.1.2) is based on the view that no theory can be proven right, although every theory can be potentially proven wrong (Popper 1934). He viewed falsification as an adequate solution of Hume’s problem of induction, although not everybody agrees with him on this.

According to Popper’s mode of thinking, a scientific problem–solution should be derived in terms of a pluralistic approach that eliminates alternatives by fostering a culture of *constructive criticism*. This is because for Popper falsification constitutes an effective way to distinguish between a scientific and a nonscientific solution (i.e., it can be used as a definite demarcation criterion for IPS purposes). The problem–solution exists independent of the human agent and can be tested through experimentation. It does not represent certain knowledge, and is primarily based on an intellectual model that has “worked” so far but should be replaced when a new, more productive theory is developed. Accordingly, Popper was against induction and rather favored the use of a hypothetico-deductive mode of reasoning in IPS (Section 5.2.1.4). Many of Popper’s views have influenced a considerable number of scientific problem-solvers during the twentieth century and continue to do so up to nowadays.

2.2.15 Kuhn’s Paradigm

While Karl Popper adopted a normative view of epistemology (how scientists should operate), Thomas Kuhn (1922–1996) favored a sociological view of epistemology

(how scientists, in fact, operate as a social system). Kuhn introduced a historical perspective in the study of scientific practice and used the term *paradigm* (Section 1.7.3.2) to describe a particular way of looking at things. The paradigm includes a set of theories, laws, techniques, applications, and instrumentation together. Accordingly, a paradigm is more than a theory but less than a worldview (Kuhn 1962). Remarkably, over the years Kuhn's perspective has been considered in the context of several different disciplines and, at the same time, it has also been misunderstood in many different ways. Kuhn's ideas have been very influential, although more recent scholars argue that he did not pay sufficient attention to the sociological forces that bound a group to its paradigm.

From Kuhn's reference frame, IPS should be generally viewed as a process strictly determined by what Kuhn called *normal science*, i.e., the dominant framework of actual scientific practice that decides the problems worth studying, the theoretical methods to be used, and experiments to be performed in attempting to solve these problems; it establishes the peer-review procedures that control both the boundaries of accepted solutions and their quality. Even data and experiments are subject to different interpretations.⁶ Eventually, it is the accumulated inability of a paradigm to solve new problems and explain the emerging phenomena that make it necessary to replace the paradigm with a new one. However, replacing the old paradigm is usually not as straightforward an affair as it may seem, even if the accumulated evidence against the paradigm is overwhelming. Senior scientists who have built their professional reputation around the old paradigm will go out of their way to defend it, even if strong evidence against it exists, which may explain, e.g., why scientists who defend their use of regression models in environmental exposure studies refuse to participate in an open discussion that could question the usefulness of these models (Section 9.4). As a matter of fact, Kuhn believed that in most cases a new paradigm is accepted, not because of the persuasive force of striking new evidence, but because old scientists die out and young ones, who have no vested interests in the old paradigm and are troubled by its inadequacy, decide to replace it with the new one. That is, paradigm change is a synthesis of scientific and social forces working in parallel.

An interesting Kuhnian phenomenon emerges when in order to win acceptance of their ideas and methods, newcomers in a field decide to change the "evidential context" of their work, i.e., to search for a new evidential context into which their work can fit nicely and be accepted, while avoiding the old context dominated by the orthodox view of the core-group in that context. For example, common is the case of uncertainty modelers who, instead of wasting their time trying to convince in vain the statistics orthodoxy about the value of their work, chose to present their ideas to new audiences of scientists and engineers. The statistics orthodoxy soon becomes aware that these ideas have come to the ears of new audiences, which clearly presents a threat to its authority, and reacts accordingly. This is how the so-called "turf wars" usually start.

⁶As happened with many original thinkers before him, the clerkdom deeply disliked Kuhn's views, because they questioned the merit of the established framework that worked to the advantage of the ruling elites.

2.3 Rethink Everything

Philosophy is often practiced as a form of conceptual analysis, in which case the aim of the previous section was to consider IPS from a variety of philosophical perspectives. Some of the perspectives were built on preceding ones, whereas others sought to overturn established theories. It is worth the effort to develop a conception of what a *solution* to a real-world problem is by incorporating elements of the above philosophical perspectives together with a scientific assessment of the in situ situation.

2.3.1 *Che Fece . . . Il Gran Rifiuto*

Since science can have a significant social component, one should not neglect the fact that searching for something out of the ordinary, like a novel IPS approach, has broader consequences, and one should be prepared to deal with them accordingly.

2.3.1.1 In Berlin You Will not Fit in

As noted earlier, there is nothing that the scientific cabals dislike more than new ideas that could question established practices. Fighting quality, especially when it originates outside their own club, has always been a top priority for the cabals. This has the result that many highly promising young investigators forever remain in the shadows. The situation reminds one of Nicollò Paganini's advice to a brilliant young violinist: "You are very good, but make sure that nobody listens you play the violin."⁷ According to Vilayanur S. Ramachandran (2006: 49), "People who are in the same club engage in mutual admiration and reward each other by funding each other. Their papers are 'peer reviewed' by people in their own clubs, and as a result, no one seriously questions the meaning of the whole enterprise or where it is headed. Anyone who dares to do so is in danger of excommunication by the priesthood, so to speak." It is common knowledge that the "conform-or-perish" rule of the clerkdom strictly demands that its members routinely demonstrate their loyalty by resorting to means closely resembling the medieval obedience most infamously expressed by the act of kissing the *Cardinal's ring*.

As an authoritarian social unit, the established clerkdom has its own rigid behavioral codes that, however shallow they may be, should be religiously observed

⁷ Paganini was a celebrated nineteenth century Italian violinist and composer, considered by many as the greatest violin virtuoso of all time.

and never be violated (Section 1.4.2). The following is a telling incident linked to Ludwig Boltzmann's visit to Berlin, where he was considering a possible faculty appointment. One evening, during dinner Boltzmann picked up the wrong piece of cutlery, at which moment the wife of a Berlin professor turned to him and uttered the fateful phrase: "Herr Boltzmann, in Berlin you will not fit in." David Lindley (2001: 102) infers that, "Some inner hesitation prevented Boltzmann from following through on his acceptance of the Berlin offer." Boltzmann was a pioneer in many fields of scientific inquiry, but his many contributions were recognized after his death, which shows that death can be a good career move for those who are not favored by the power holders of their time.⁸

2.3.1.2 The Big Yes and the Big No

Eventually, a time comes in a Man's life when one has to choose between the big "Yes" or the big "No" to the dilemma imposed by the clerkdom, which is the message of Constantin P. Cavafy's poem *Che fece . . . il gran rifiuto* (Cavafy 2007):⁹

There comes a day for certain types when they
must say the noble Yes – or noble No.
The one who has the Yes within will show
himself prepared by speaking it, to say
that he proceeds on faith and sense of pride.
The one who doesn't have it doesn't fret;
if asked again, he'll still say No, and yet
that proper No must evermore abide.

For those who, despite the odds, chose the big *No*, an adequate analysis of the IPS situation will depend on the honest assessment and careful elaboration of its paradigmatic context, essential concepts, underlying assumptions, and knowledge sources, and not on criteria that merely serve the agenda of the clerkdom that currently dominates the field. On occasion, this big *Yes* is the rock on which attempts to build new theories and better solutions are foundering.

⁸ David Hilbert recognized the importance of the Boltzmann equation and proposed a method for obtaining approximate solutions. Ergodic theory is based on Boltzmann's statistical mechanics concepts. He anticipated Thomas Kuhn's views on scientific revolutions. He applied Charles Darwin's theory to the evolution of the mind, anticipating certain aspects of evolutionary epistemology and the theory of science later proposed by Konrad Lorenz and Karl Popper. "In his realization of the hypothetical character of all our knowledge, Boltzmann was far ahead of his time and perhaps even our time", said Paul Feyerabend.

⁹ Cavafy borrowed his poem's title from Dante's *Inferno* (iii, 60); the title means "Who made. . . the great refusal." Cavafy deliberately omitted the words *per viltà* ("because of cowardice").

2.3.1.3 The Need for a Fresh Look

Before proceeding any further, let us consider a plausible question: Why is a fresh look at problem-solving constantly needed in science? There are at least four inter-related answers to this question. First, ongoing developments in interdisciplinary sciences require that one reconsiders the manner a problem is *conceived* and *presented*. If a problem is conceived in a misleading manner, its solution will probably turn out to be meaningless and utterly useless. In Douglas Adams's book *The Hitch-Hikers Guide to the Galaxy*, the quality of the answers provided by the most powerful computer ever built (the so-called "Deep Thought") depends heavily on the structure of the questions asked. Adequate problem conception and representation should be a synthesis of different viewpoints. If the right questions are asked, one should expect to get the right answer. Otherwise, the situation resembles what in computer science is called GIGO: "Garbage in, garbage out." Second, the target is not so much the solution of closed-system problems (ideal for a preliminary mathematical analysis, yet usually representing unrealistic situations), but rather the solution of in situ *open-system* problems (Section 1.8.2.1). Gregory Chaitin's suggestion is that (Chaitin 2005; 12–13), "You have to shut your eyes and focus on only one tiny little aspect of the problem . . . But after the brief elation of 'victory,' you, or other people who come after you, begin to realize that the problem that you solved was only a toy version of the real problem, one that leaves out significant aspects of the problem . . . And those forgotten aspects of the problem never go away entirely: Instead they just wait patiently outside your cozy little mental construct, biding their time, knowing that at some point someone else is going to have to take them seriously." Third, many in situ problems are messy, perplexing and even contain contradictory elements. Their solution requires that one's thinking mode extends beyond ordinary thinking into the domain of *creative* thinking. This is a serious step, since most mainstream problem–solution techniques are built on the basis of the former rather than the latter thinking mode. And fourth, findings in brain and neuropsychological sciences have significantly affected the way many fields look at themselves and at the problem–solution process (Read 2008). The possibility should be examined that mainstream problem-solving based on the design of a set of general content-independent formal rules is outdated and a fresh look at a *content-dependent* solution approach is necessary. One may plausibly anticipate that an IPS theory designed to fit neuropsychological and behavioral brain features shaped during many years of evolution would be more efficiently implemented by the human brain than the mechanistically designed mainstream approaches.

The take-home message is that in today's world many problems are becoming too large and complex to be confronted by conventional means. In this respect, while physical science has progressed by leaving out the consideration of mental states, this is no longer the case: There is more to real-world problem-solving than is understood by physical science methods alone.

2.3.2 *Problem Formulation and Solution Meaning: Einstein's 19/20 Rule*

I will now focus on the very important yet not sufficiently appreciated fact that in the real-world the greatest obstacles often arise from the way the problem is formulated and the meaning one assigns to its anticipated solution, rather than by finding the right IPS method to solve the problem. To quote Einstein,

If I had 20 days to solve a problem, I would take 19 days to define it.

Likewise, before painting the final form of his masterpiece *Les Femmes d'Alger*, Pablo Picasso spent countless days with preliminary sketches, since for him, "To model an object is to possess it." Ignoring any advice, many contemporary, investigators do not spend sufficient time to explore and understand all the key elements of a new problem, before making an attempt to derive a solution. It is like a new body is brought on the table and dissected before it has had time to cool.

The formulation of many in situ problems requires an integrative discussion of the issues raised by the contributing disciplines about themselves as well as about their relations with others. Decisions made in an integrative manner may address issues like, whether the problem and its solution should be studied from an "inside" subjective perspective or an "outside" objective perspective, and what is the significance of this decision. As a result of this integrative effort the participating investigators may gain new knowledge and ideas to use profitably in their own disciplines or they may find it appropriate to pay more attention to the openness of notions and purposes upon which their disciplines were built.

2.3.2.1 **Travelers' Tales in Cancer Research**

Health sciences provide several high-profile cases in which the scientific effort focuses on the solution of an artificial problem that has little in common with the actual problem. Such is the case of cancer research. In a widely cited article, Clifton Leaf discussed the failure of the war against cancer. For Leaf (2004), cancer research is fundamentally flawed in its orientation. He quoted one of U.S.A.'s most celebrated cancer researchers, Dr. Robert Weinberg of the Massachusetts Institute of Technology: "A fundamental problem which remains to be solved in the whole cancer research effort, in terms of therapies, is that the pre-clinical models of human cancer, in large part, stink." Why then are these inadequate problem perceptions and misleading models still being used?

The answer turns out to be rather simple: these artificial models are "very convenient, easily manipulated," says Vishva Dixit of the Genentech company. Cancer scientists have self-confidently created "animal models" that supposedly mimic an equivalent human disease. These scientists then triumphantly "cure" cancer in these laboratory models. But cell lines and tumors growing in mice are drastically different from spontaneous human tumors. A flawed model is not likely

to yield useful results. Those who closely follow the cancer field have become inured to an endless series of “breakthroughs” in mice that almost never pan out when tried in the clinic. It seems that ordinary humans are a species with which many cancer researchers are unlikely to have had first-hand acquaintance, although, to be fair, they may have heard travelers’ tales about them. “Hundreds of millions of dollars are being wasted every year by drug companies using these models,” says Weinberg. As a result, despite the huge amount of money spent on cancer research (the total amount of funding, from a variety of sources, has been about \$200 billion for the period 1971–2004), the research has become increasingly irrelevant to the real-life problems faced by cancer patients.

2.3.2.2 The Sequence

A problem formulation develops in the agent’s mind as a thought, whereas its physical manifestation is a product of the mental state and the in situ conditions. An adequate formulation must account for the multifaceted characteristics of reality. The sequence involving the three entities, “real-world system Q ,” “problem Π linked to Q ,” and “representation M of Q ,” is not always a clear-cut affair. One may consider several possibilities, two of which are discussed below. These and similar possibilities suggest a distinction between problem-formulation and problem-solving, where each has its own informational needs.

Case 1: A problem Π is carefully defined, and the “right” system Q is chosen that offers a sound framework for solving Π . A model M is developed that represents Q adequately (in some sense), is consistent with the needs of Π , and can be studied with the existing (experimental, analytical or computational) tools. Consider, e.g., the problem Π : *Does the birth control pill cause birth defects to women?* The associated system could be, say, Q : *European white women between 20 and 35 years old*. Then, a model M may use study participants at the county scale and monthly intervals and involve first-order pharmacokinetics (Christakos and Hristopoulos 1998).

Case 2: A real-world system Q exists, and a problem Π linked to Q is subsequently described. Consider, e.g., the real-world system, Q : *San Diego county and the exposure conditions to certain pollutant X*. The corresponding problem may be Π : *Does exposure to X cause cancer to residents of the San Diego county?* A model M may be chosen that combines samples from specific geographical regions and time periods, a pollutant space-time distribution law, and a stochastic toxicology theory.

Notice that in Case 1 the sequence was “ Π - Q - M ,” whereas in Case 2 it was “ Q - Π - M .” The steps involved in each sequence are by no means trivial. A number of issues arise. Is in Case 1 the selected system Q satisfactory for the problem Π ? Should Q include women of all ages, races, and nationalities or should focus on a specific group? Is the model M an adequate choice or a multicompartamental model of higher-order pharmacokinetics should be used? Similar questions may be valid for Case 2. Surely, the investigator’s prime goal should be to develop an adequate

problem-formulation that does not obscure the real issues by piling up irrelevancies around them. Moreover, the matter with some solutions is not that they have a specific aspect (say empirical), but that they have nothing else. Empirical biostatistics based on unexplained correlations, e.g., while useful in capturing elements common in groups of similar systems, does not necessarily capture essential features of the actual open system as expressed by the underlying laws of space–time change, outside influences and dependencies, boundary conditions, and secondary effects. In a large number of cases, a well-established convention is to formally express the representation or model M as follows

$$M(a_i, BIC, X) = 0 \quad (2.1)$$

where a_i ($i = 1, 2, \dots$) are input coefficients, BIC denotes boundary and initial conditions, and X is the attribute of concern that is distributed across space–time. Admittedly, a problem formulation of the form (2.1) is more rigorously established in exact sciences (in which a high level of theorizing combined with adequate experimentation is the norm) rather than in nonexact sciences (where the attention focuses on experiments, and theorizing is rather underdeveloped).

2.3.2.3 Questions of Meaning

Understanding a problem is an authentic act that assigns *meaning* to objects. In a sense, the meaning expresses the mind’s reaction to its inherent decay, just as time imprints body’s resistance to its progressive decay. The conventional problem formulation raises a fundamental question. In light of well-known knowledge reliability issues linked to the measurement (or observation) of a_i and BIC, approximations in the technical form and physical interpretation of X , conceptual uncertainty concerning the model M , and the open-system Q effects, what is the meaning of a solution based on formulation (2.1)? As a matter of fact, a motivation for the development of an improved solution meaning is the realization that the conventional solution concept may suffer from a twofold inadequacy, as follows:

The *abstraction* inadequacy: Reality is viewed as a set of abstract mathematics of the form (2.1). This abstraction, regardless of its usefulness, remains a creation of the human mind rather than reality itself, which means that Eq. (2.1) could be an incomplete in situ representation. Many thinkers raise plausible questions concerning the general validity of current mathematics in real-world circumstances. One of them is Gregory Chaitin (2005: 16): “How much of our current mathematics is habit, and how much is essential? . . . Would mathematics done on another planet by intelligent aliens be similar to or very different from ours?” It is not sufficient that an abstraction is rigorous according to the current mathematical fashion. The real issues are whether this abstraction is relevant, whether it adequately represents the actual problem, and whether it offers insight and points to important directions. These issues are related to language matters, as discussed by Ludwig Wittgenstein and Niels Bohr (Section 3.7). Mathematical abstractions,

including those representing physical laws, are not universal truths corresponding exactly to the real system but rather an approximation valid within restricted domains. Mainstream techniques sometimes try in vain to derive a picture of what a solution should formally look like to fit in with preconceived ideas derived from closed-form considerations of the physical system or past experiments. Under the circumstances, it is possible that a formal solution of the model M has limited similarity with the actual behavior of the in situ problem Π . Typical is the case of so-called “aggressive ignorance”: mathematical models combined with experimental techniques are employed to represent what definitely is a poorly understood phenomenon, in which case the models have little to do with the actual phenomenon they represent, and the experiments have no relevance with the attributes they are supposed to measure. An extreme case of senseless use of mathematics to describe the unknown reality is found in finance and economics. In these fields, many individuals have made a highly profitable career by subscribing to an approach that Nassim N. Taleb (2008a: xviii) calls “dressing up the intellectual fraud with mathematics.”¹⁰

The *solution* inadequacy: One often conceives as problem “solution” the numerical realization χ of the attribute X that is determined according to the formal convention

$$X = \chi : M(\alpha_i, \chi_{BIC}, \chi) = 0 \quad (2.2)$$

where α_i ($i = 1, 2, \dots$) are specified values of the coefficients a_i in Eq. (2.1), and χ_{BIC} denotes the attribute values at the system boundaries and time origin. The crux of the matter is that formulation (2.2) is not necessarily physically meaningful and, as is explained in more detail later, the reason for this is multifold. The first reason is the inadequacy of the abstraction itself. Formal mathematics view (2.1) as a collection of symbols linked in a logical manner, which implies that the solution (2.2) is a matter of applying purely formal definitions and theorems. But, knowing how to solve an equation does not necessarily mean that one comprehends the deeper meaning of what one has solved. A second reason is that the solution (2.2) is restricted by the fact that it must be expressed in terms of the currently available mathematical formalism. This is not always an adequate approach in complex real-world studies given the inherent limitations of the formalism. To put the matter in slightly different terms, the way the problem is formulated also determines the kind of solution one anticipates. If the problem is formulated in terms of deterministic variables, the solution will be expressed in terms of numbers (values of the variables), whereas if the problem is described in terms of shapes (e.g., probability distributions), the solution will be expressed in terms of shapes too. A third reason is that in several cases the solution (2.2) may not even exist in a rigorous sense, which

¹⁰ Yet, one cannot blame mathematics for its inappropriate use by some people, which seems to escape Taleb’s attention. As a result, his otherwise thoughtful book contains some unfair criticisms of the mathematical method.

is kind of paradoxical, since the phenomenon that mathematics are called upon to study is a reality that can be observed and appreciated. Otherwise said, the notion of reality may be beyond the boundaries of known mathematics. In the words of Wolfgang Pauli, “That which we come upon, which is beyond our power of choice, and with which we have to reckon, is what we designate as real.” Approximate numerical schemes that are proposed to replace the mathematical solution may be logically inconsistent. The readers should not have any difficulty guessing the sources of these logical problems. For example, since the exact (analytical) solution is unknown to the investigator, one may question the meaning of the term “approximate.” Indeed, a legitimate question would be: Approximate solution with respect to what?

2.3.2.4 The “Cargo” Solution

Related to matters of solution inadequacy as described above is the so-called *cargo* problem–solution: what may appear to be a solution (it satisfies the problem’s statement in a certain sense) but, nevertheless, lacks the substance that would have made it a real solution. The characterization “cargo” belongs to Richard Feynman. To illustrate the situation in his own unique way, Feynman (1985: 308–317) referred to the case of the aboriginal islanders of the South Pacific. The problem that these islanders had after the Second World War was how to make the U.S. cargo planes return with all kinds of goods. The islanders’ solution to the problem was to erect towers and wooden antennas near the airstrip, act like controllers, and then wait for the planes to come in. This was, clearly, an “apparent” solution: it had a form that seemed to be correct but, nevertheless, it lacked any substance, and so, naturally, in the end no planes came in.

One finds an increasing number of “cargo” studies in the literature. Leo Breiman (1983) described a major U.S. health study that used complex multiple time-series techniques that were nonetheless totally irrelevant to the problem at hand (due to the lack of substantive content, incompatible measurement procedures, and misinterpreted data). Several decades later, this “cargo” mindset continues to characterize corporate geostatistics and its profound neglect of substantive issues. For example, every time Pierre Goovaerts faces a problem, no matter if it is about cancer incidence, exposure assessment, soil properties, crime date, or racial disparities, the answer is always the same: “Krige it” (Goovaerts 1997, 2008, 2009, 2010a, b). Then, if he actually possesses “Midas touch,” as he seems to believe, one would assume that the queues outside Goovaerts’ office are as long as those outside Lenin’s mausoleum during the Soviet era. Similarly, empirical models that routinely focus on unexplained correlations and the outward appearance of physical evidence but neglect its inward significance (e.g., De Gunst et al. 2001; Gelpke and Künsch 2001) should be always considered *cum grano salis*.¹¹ Such models often mistake random noise for information, lack physical substance, and rely on unrealistic technicalities, thus shifting the

¹¹ Commonly used expression meaning “with a grain of salt.”

emphasis of reasoning from scientific truths that are verifiable to “narratives” that can be manufactured. In short, rarely do any interesting results come out of “cargo” studies due to their innate sociocentrism that focuses on trivial formulations of the phenomenon, uses information in a self-serving way, and lacks epistemic essence and substantive interpretation.

2.3.3 *Taking Stock: Four Key Elements*

Metaphorically speaking, the conventional perspective of problem–solution may resemble a machine that operates on Eq. (2.1) according to a set of formal rules to produce solutions of the form of Eq. (2.2). It is increasingly recognized that this perspective does not pay sufficient attention to four critical elements (which, in a way, constitute a restatement of the four plausible answers previously considered in Section 2.3.1.3): (a) knowledge *reliability* issues concerning the applicability of formal constructions (like model M) to in situ situations; (b) *neuropsychological* findings concerning the way the mind functions and its relation to human inquiry (including problem-solving); (c) the lack of an *externalist* perspective, i.e., the paradox that the agent is at the same time observer and part of what is trying to observe and comprehend (Section 1.6); (d) understanding the nature of the problem by examining its *environment*, including the social and informational reality of system Q .

Concerning element (a), knowing the principles and techniques of a scientific field and applying them in a real-world problem can be two different things. For illustration purposes, imagine someone who has an excellent formal knowledge of physics (allowing one to solve all kinds of theoretical problems) and, yet, one cannot apply basic physical laws to address real-world concerns, like driving a car or riding a bicycle. Famous is the case of the great theoretical physicist Werner Heisenberg who almost failed his Doctorate examination because he could not explain how a storage battery works (Powers 1993). Concerning element (b), the fact that the human brain has been a critical factor in human survival for thousands of years should be a good enough reason to consider its main operations in the search for meaning concerning the term “problem–solution.” This is a topic that will keep us busy in various parts of the book. About element (c), there cannot be such a thing as “a true, complete, and unique representation of the real system Q .” That is, there can be no God’s eye view of reality. Such a representation would presuppose, at a minimum, a privileged correct description from an externalist perspective of reality, whereas human agents have only a restricted “internalist” perspective from within reality. Lastly, concerning element (d) solutions that isolate the problem from its environment are often meaningless. Again, let us allow ourselves to use a metaphor: The solution of a problem may vary considerably, depending on its environment just as a plant varies in taste and form depending on the local climate, on the soil in which it is planted, on the fertilizer used, and even on the potential use of grafts that may produce a fruit quite different from its predecessors. Also, in the multidisciplinary (intra- and interdisciplinary) environment of element (d), the agent is an *interpreting*

and an *interpreted* being at the same time. In such cases, the environment contains information that is not limited to one's sensory immediacy.

2.3.4 Different Kinds of Problem–Solutions

The discussion so far clearly shows that in the IPS front, the learning challenges are immense. A solution framework needs to pay sufficient attention to the problem content and context. Hence, a problem–solution should involve (*inter alia*) the use of epistemic tools for conceptual clarification and exploration, for examining the meaning and implications of concepts and argumentation modes, and for considering the realizability of the generated solutions.

2.3.4.1 Problem–Solution Realizability

Concerning the *realizability* of the generated problem–solution, basically one may distinguish between: (i) a solution that is *physically* possible, because it does not violate any physical law; (ii) a solution that is *practically* possible, because it is physically meaningful and we currently possess the technical and other means to materialize it; and (iii) a solution that is *logically* possible, since it does not violate the laws of logic. Clearly, a solution can be physically possible but not practically so (it may be beyond the currently available means). Also, a solution can be logically but not physically or practically possible. In some cases, a problem–solution should not go beyond what is possible in this world, whereas in other cases it is useful to consider solutions that are merely logical. Of course, nothing is absolute in this world: one can find very complex and highly esoteric problems in sciences that are not sufficiently understood by scientists to be classified as above (e.g., nobody possesses a sufficient understanding of the physical underpinnings of the modern M-theory). In such cases, the adequate problem classification becomes clear only when its solution is partially known.

2.3.4.2 Open and Closed Systems Revisited

The classification of the problem–solutions reviewed here also depends on whether the system Q has an open or a closed form. A closed-form system has its significant merits (by abstracting out irrelevant details, important patterns and even principles of Nature may be revealed). We have seen, however, that confusion can arise when one works under the restrictive conditions of a closed system environment and yet one behaves like it is an open system (Section 1.8.2). “There’s always this tension in science that you want to control your variables and you want to know what it is you’re studying. And yet you want to have what we call ecological validity, which is a fancy way to say it has to be like the real-world” (Byrne and Levitin 2007: 46).

Open systems are rather complex systems, i.e., their input parameters are incompletely known, reasoning goes beyond the strict application of formal logic, and uncertain influences and outside dependencies exist. It is a fact of life that very rarely can an open system be understood and described by means of a simple extrapolation from the properties of its basic components. Unlike pure mathematics, which limits itself to the solution of problems representing closed systems, in the vast majority of in situ situations one is concerned with the solution of problems representing open systems. According to Thomas A. Brody (1994: 125), in many cases outside dependencies can be more important than the inside features of the in situ system. When calculating the sea tide, e.g., one includes the positions of the sun and the moon, although they are very far, yet one does not consider the boats floating on that tide.

As we saw in Chapter 1, closed system problems are usually associated with curiosity-based (basic) research, whereas open system (in situ) problems are linked with action-based science. Serious difficulties arise when investigators are actually doing the former kind of research while falsely thinking they are doing the latter. There may be a substantial difference between the cognitive processes, basic skills, and thinking modes used in the solution of problems associated with closed systems and those used in the solution of problems linked to open systems. This situation parallels that observed in neuropsychological studies of the nature of problem-solving: empirical findings and theoretical concepts derived on the basis of simple closed systems (e.g., laboratory tasks) do not necessarily generalize to more complex, real-life problems (i.e., open systems). Unfortunately, this kind of valuable information is not available to many laboratory investigators, since they have isolated themselves within their institutional walls and sectoral silos. Furthermore, the processes underlying creative problem-solving differ across knowledge domains and across levels of expertise (Sternberg 1995). Accordingly, the IPS of an open-system may face significant challenges such as how to account for differences having to do with the way each discipline acquires and communicates knowledge. Physical sciences use mainly mathematical models to express conceptual, observational, and experimental findings. In humanities, there is little resort to mathematical formulas – chiefly, reliance is placed on analogy and metaphor. Briefly speaking, humanities emphasize emotion, sciences cognition, and technologies action.

2.4 Va, Pensiero, Sull' Ali Dorate¹²

In Giuseppe Verdi's famous opera *Nabucco*, the chorus of Hebrew slaves sings: "Va, pensiero, sull' ali dorate." It is a deeply human reaction that in critical moments of life (social, spiritual, professional; collective or intensely personal)

¹² "Fly, thought, on wings of gold" is a song from Giuseppe Verdi's famous opera *Nabucco* (or *Nebuchadnezzar*), which made its debut in 1842, and relates the Biblical story of the captivity of the Hebrews in Babylon during the sixth century BC.

the thoughts that fly are often the people's last resort. As a central element of scientific inquiry, thoughts that fly represent various expressions of creative imagination, among the most significant of which are thought experiments, mental images, and metaphors. Otherwise said, it is sometimes necessary to create a space for thought (Section 10.2.1) where excessive pragmatism and defensiveness can take a back seat while imagination and vision go beyond conventional wisdom to produce new ideas and radical innovations.

2.4.1 *The Color That Fills in the Missing Data Gaps*

A basic component of the IPS process is *imagination*, i.e., the human brain's ability to generate an extraordinary mental life. The importance of imagination can hardly be overemphasized. Relevant is the quote by Jim E. Baggot (2006: 17): "But there is obviously more to our mental lives than the passive impression of an external reality resulting from an ability to observe. Here lies the secret. With our highly developed minds we can also have imagination." Imagination allows conscious living and innovative dreaming while keeping open the access to reality. Imagination is the color that fills in the missing gaps in a data-based description of reality. Thought experiment and metaphor are two basic products of imagination.

The *thought experiment* (*gedankenexperiment*)¹³ is an integral part of the IPS process. Thought experiments have been instrumental in the progress of science and beyond, and they constitute a powerful tool for understanding the world. It is indisputable that thought experiments are a common reasoning device in the context of both formal argumentation and in everyday life (Georgiou 2005). A thought experiment may take various forms that make it possible for the mind to discover things about Nature by sheer intellectual power, independent of empirical evidence (which may be unreliable). In this sense, thought experiments are formalizations of an intuitive grasp of an objective reality. They may also be viewed as arguments based on a proper mix of induction (empirical premises) and deduction (logical and scientific means). Thought experiments often employ closed-system reasoning that starts from empirically justified premises, abstracts out all irrelevant detail, and then uses deductive logic to yield valid conclusions.

Massimo Pigliucci (2006) considered Galileo's famous thought experiment that demonstrates (rather counterintuitively) that two objects of different weight must fall at the same speed. Contrary to popular belief, Galileo never actually climbed the leaning tower of Pisa to do this experiment – he didn't need to. He rather used the power of a thought experiment. Aristotelian physics would have predicted that a heavy body (H) would fall faster than a lighter one (L). But, Galileo's thought experiment goes, suppose we connect the two bodies by a string, thereby making the compound object $H + L$. Following Aristotelian physics, one would predict that

¹³ The term was coined by Ernst Mach at the end of the nineteenth century to describe a specific method of enquiry used by professional scientists as a mental analog to physical experimentation.

$H + L$ should fall faster than H by itself because of the compound weight, i.e., $V_{H+L} > V_L$, where V denotes speed. However, the same logic can be used to claim that the compound body should fall at a slower pace than H because of the drag created by L , so that $V_{H+L} < V_L$. But this yields a contradiction, which means – by *reductio ad absurdum* – that really $V_H = V_L = V_{H+L}$. Neil Armstrong, the first man to set foot on the Moon, dramatically showed the whole world that Galileo’s thought experiment was correct when he let go of a hammer and a feather in the absence of atmospheric friction while standing on the Earth’s satellite, and they hit the Moon’s surface at the same time. Such is the predictive power of thought experiments.

There are thought experiments that are abstract yet tied to physical entities that one can picture (like riding a beam of light). Einstein was well known for developing these kinds of thought experiments. His famous thought experiments concerning the completeness of quantum theory have led to serious debates among physicists that have greatly contributed to the advancement of the field. Other types of creative work may involve thought experiments with a strong visual aspect that contains images of processes and relationships rather than pictures of physical things. Also, thought experiments may rely on entities purely living in an equation world. In neurosciences, John Searle (2003) proposed an intriguing thought experiment, as follows: Imagined an agent in a locked room who receives written sentences in Chinese and uses an instruction manual to generate written sentences in Chinese. The relevant question this thought experiment attempts to address is whether the agent understands Chinese and, more broadly, whether a functionalist theory of mind is correct. Brain sciences benefit considerably from key questions posed by similar thought experiments. Many thinkers justifiably speculate that the well-designed implementation of thought experiments could have saved a lot of time, effort, and resources spent on real experiments.

2.4.2 *The Essence of Metaphor*

The reader may have noticed that in various parts of the preceding sections we have used the term “metaphor.” This is because the use of literary metaphors constitutes a crucial element of theoretical IPS as discussed in this book. The great value of a good metaphor is that it implies an intuitive perception of the similarity in the dissimilar. The word has Greek roots: *meta* (μετά, meaning “beyond”) and *pherein* (φέρειν, “to carry”), i.e., “to carry beyond.” Generally, the essence of a *metaphor* is understanding and experiencing one kind of thing in terms of another (Lakoff and Johnson 2003: 5). A considerable part of human reasoning is metaphorical in nature.¹⁴

In our discussion of the links between science and art (Section 1.9.3), we already considered some intriguing metaphors. The kinds of metaphor people use vary from

¹⁴ Naturally, metaphors are intimately connected with thought experiments.

simple linguistic expressions like “time is money” to thought representations of space–time as a container and a theater. Concerning the latter, the separate space–time metrical structure would be suitable to represent our common sense view of space as a container (within which all events take place) and time as an absolute entity (that registers the successive or simultaneous occurrences of these events); space and time exist independent of natural processes and laws, as a kind of a theater for the natural processes and laws to enact their drama. On the other hand, the basic idea underlying composite space–time is that, the theater (space–time continuum) is intimately linked to its actors (natural processes and laws) and cannot exist independent of them (Chapter 4). Many eminent scientists have emphasized the role of metaphors in scientific inquiry. One of them was Niels Bohr who argued that the intrinsic reality of entities in modern physics (e.g., electrons) was inaccessible to humans, in which case one can only hope to describe these entities in terms of metaphors. In an effort to emphasize the importance of the metaphor, Johann Wolfgang von Goethe famously uttered:

Leave me at least the metaphor, so that I can express myself.

Under the circumstances, it is often a matter of human ingenuity to discover common elements between apparently very different domains of life. Robert Frost described the situation most vividly: “An idea is a feat of association, and the height of it is a good metaphor.” As another example of a metaphor with a powerful message, the readers may imagine an ichthyologist exploring the life of the ocean. The ichthyologist casts a net into the water and brings up a fishy assortment. Surveying the catch, the ichthyologist proceeds in the usual manner of a scientist to systematize what it reveals and arrives at two generalizations: No sea-creature is less than two inches long, and all sea-creatures have gills. These are both true of this catch, and the ichthyologist assumes tentatively that they will remain true however often one repeats it. In applying this metaphor, the catch stands for the body of knowledge that constitutes physical science, and the net for the sensory and intellectual equipment that one uses in obtaining it. The casting of the net corresponds to observation. Knowledge that has not or could not be obtained by observation is not admitted into physical science (Eddington 1967: 16).

2.5 Too Many Data–Too Little Sense, Mr. Grandgrind

Undoubtedly, careful and thoughtful data gathering is an essential ingredient of scientific inquiry. But human life has the nasty habit of transforming a creative activity into a trivial addiction. Considerable caution is then required so that data gathering does not turn into a mind-numbing process or an easy way out of an uncomfortable situation when one dries out of ideas. Lack of ideas is often the “kiss of death” as far as creative inquiry is concerned, since it is not only data that can determine the evolution of ideas, but also the ideas that can generate scientific and technological development.

2.5.1 *The Datacentric Worldview and Its Perils*

The problematic nature of *datacentrism* (data is the whole story and general conclusions fall directly out of particular data) is well understood. In a famous letter to Sir Karl Popper, dated November 9, 1935, Albert Einstein admitted that (Popper 1968: 458),

Altogether I really do not at all like the now fashionable ‘positivistic’ tendency of clinging to what is observable . . . and I think that theory cannot be fabricated out of the results of observation . . . it can only be invented.

Many years later, several serious concerns still emerge about the collection of large amount of data in sciences without a deeper understanding of the underlying mechanisms and scientific principles. Adrian Berry notices that an increasing number of biologists realize that some areas of biology are dominated by mediocrities who are interested only in amassing vast quantities of information and who are hostile to new ideas (Berry 2007: 123). This view is echoed in Mary Midgley’s thought (Midgley 2004: 3): “We do indeed sometimes think of science just as an immense store-cupboard of objective facts, unquestionable data about such things as measurements, temperatures and chemical composition. But a store-cupboard is not, in itself, very exciting. What makes science into something much grander and more interesting than this is the huge, ever-changing imaginative structure of ideas by which scientists contrive to connect, understand and interpret these facts.” Particularly instructive is the case of the discovery of the DNA structure. One of the early investigators was Rosalind Franklin of King’s College, London University. Using X-ray techniques, she had collected vast amounts of data. “Nevertheless, Franklin was unable to produce a meaningful synthesis of her data . . . disdaining a theoretical, less datacentric approach (which she evidently regarded as ‘too flashy’), Franklin failed to see what she had before her” (Ogle 2007: 33). Franklin was probably unaware of Charles Darwin’s confession made back in 1860 (Darwin and Seward 1903: 195):

I have an old belief that a good observer really means a good theorist.

Beyond failing to make important discoveries, the one-sided, datacentric worldview can also cause other kinds of problems. Richard Feynman (1985) gives examples of fudging data not fitting the theory the investigators wanted to prove. “What is missing,” Feynman says, is “utter scientific integrity,” meaning “a kind of utter honesty, a kind of leaning over backwards,” the duty “to report everything you think might make your conclusion invalid,” and “giving details that could throw doubt on your interpretation.”

Feynman’s observation seems to apply in the case of recent studies at the aftermath of the WTC disaster (World Trade Center, New York City). In a series of reports (Jenkins 2006a, b), the EPA biochemist Cate Jenkins openly criticized the scientific validity of experimental results concerning the environmental pollution and health effects following the WTC collapse (Liroy et al. 2002; Yiin et al. 2004). Jenkins even claimed that the inconsistent reports about inhalant alkalinity were part of a cover up by government-funded scientists. The WTC dispute does not

come as a surprise. As noted earlier, if it is not clear within which theoretical framework the experiments are performed, what exactly the experimental conditions are and how they could affect the results of the experiment, then disputable findings are obtained. One can find several examples in the history of science, some of which are rather famous. When Heinrich Hertz, e.g., was trying to prove the existence of radio waves, he did not think that the size of his laboratory was relevant to the experiment (but it was, because of wall echoes). But history teaches only those who are willing to learn, which does not seem to be the case with the WTC aftermath investigation. Alas, those who do not learn a lesson *from* history, history teaches a lesson *to* them, which seems to be the situation with the WTC investigation. This is yet another case of questionable experimental data analysis that could have been avoided if the agencies involved had invested thoughtfully on the integration of theoretical and experimental research, rather than relying on naïve data gathering from different sources. One ought to know that there is an irreducible tension in scientific inquiry: theory is not just the conceptual grounding of practice, it simultaneously accounts for why practice is ultimately doomed to failure. Hence, it is of utmost priority that the design of an *experimentum crucis* involves both the daring abstract thought of a theorist and the measurement skill of an experimentalist. Because experience has showed that when it comes to experimental data, one should be always reminded of Juvenal’s old question: *Quis custodiet ipsos custodies?*¹⁵ Before leaving this section, it is worth noticing that naïve induction can influence certain aspects of human culture, as well. For example, in the far past some ancestors of today’s datacentrists had an accident after they saw a black crow or a black cat, and by generalizing on the basis of these accidental observations they concluded that black crows and cats bring bad luck. This is, indeed, how many superstitions are born.

2.5.2 *Empty Cliches and the Illuminati*

Supporters of the data-messaging and naïve induction techniques often use clichés like “let the data speak for itself,” or “the evidence does not lie.”¹⁶ These are rather empty clichés that have little to do with reality. As Arnold Hermann once noticed (Hermann 2004: 152–153),

The tired adage that ‘the evidence does not lie’ has an impressive, even authoritarian sound, yet it is no less than a myth.

A clear warning against the naïve viewpoint came almost a 100 years ago in the insightful words of Friedrich Nietzsche (1910): “Everything that reaches consciousness is utterly and completely adjusted, simplified, schematized, interpreted.” Nietzsche’s view was shared by Kant, Darwin, Heisenberg, Bohr, Medawar, and

¹⁵ “Who observes the observer?”; *Satirae*, VI, 347.

¹⁶ Some people argue that “if one tortures the data long enough it will finally confess”; which is a cute way of saying that one can prove almost anything if one massages the data long enough.

many other eminent scientists and philosophers. Without underestimating the importance of thoughtful data gathering, mechanical reliance on the data should not be mistaken for objectivity. There are many substantive questions that cannot be answered in terms of data. Which is why, instead of “letting the data speak” and other naiveties, the following chapters focus on approaches that can integrate the language of the data with the language of daring abstract thought.

The ubiquitous *pseudo-practical* individual, petulant and critical, will protest against “sophisticated mathematical developments,” “intellectually challenging theories,” “abstract thinking,” “contemplative analysis,” and the like. Such peevish criticism is anything but practical, of course. By now, it is widely known that many of the simplistic techniques routinely used by the pseudo-practical “experts” lack methodological continuity and maturity, are not interrelated in a way that can offer a sound body of knowledge, and refer to situations with no scientific substance. Corporate science knows all too well that self-styled clichés like “bottom-line” and “no-nonsense practicality” (Goovaerts 1997: vii) are classic throwaway lines with a pleasant populist tinge that satisfy the “limited attention span” requirement. Yet the reasoning mode underlying such sound bites and pseudo-practical slogans is deeply unsatisfactory and inefficient, ignoring the basic principles of space–time change and consistency (physical and logical) between the different data sources. The same reasoning mode de-emphasizes the quality of knowledge in favor of satisfying the need of the “quick and dirty” solution, by which knowledge is encumbered and to which it is subordinate. Adding a small dose of culture into our discussion, the pseudo-practical approach reminds one of Mr. Grandgrind’s teachings in Charles Dickens’ novel *Hard Times*. Mr. Grandgrind taught his children large quantities of facts and statistics, but nothing that was remotely useful.

Why are pseudo-practical datacentrists so deluded? The delusion can be traced to their mistaking unprecedented access to information with the actual consumption of it. Moreover, these practitioners often confuse statistical issues with matters of scientific expertise (Section 9.4). This is largely due to their reliance on the beguiling “quick and dirty” practice, which considers it appropriate to criticize scholarly ideas that one does not fully grasp and to comment about a scientific work without reading it.¹⁷ Some of the “bottom-line” techniques, while seemingly correct in formal terms, have serious methodological problems that undermine their validity. For example, if the ubiquitous “bottom-liners” had their way in astrophysics, one would be expected to obtain all useful scientific findings by looking at stars as finished products with no need to study the processes of star birth, formation, explosion, etc. In other words, the datacentrists who claim that they “let the data speak” are not being really honest. If they actually allow the data to speak, the data would tell an interesting story about the natural mechanisms that produced them, and answer questions about the physical processes represented by the numerical data values. But this is not the goal of the “bottom liners,” who merely constraint the data to “quick and dirty” answers.

¹⁷ In corporate geostatistics, e.g., this code has so much distorted the cognitive abilities of its practitioners, that they seem to have self-appoint themselves the role of “Illuminati.”

As such, the pseudo-practical mindset is distinguished by its remarkable dullness, failing to reach the minds of those who think of something more than the appetites of the hour. This is what Lawrence R. Klein probably had in mind when he criticized the use of purely data-driven techniques, like time-series, in economics (Klein 1970): “The use of an estimated-structural model is clearly superior to any purely time-series analysis that has no explicit behavioral theory built into it.” It is safe to say that econometrics that is not based on substantive knowledge but is purely data-driven or simply assumed can be a risky business. When this sort of knowledge is not available, insistence on the use of these models does not make much sense. It claims to deliver what cannot be delivered under the circumstances, invites potentially serious misinterpretations of the actual phenomenon, and can do a disservice by diverting attention from the real issues. The Microsoft Chairman Bill Gates compared the role of deep thinking against the mechanization of things by saying that (Friedman 2007: 365): “You need to understand things in order to invent beyond them,” a view that directly opposes the naive “bottom line” model. Another well-known example is the mechanistic use of the copula technology. In the banking and insurance industry, e.g., the extensive yet arbitrary implementation of simplistic formulas based on Gaussian copulas has been linked to the 2008 financial meltdown (Salmon 2009). The irony is that many scholars tried to warn the financial practitioners about the serious dangers of using such simplistic yet substanceless formulas. Thomas Mikosch wrote about the copula concept: “I do appreciate that practitioners, in contrast to academic researchers, have to come up with solutions to their risk problems within deadlines and that ‘quick and dirty methods’ cannot always be avoided. Yet one may of course ask how much safety the banking and insurance industry (and maybe the rest of the world) really gains by using the copula concept” (Mikosch 2006a: 4). As a matter of fact, it comes as no surprise that the cemetery of applied science is well stocked with self-styled “bottom-line” and “no-nonsense practicality” techniques. Rather characteristic, in this regard, is the fate of geostatistics. Like Gabriel Garcia Marquez’s short story *Chronicle of a Death Foretold*, for several years geostatistics’ demise was widely known to be imminent but, nonetheless, those who cared about the field felt powerless to stop the demise,¹⁸ which has been attributed to: (a) the complete domination of geostatistics by the corporate perspective, which led to its isolation from major theoretical developments in relevant fields of scientific research and rendered geostatistics unable to reflect on new concepts, abstract ideas, events, and relationships; (b) the lack of an intellectually credible representation, which allowed competing disciplines to hijack its message and claim ownership of much of its contents and scope; and (c) the inner alienation of geostatisticians themselves. The impression shared by most outside observers of the evolution of geostatistics has always been the same: This is a community of individuals who have little in common.

¹⁸ It is, perhaps, a telling fact that more than half a century since its first appearance there is hardly any geostatistics department in American or European universities.

2.5.3 *The Didactic Case of the Deutsche Physik*

As noted earlier, one wonders why naïve empiricists blindly employ such ineffectual techniques based on an uninspiring mechanization that is fatal to thought and style. People suspicious of brute utilitarianism believe that many of the “bottom-liners” have left honest scientific inquiry behind in favor of the sound of the cash register. Other thinkers believe that this sad state of affairs is the consequence of a twofold cause: the naïve empiricists becoming increasingly intolerant to intellectual depth and creative thinking, and the agenda-driven commitment of the decadent elites to support this sort of anti-intellectual attitude.

The above attitude has a rather long history. Famous is the case, e.g., of the brutal assault of the experiment-driven *Deutsche Physik* clerks against theoretical physics, with the hidden agenda to harm prominent Jewish theorists. The ruling elite of experimental *Deutsche Physik* made a systematic attempt to completely eliminate from the face of the Earth some of the best theoretical physicists the world had ever seen, instead claiming the sole legitimacy of experimental physics that was supposed to faithfully collect the bare data and facts of Nature. Those who know twentieth century history can appreciate the grave consequences of this brutal anti-intellectualism. Any resemblance with today’s events and situations is purely coincidental – or maybe is not.

2.5.4 *The Glass and the Mirror*

Once a child asked her father: “Father, what is the value of silver?” The man smiled, took a piece of common glass and carefully placed it in front of his daughter’s eyes. Then he asked his daughter to tell him what she sees. The child looked through the piece of glass and said: “I see houses and trees, the sky, the sea, and other people.” Then the father took the piece of glass and brushed its back with silver. After that he turned to his daughter and said: “Look again, now you can see nothing, except yourself.”

Pseudo-practical minds unhesitatingly chose the mirror, because its reflective surface satisfies their egocentrism and its silver brush represents their narrow-minded cupidity. By focusing on their reflection in the mirror, these minds avoid being challenged by critical thought, constructive criticism, differing perspectives, changing environments, new ideas, and other people’s legitimate concerns. However, one would like to hope that instead of the mirror, many problem-solvers will choose the piece of clean glass, thus assuming the role of a critical thinker with an open-mind, genuine intellectual curiosity, interpenetration, creative imagination, and an innate ability for skepticism and self-criticism. This is the role of non-egocentric individuals (Section 1.11) who possess a sophisticated understanding of the issues needed to neither be the subject of manipulation (by corpomanagers, pseudopractical phonies, “bottom-line” fakes, charlatans, and the like) nor be

deceived in things that really matter in life. *Ουκ ἐπ’ ἄρτω μόνο ζήσεται ἄνθρωπος*,¹⁹ said Matthew, and if he was right, then truth cannot be abandoned to radical deconstructionism, and human existence cannot be limited to the satisfaction of lower needs.

2.6 Paradigm and Via Negativa

Being an expert in the technical literature is highly prized in many disciplines, as it should, whereas originality and creativity are looked on with suspicion, as they should not. In some cases this asymmetry reaches a critical point, which is why the philosopher of mind Colin McGinn chooses to view the situation as a sort of “graduate student mentality” that creates an environment in which “the people are less amusing, shallower, more one-dimensional.” In a certain respect, the matter is summed-up succinctly in Einstein’s well-known statement: “One of the definitions of insanity is to do the same thing over and over and expect a different result.” What Einstein describes is a situation in which all kinds of techniques are employed and expensive experiments are devised, but if they are guided by the same perspective and function within the same inadequate conceptual framework, unsatisfactory results will be obtained again and again. No doubt, many of these results will be published in research journals – the sign of success being the treatment of research topics according to institutionally accepted methods. This is a situation largely favored by the clerkdom because it does not challenge the *status quo*, which means that, if necessary, a discipline must be ready to challenge the established paradigm.²⁰ To follow Blaise Pascal’s advice, “after every truth one must be mindful of the opposite truth,” one must find the courage to adopt a culture that is less “institutionalized” and “corporate,” and more creative and open-minded, even if this implies considerable risk for one’s professional career (promotion, social status, and prestige). But this is the price one has to pay when one lives in decadent times that try people’s souls.

2.6.1 *The Decisive Role of the Paradigm*

To entrench into readers’ minds how much the meaning of an entity depends on the context, let me risk a resort to religion. In a passage from the Gospel according to Luke, Jesus responds to a man as follows: “Why callest thou me good? None is good, save one, that is, God.” Jesus’ response is a classic case of the importance of considering an entity within the adequate context: as a God, Jesus is good, but as a human, He is bad.

¹⁹ “A human being cannot live on bread alone;” *Matthew* 4:4.

²⁰ Section 1.7.3.2 used the term “paradigm” to describe a particular way of looking at things. Scientists develop hypotheses, solve problems, and advance understanding within the specified paradigm.

2.6.1.1 Goodnight Mr. Greenspan

Indeed, an agent's mode of thinking is a contextual matter that is closely associated with the agent's worldview or paradigm (including ultimate presumptions, theoretical background, social conditions, and traditional attitudes). If one (expert or layman) has any doubt about the crucial roles of worldview, paradigm, and mode of thinking, one can look at the testimony of the former Federal Reserve Chair Alan Greenspan at the U.S. Congress. The man, who is considered by many greatly responsible for the financial crisis of 2008, attributed his failure to regulate the financial markets to his inadequate worldview and reasoning mode. For many years the brief passage from Greenspan's testimony (Table 2.1) will remain a prime example of the grave consequences of a flawed worldview.

History repeats itself and has the habit to punish those who choose to ignore this fact. One may recall that President Herbert Hoover's main problem while fighting the Great Depression of 1929 was his flawed worldview. According to Kevin Baker's penetrating insight: "Farsighted as he [Hoover] was . . . he still could not convince himself to take the next step and accept that the basic economic tenets he had believed in all his life were discredited; that something wholly new was required . . . And it was this inability to radically alter his thinking that, ultimately, distinguished Hoover from Franklin Roosevelt. It was FDR, brought up with the entitled, patronizing worldview of a Hudson Valley aristocrat, who was able to overcome attachments to all classes, all theories" (Baker 2009: 34). Unfortunately for Hoover and for the Nation, he chose to espouse the pseudo-pragmatism of the clerkdom of its time and surrender to the usual interests of the powers-that-be rather than cut himself free of the dogmas of the past and realize the much needed new worldview. Which is what FDR finally did after him, thus enabling unprecedented advances in prosperity and quality of life.

Those who do not associate themselves with ahistoricism are able to learn from the fate of the great Byzantine empire. In the Byzantine worldview religion was the

Table 2.1 Passage from Alan Greenspan's testimony at the US Congress (October 23, 2008)

Rep. Henry Waxman: You had the authority to prevent irresponsible lending practices that led to the subprime mortgage crisis. You were advised to do so by many others. And now our whole economy is paying its price. Do you feel that your ideology pushed you to make decisions that you wish you had not made?

Alan Greenspan: Well, remember what an ideology is, is a conceptual framework with the way people deal with reality. Everyone has one. You have to – to exist, you need an ideology. The question is whether it is accurate or not. And what I'm saying to you is, yes, I found a flaw. I don't know how significant or permanent it is, but I've been very distressed by that fact.

Rep. Henry Waxman: You found a flaw in the reality . . .

Alan Greenspan: Flaw in the model that I perceived is the critical functioning structure that defines how the world works, so to speak.

Rep. Henry Waxman: In other words, you found that your view of the world, your ideology, was not right, it was not working?

Alan Greenspan: That's precisely the reason I was shocked, because I had been going for 40 years or more with very considerable evidence that it was working exceptionally well.

dominant force—natural science, geography and the like merely served as minor adjuncts to Biblical explanations of the world. There are several examples of theologians who tried to propose a new worldview that reconciled the physical world with Biblical concepts, but without success, due to the strong resistance of the ruling elites. As a result, Byzantium, unlike the fourteenth century Europe, did not acquire the new worldview (about the concept of time etc.). In this historical context, the birth of the Byzantine Renaissance never took place, despite the favorable conditions for such a birth during the period between tenth and twelfth centuries. In a sense, this was the beginning of the end for the empire.

2.6.1.2 Euclid's Contribution and Marx's Historical Observation

A problem and its solution are always considered within the boundaries of a paradigm; i.e., the problem and its solution may look very different when considered under the lights of different paradigms. The IPS approach may well turn out to be a meaning-dependent process, since the essence of its various concepts is determined by the chosen paradigm. The same biological data, e.g., can be interpreted differently, depending on the underlying evolutionist vs. creationist paradigm. The former may consider the data confirming the Darwinian view (species have involved over millions of years by means of natural selection and genetic variation), whereas the latter will regard the same data as confirming the creationist view (God simultaneously formed all the distinct species several thousands of years ago). The notion of a paradigm emerges in many different facets of life with intriguing consequences. Slowik (2007) suggests that an interesting parallelism can be drawn between a *sonata* and a paradigm. As with physical theories, one has to know and understand the relevant paradigm, classical sonata form, and to know what the relevant musical concepts (e.g., “theme” and “chord”) really mean.

There should then be little doubt that the paradigm and mode of reasoning an investigator employs are crucial IPS components. In fact, they are often more important than any other solution component. The readers may find it interesting that, highly significant as it was, plane geometry was Euclid's second most important contribution. His most important contribution was the introduction of a way of thinking known as “axiomatic reasoning.” An investigator's mode of reasoning can restrict the statement of the problem, the questions that can be asked about the problem, and the solutions that can be obtained. An improved reasoning mode may lead to a formulation of the problem that brings the investigator suddenly up against the deepest questions of knowledge. Get to the root of the problem, which can demonstrate the necessity of bringing multiple disciplines and crafts together. And reveal whether the necessary pieces (databases, techniques, etc.) are in place yet for a problem–solution to be possible. Incidentally, Karl Marx (1859) had made an interesting historical observation: “Mankind always takes up only such problems as it can solve, since closer examination will always show that the problem itself arises only when the material conditions for its solution are already present or at least in the course of formation.”

2.6.1.3 The Role of Consciousness in Scientific Explanation

The reasoning mode is at the heart of the debate concerning the hierarchy of scientific explanation. The mode known as *reductionism*, e.g., seeks to reduce a problem to the underlying science (Section 2.2.6). In this way, psychological phenomena are to be explained in biological terms; biological phenomena, in turn, are considered in terms of chemistry; the latter is described using basic notions of atomic physics, whereas physics itself relies on solid empirical ground (Fig. 2.1a). With the advent of quantum physics, the classical hierarchy was challenged by the modern hierarchy that replaced “empirical facts” with “consciousness” (Fig. 2.1b). Remarkably, as early as 1932, John von Neuman (1932) showed that quantum mechanics makes inevitable the serious consideration of consciousness by physics. Since then, physics rests on the wavefunction collapse by agent’s observation, which implies that one needs to add a somewhat “cloudy” consciousness at the base of the reductionist pyramid. Consciousness in an IPS setting is a notion that involves oneself within one’s environmental context (Section 3.2.3ff).

Yet another crucial element of the reasoning mode is the serious consideration of rigorous testing of the solution obtained. A common solution testing is in terms of some kind of experimentation or observation campaign. Comparative analyses of theoretical derivations vs. experimental (observational) results are considered an integral part of the problem-solving process and have worked well in many studies (see, e.g., the works of Biryukov and Slekhova 1980; Will 1993; Bronnikov et al. 1996; Luini 1998; Dumin et al. 2000; Willer and Walker 2007). In some other cases, however, the comparative analysis was poorly conceived, ill-designed, and scientifically meaningless. Typical in this respect are environmental studies that emphasize a certain version of “brute force” engineering at the expense of basic science (e.g., Wilson 1993, 1994; Szilagyí and Parlange 1998; Zheng and Gorelick 2003). As a rule, the underlying comparative methodology of this kind of study is internally inconsistent and logically contradictory, whereas theory and experiment are noticeably incommensurable (Section 1.7.3.2): What is measured is not what is implied by the corresponding theory, the comparative setup is unable to translate the theoretical concepts into substantive experimental quantities, and there is no sufficient justification why the theoretical solution should be tested by means of its adequate fit to the specific experimental result and not the other way around. This is a process that routinely produces masterpieces of banality in which the underlying

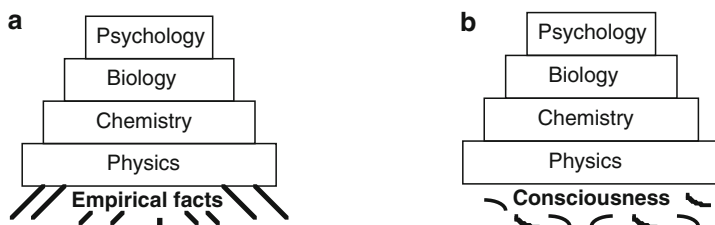


Fig. 2.1 Hierarchies of scientific explanation, (a) classical and (b) modern (reconstructed and modified from Rosenblum and Kuttner 2006)

reasoning is so meaningless and irrelevant that is probably best characterized by the phrase “saving fish from drowning.”²¹

2.6.1.4 Critical and Creative Thinking Modes

The above considerations point to the real possibility, already hinted in [Section 2.3.1.3](#), that certain problems are so perplexing and even intractable that their solution may require that the investigator’s thinking mode extend beyond ordinary critical thinking into the domain of *creative* thinking. This is a serious development, since most mainstream problem–solution techniques (in terms of mathematics and statistics) have been built on the basis of the former rather than the latter mode of thinking.

Critical thinking is based on logical, structured, and systematic reasoning, which makes it a perfect tool for well-defined problems that require dissecting minute details. However, these same highly effective characteristics of critical thinking make it inadequate when a new perspective is needed to attack an otherwise intractable problem. This is because critical thinking operates within specific boundaries (“within the box,” as is usually said) that often involves single-minded patterns of automatic thought. Creative thinking, on the other hand, requires that the agent thinks “outside the box” in order to find and assess the hidden assumptions that limit one’s problem-solving abilities and generate new and unexpected solutions. The suggestion that during creative thinking certain parts of the brain linked to ordinary thinking are shut down is supported by experimental brain studies (e.g., a number of studies have shown that during creative thinking the agent’s prefrontal cortex, the brain’s reasoning and conscious control center, is not functioning; Limb and Braun 2008). Nonetheless, critical and creative modes are often interrelated: Creative thinking (a divergent process that generates all possible ideas) precedes critical reasoning (a convergent process that analyzes the ideas and evaluates their relative merits).

2.6.2 *Learning Through Unlearning: Like Howling Bullets at Crux Moments*

It was disappointing to discover in the 1990s that the sophisticated mathematics of diagrammatic theory and high-order perturbation analysis could not be used efficiently in the realistic study of flow and transport in subsurface media (e.g., Christakos et al. 1995), mainly because this is a poorly understood field that has suffered in the hands of outdated hydrogeology. In other words, one was dealing with a rather typical case of trying to use powerful mathematics to solve a physically ill-defined in situ problem. Because of misinterpreted natural heterogeneities,

²¹ “Does anyone really care?” Probably no. In the corporatism era what counts is the ability to impress your colleagues not with your research findings but with your new luxury car. At least, if the car’s technology is environment-friendly, the investment of the funding agency may not go completely astray.

unaccounted uncertainty sources across multiple scales, discredited measurement tools, and inadequate conceptual models that characterized the description of the phenomenon, it has led different authors to understand quite different things by it. The above episode shows that without ignoring the positive elements of an established paradigm, it is sometimes the case that the only road to new understanding is *via negativa*: much of learning is done through unlearning of what is established within the boundaries of the current paradigm, yet outdated (Schlesinger 1991).

Part of the difficulty of certain paradigms (like that of subsurface flow and transport above) is that they persist in talking about modern problems in an outmoded vocabulary. As Thomas Kuhn observed, the scientific establishment usually evaluates research solely on the basis of the potential contributions to the dominant paradigm; any ideas, proposals, or results that question the paradigm are rarely welcomed (Fuller 2006). In many cases involving novel phenomena and previously unobserved evidence, the solution of the associated problems is not simply a matter of established technical rules and mathematical proofs. What is needed is a new and clear view, which implies that an original thinker should reject the “conform-or-perish” approach of the cabals. Kurt Gödel, Ludwig Wittgenstein, and others have demonstrated that questions related to the nature of mathematics cannot be answered by means of mathematical constructs. Also, according to many investigators, an answer to the question of life cannot be obtained merely by logical and scientific means. Human minds have boundaries, and humans may not yet be advanced enough in their evolution to solve certain kinds of problems.

In view of the above considerations, an investigator should view IPS in a context that mimics the richness and interconnectedness of the knowledge sources available as well as the mental functions inherent in creative thinking. In other words, the reader may find that the following comments are worth examining: An issue of serious consideration is whether it actually constitutes a more realistic approach to invoke “optimal brains” (i.e., capable of searching for solutions that optimize meaningful epistemic goals) rather than to merely seek “optimal solutions” (in some ontic sense of “accuracy” and “speed,” which may be inadequate under real-world conditions of uncertainty and incomplete knowledge). Any problem–solution is a mental process, and as such, it is based on human consciousness. The study of consciousness involves neuroscience, mathematics, psychology, philosophy, cognitive science, and computer engineering. Hence, it makes perfect sense that in setting up the appropriate paradigm the agent should fuse ideas and developments from these fields.

Often a problem–solution is based on new ideas that arrive like howling bullets at crux moments and split the face of the problem wide open, exposing concealed aspects and clarifying previously unexplained facts. On the one hand, the ideas may appear as precisely what was needed at their crucial point of entry. On the other hand, the ideas may appear at the present but with a sense of coming from the future. Whatever the case may be, it requires a certain level of mental finesse and self-cultivation on behalf of the investigator to appreciate the unique moments of innovation and creativity. Self-styled “practicality,” overrated “common sense,” and other fixations of single-minded individuals (Section 2.5) are completely inadequate and even irrelevant in such cases. In the following chapters, we turn our attention to the development of the conceptual Epibrainmatics framework.



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Integrative Problem-Solving in a Time of Decadence

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