Chapter xx

Science and The Spectrum of Critical Thinking

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"The term 'critical thinking' is a bit like the Euro: a form of currency that not long ago many were eager to adopt but that has proven troublesome to maintain. And in both cases, the Greeks bear an outsized portion of the blame."

Peter Wood [1]

Summary

Since the 19th century, the scientific method has crystallized as the embodiment of scientific inquiry. But this paradigm of rigor is not confined to the natural sciences, and it has contributed to a sense of scientific "exceptionalism," which obscures the deep connections between scientific and other kinds of thought. The scientific method has also indirectly given rise to the complex and contested idea of "critical thinking." Both the scientific method and critical thinking are applications of logic and related forms of rationality that date to the Ancient Greeks. The full spectrum of critical/rational thinking includes logic, informal logic, and systemic or analytic thinking. This common core is shared by the natural sciences and other domains of inquiry share, and it is based on following rules, reasons, and intellectual best practices.

Keywords: *Analysis, Complexity, Critical thinking, Informal logic, Logic, Rationality, Science, Scientific method*

1. Introduction

The scope of this chapter, as the title suggests, goes beyond the domain of science. But its overarching theme is that the scientific and non-scientific realms are deeply integrated spheres of knowledge. The familiar academic boundaries between (for example) the natural sciences, the social sciences, and the humanities, while useful and important, also obscure deep connections. And it is in the higher realm of thinking–how we think, by what rules, and why, as opposed to what we think about–that such connections come to light.

Exploring these connections means viewing science within a larger intellectual context: the context of rational thinking in general. But it is a context in which the scientific enterprise is firmly embedded. In other words, science is a crucial part of organized learning–and indeed of the liberal arts–and a part that is integral to the whole.

I do not say this merely because science is part of virtually every liberal arts curriculum or because the scientific method is a paradigm of human rationality, nor again because technology is a growth sector in the contemporary knowledge economy. All of these statements are true. It is likewise true that all scientists are citizens, that all citizens are affected by science and need to make informed decisions about it, and that no comprehensive approach to education can leave nature out of the equation. But most of all, science is crucial to liberal learning, and vice versa, because they are organized under the same umbrella of rationality.

The general public tends to think of the scientific method as the singular characteristic of the scientific enterprise that distinguishes it from other kinds of thought and knowledge. But the scientific method is itself a complex idea, variously practiced. In general form, it is the systematic process of observing and measuring, experimenting, forming and testing hypotheses, rigorous computation, and unbiased acceptance of the results, however uncertain or tentative. This method does not result from the conduct of scientific research or inquiry. Rather, science itself is predicated upon the method, which is an extension of logic and thus of philosophy, as the study of thought. It is not the method of thinking, per se, that distinguishes science from other forms of inquiry: it is the object, which is physical nature, and humankind as part of nature.

To say that all systematic thinking, scientific or otherwise, ultimately derives from philosophy is not to privilege philosophy arbitrarily; it is a historical fact and one that is not hard to explain. Philosophy, to the Greeks, meant not just what we call philosophy today, but the more general "love of wisdom," out of which the systematic study of thought emerged and gave rise to the sciences and many other disciplines (mathematics, history, literature, and drama got started on their own). The most important figure in that emergence was Aristotle, who, building on Plato and the pre-Socratic thinkers, started philosophy on its career as thinking about thinking. Significantly, Aristotle pioneered the study of both logic and biology.

The aim of this chapter, then, is to suggest that the distinction between scientific and other forms of thinking is an important but limited one. On the one hand, the scientific method, as a paradigm of rational thinking put into practice, is rooted in logic and applicable to other areas of inquiry, particularly the social sciences, which study human behavior and institutions. And conversely, the entire range of skills, principles, rules, and best practices that define human thinking in general–or at least intellectual pursuits and higher learning–is intrinsic to the pursuit of scientific knowledge. Those principles and guidelines are used interchangeably across the disciplines of open inquiry and form the essential unifying elements: the constitution, as it were, of the republic of learning. In mapping those forms of rationality, I will offer only brief and condensed overviews of each because it is the map itself, not the vast territory it aims to survey, that is at issue here.

In addition to those constituting methods, there are certain "master concepts" that apply across the disciplines, scientific and otherwise. One is causality: scientists are not alone in recognizing–and puzzling over–the law of cause-and-effect. Another is language itself, which we need to use with care regardless of what we are thinking about because it is the vehicle of virtually all human thought. A third master concept, as I will suggest later on, is complexity. But our main focus is on the spectrum of critical thinking.

2. The Unity of Science

What is unique about science is the ontological unity of its subject matter, which is nature. The French philosopher Maurice Merleau-Ponty observed that "there is only one history and one world." Likewise, there is only one nature–although there may be many theories, hypotheses,

conjectures, interpretations, or conflicting data before common provisional truths are attained. Scientists, like all experts, disagree about many things. But their debates are in principle resolvable through experimentation and fact-gathering. There remain some big questions that science has yet to answer. We do not fully understand the origins or destiny of the universe (or whether it is a single universe), the nature of time, or the riddle of human consciousness. But we agree about what we are trying to understand and that any such understanding would apply universally.

Because of this homogeneity, science, like mathematics and logic, is in principle observer-independent. It appears to be governed by universal laws, such as those of gravity, motion, and thermodynamics. There is one temperature at which water boils, and all objects fall at the same rate. Thus, for all its disparate tentacles of inquiry, science is a unified enterprise with the common goal of understanding nature, and it is conducted using shared tools, techniques, and methodologies. "We may see the world, nature, science, in different ways," writes the historian Jill Lepore, "but we are looking at the same things. So a degree of workable consensus is at least possible" [2]. Scientific laws (until they are upended by paradigm-shifting breakthroughs), and the truths we glean from nature using appropriate methodological rigor, are not contestable. They hold for everyone. Based on facts and methods that are shareable across space and time (albeit subject to revision), science is about interpreting the universal language of nature.

Scientists, to be clear, are flawed, limited, and subjective creatures like the rest of us. But this singular language–and the limited forms of objectivity that go with it–have given rise to a kind of scientific exceptionalism since the 19th century, when the term "science" was first used in English in the modern sense. This exceptionalism is enhanced by the close connections between science and mathematics and by the fact that science makes visible incremental progress, constructing knowledge by accretion through discovery, invention, experiment, and endless theoretical revision and refinement. The fruits of such progress are widely experienced, for better and for worse, in the form of technology. Its "shiny objects" include the computer I am writing on.

Science's exceptionalism is a source of awe and envy among non-scientists–awe and envy that are arguably misplaced and even destructive. Scientism, the overvaluing of science, is as

dangerous to society as pseudo-science or (worse) the undervaluing of science that we are witnessing today. Historians, philosophers, economists, and literary scholars have equally valid intellectual missions. But that is a subject for another occasion. There are radically different kinds of knowledge, and we need and pursue them all. But there are not radically different human minds or kinds of thinking.

3. Defining Rationality

What is rationality, besides being the great common denominator? The concept itself is broad and diffuse, and so the question must be answered in different and overlapping ways at different levels. We can start by saying: rationality is thinking or acting according to rules or reasons. Already there is a clear (but not an absolute) distinction between practical and intellectual rationality. Practical reasoning is about finding the most economical means to given ends in the world; it includes any deliberate action intended to further an end or (in a stronger form) to further it in the most efficient way. Intellectual reasoning is about organizing our thought, irrespective of particular ends. Science clearly combines practical and intellectual reasoning. We will focus here on intellectual rationality, which, as I will suggest, can be usefully equated with critical thinking.

Again, to reason is, most fundamentally, *to think or act according to rules or reasons*. It is essentially a form of community–just as language, its vehicle, is a form of community–because rules and reasons, like words and grammar, are shared devices for communication and coordinated action. To reason is also to *generalize*–and to commute between the more general and the more particular. To reason is to *relate* things, not just to individuate them: to connect the dots and not simply to collect the dots. Yet we cannot individuate things without also implicitly relating them.

We cannot even experience consciousness (let alone use tools such as language or other symbolic systems–mathematics, formal logic, alphabets, codes, and so forth) without certain basic forms of reasoning, such as those necessary to identify objects, properties, or events in time. Consciousness itself, therefore, involves some ratiocination. We individuate the “dots” by comparing and contrasting them with other dots, enabling us to distinguish, for example, between you and me or up and down. And we look for the connecting patterns.

To reason intellectually is to categorize and compare; to find similarity amid difference and difference amid similarity. To reason is to critically examine our categories and comparisons metacognitively. We reason deductively to achieve consistency in our propositions; we reason inductively to form tenable generalizations about the world. To reason is also to distinguish between appearance and reality (something scientists do all the time). To reason is to set values or biases aside, where appropriate, while recognizing that reasoning is not an end in itself but a system, a common language, instrumental to our personal or shared ends.

Finally, to reason is to think both *systematically* (by arguing, exploring, or explaining, in linked steps connected by rules or reasons, and producing a path toward some end) and *systemically* (by seeing how things are connected and patterned–how dots connect). The "spectrum of critical thinking" that I will describe ranges from the systematic to the systemic. As we shall see, these various descriptions of rationality interrelate and overlap, but they cannot be reduced to a single principle or idea. Rationality is rather an example of Ludwig Wittgenstein's idea of "family resemblance:" a bundle of defining features, not all of which are present in every instance.

4. The Various Definitions–and Strange History–of Critical Thinking

Like "rationality," "critical thinking" is a complex concept that cannot be reduced to a simple definition. And as educators have struggled to define it, critical thinking has had a strange and somewhat tortuous history. It is quite recent history, yet with an ancient pedigree, rooted in philosophy and specifically in logic, rhetoric, and dialectic, dating back to the Greeks. Logic, rhetoric, and grammar formed the original liberal arts "Trivium" in late Antiquity.

A crude but helpful way of distinguishing critical thinking from philosophy proper is this: whereas philosophy involves metacognition (thinking about thinking) in the abstract, critical thinking is focused on the here-and-now: it is about your thinking, mine, or someone else's in a particular context. In the best sense, it is philosophy-on-the-fly: not a substitute for philosophy, but a baseline of intellectual rigor that imports philosophy into all other fields.

Despite that pedigree and its focus on intellectual rigor, "critical thinking" as commonly understood is something of an academic orphan. It is largely ignored by philosophers, who tend to view it as literary scholars view grammar or as mathematicians see arithmetic: as something

too elementary to be worthy of their attention. Its very breadth and relevance seem to work against it. But intellectual rigor is not just for philosophers–or scientists. It, too, is a universal language.

The term "critical thinking" is less than a century old. Its exact date of birth is unclear, but it appears to have emerged in the 1930s [3]. Earlier works refer to "scientific thinking" in attempting to extend the rigor of the scientific method beyond the sciences. John Dewey, one of America's greatest philosophers, talked about "reflective thinking" in much the same way. So there is at least a blurry line of historical influence linking the ideas of "scientific method," "scientific thinking," and "critical thinking." But "critical thinking" has meant different things to different people. Many scholars confine it to informal logic, which (as we shall see) in turn embraces a variety of guidelines for sound thinking–a conventional definition that, I will suggest, is too narrow.

Given these fissures and destabilizing factors, it is not surprising that critical thinking has had a checkered career in American academia and has been largely marginalized into an academic ghetto. That ghetto has produced some good scholarship, especially in the 1980s and '90s. It has hosted a long-running dispute about whether critical thinking should be taught as a stand-alone subject or incorporated into the teaching of everything else. Useful recent works on the subject include Tim John Moore's *Critical Thinking and Language* (2011) and Rolf Dobelli's *The Art of Thinking Clearly (2013)*, a catalog of the fallacies, faults, and biases of informal logic.

My own approach is to stipulate a broader definition of critical thinking that equates it with the entire spectrum of rationality, including formal logic, the varieties of informal logic, and analytic (or systemic) thinking. It is useful to distinguish these forms of rationality but also to recognize the continuum that they represent. Narrower definitions that confine critical thinking to a more limited skill-set (the composition of which is in any case controversial) ignore the critical functions of logic on the one hand and analytic thinking on the other.

5. Logic is Where We Start From

The quintessential form of systematic thinking (along with mathematics) is formal logic. Although consciousness entails some baseline rationality, we do not begin life as logicians. We begin, rather, by individuating objects and events. But as a rule-based system with specific,

important, and limited purposes, logic is where a map of critical thinking begins. From there, we will proceed to informal logic, with its loosely divisible subtypes, and then to the more advanced form of critical thinking that presupposes these: systemic (or analytic) thinking.

To begin with a capsule definition: logic is the study and application of rules governing the relationships between propositions of various kinds, the types of those relationships, and how propositions connect to form valid arguments. As such, logic tells us nothing new or factual about the world. It does not tell us whether propositions are true or false, interesting or dull, important or trivial, relevant or irrelevant to a particular argument or line of inquiry. It merely gauges the structural soundness of our thinking: whether the links *between* those propositions are valid; and that is enough to make it Ground Zero of critical thinking.

When we speak of "logical truths," we are not talking about truth *per se* but about logical validity. A logically valid argument may contain false premises and/or false conclusions, as long as the conclusions follow from the premises. Logic thus concerns the preservation of truth across argumentative steps, not its discovery [4]. In a logically *valid* argument, the conclusion is true if the premises are true. In a *sound* argument, both the premises and the conclusion are true. Thus, the classic logical syllogism: *All bachelors are men; Socrates is a bachelor; therefore, Socrates is a man.* Or again: all pizzas are round; *x* is a pizza; therefore, *x* is round. It is a valid deduction–even though Sicilian pizza is not round.

For truth, or any approximation of it, we need to consult facts that we can agree on; inferences or generalizations based on facts; and inductive arguments, which are empirical statements of probability about the future based on experience. Inference and induction tell us something about the world but do not carry the weight of necessary (logical) truth. As the philosopher Bernard Williams observes, if you have been swindled at cards multiple times by strangers on a train bound for the racetrack, you might be wise not to play cards on that train [5]. It almost sounds like common sense.

Like *critical thinking*, however, terms such as *logic*, *rhetoric*, and *dialectic* have been used over time in various and often overlapping ways. All involve the analysis of language but for different purposes. We might think of logic as a tree with a trunk, branches, roots, underlying soil, and a history of growth and entanglement with neighboring conceptual trees.

Formal or deductive logic, as noted, begins with Aristotle. Since the late-19th century, more recent branches have focused on its relationship to mathematics and to language. Logic and rhetoric share a long history and a kind of sibling rivalry since their birth. Rhetoric, which focuses on the art of argumentation and persuasion, got a head start, dating back to the Sophists, Plato, and beyond. Logic gained the upper hand in medieval thought, while rhetoric enjoyed a resurgence during the Renaissance.

Both are alive and well today, with different but sometimes compatible aims. Whereas logic is about the *means* of speech–above all, formal consistency and avoiding contradiction in using language–rhetoric focuses primarily on the *ends* of speech: the best ways of saying things and winning arguments. Thus, rhetoric is more akin to (and largely subsumed within) the types of critical thinking associated with "informal logic." Rhetoric has an obvious democratic function because democracy requires argument and persuasion. But rhetoric also has commercial and polemical functions that are at once inherent in, and potentially inimical to, democracy: the use of deception or manipulation to persuade you to do something, buy something, believe something, or vote for someone. It is akin to what Cordelia in "King Lear" [I, i] calls "that glib and oily art/To speak and purpose not."

In ordinary language, we tend to obey the laws of formal logic almost intuitively. Logical contradictions have a way of leaping out at us because they center on inconsistencies in how we use words based on their definitions. Similarly, most of us do not remember much grammar from high school; we learn it mostly by reading, writing, and hearing our mother's voice correcting us. The rules of formal logic are like roadside barriers that keep us from going over the cliff into an abyss of nonsense or self-contradiction. The guidelines of informal logic are more like rules of the road that keep us from straying across the median or otherwise endangering our reasoning. These rules are many and varied, and unlike formal logic, they cannot be reduced to a fixed set or system.

6. Other Senses of "Logic"

We do not always use the English words "logic" and "logical" in this strict sense. For example, there is the informal usage that means something more akin to common sense: it roughly equates with what is rational, sensible, practical, plausible, or obvious. Calling something the

"logical thing to do" does not mean it is the logically valid thing to do; there is never a logically valid thing to do. But there is often a sensible or practical thing to do to advance particular ends. Formal logic means something else entirely.

Another sense of logic refers to the internal rules, laws, or patterns that define particular systems or phenomena: for instance, when one speaks of "the logic of scientific discovery" or "the logic of globalized competition" [6]. To talk about "the logic of something" is to ask the most general questions about it: What laws govern it? What are its essential parts, and how do they relate? How does it change, and what are its causes and effects? This is the logic of organization; it is a form of systemic thinking (to be discussed), as distinct from (but predicated upon) systematic thinking.

Finally, there is another intermediary sense of "logic" and "logical" between the poles of deduction and common sense. It identifies a class of relationships–that is, of distinctions and connections–that we make with ease, if not by necessity, because they map essential divisions or polarities in our grasp of the world, and accordingly, clear definitional and categorical boundaries. We can call these relationships "logical" because they are basic, useful or necessary, and precisely definable, i.e., free of ambiguity.

Among the most common of these relationships are logical *tautology,* or definitional identity between two terms or expressions: for example, a bachelor is an unmarried male; *part to whole* (my arm is part of my body, not vice versa; *cause and effect* (biologically, I am causally related to my parents, siblings, and children); *polarity,* where things share a continuum relative to some property, defined by the polar extremes: hot/cold, birth/death, day/night; *dichotomy* (in contrast to polarity), where there are only two logical possibilities: my arm is either my left arm or my right arm; and *analogy*, where properties are shared among distinct phenomena or classes of phenomena: a car is like a bus, both being vehicles; a glove resembles a hand; sound and light are analogous as wave-based phenomena. Wittgenstein's concept of *family resemblance* is a complex form of analogy, wherein disparate things share a set of common attributes, even if not all of them share anyone such attribute. His famous example is the concept of a game.

Binaries such as part-whole, form-content, cause-effect, inner-outer, past-future, here-there, you-me, among many others, are indispensable tools of thought, and they are sufficiently unambiguous that we can call them "logical" distinctions. We often need to refine or qualify them in a given context; like Euclidian geometry, they do not mirror reality directly but are essential tools for navigating it. Critical thinking enables us to go beyond such binaries–but we cannot think without them.

7. Informal Logic: A Passing Glance at Facts and Arguments

The Greek dialectical tradition of probing a subject via serial questions and answers predated the Trivium of logic, grammar, and rhetoric by several centuries. But it did not disappear when those new ways of organizing thought arose because there is more to sound thinking than being logical, grammatical, or persuasive. We also need to consider facts and values, relevance and clarity, legitimate and illegitimate means of persuasion, and the slew of other rules and guidelines of informal logic.

As a closed system based on a finite set of universal rules, formal logic is a necessary but not sufficient condition for critical thinking. Informal logic is an open system whose regulative principles are rooted not in thought alone but also in experience. And those rules and guidelines do not form a definite set or relate to one another in definite ways. They can be loosely categorized as informal fallacies that weaken arguments or propositions; other common epistemic or perceptual blunders; and pre-existing psychological conditions that are hardwired in our minds, such as the varieties of bias, blindness, and delusion to which we are prone.

We will begin with a brief look at arguments because that is where many of these blunders, blind spots, and biases come into play. But not everything we say can be considered an argument, and argumentation is not the only mode of expression that calls for critical thinking. So, I will focus here on one crucial distinction that frames most arguments and is a cornerstone of critical thinking: the distinction between facts and values.

Facts are states of affairs that we can agree to be the case, at least in principle. Values are goals, opinions, desires, or ideals that we do not necessarily agree on. They reflect states of affairs that we wish to bring about (or preserve, remove, or prevent, as the case may be). Facts

and values interconnect in complicated ways. But it always helps to be clear which we are talking about by examining the nature of the argument at hand.

Asking certain questions can promote such clarification. Whom are you arguing against, and how and why are you trying to persuade them? Is the argument strictly factual, or do values also shape your case? Is it possible you are wrong, or only partly right, about the facts? Are your beliefs based on hard evidence, intuition, generalization, wishful thinking, settled personal opinion, firm principle, or some combination of these? How sure are you of those beliefs–and why does it matter?

Factual questions are at least in principle resolvable and often beyond dispute. Spain does not share a border with Switzerland–you can look it up. But there are other facts that we disagree about pending further evidence; and we also differ on how to interpret the facts and which facts are most relevant or important, based on our pre-existing frameworks and worldviews. This is one reason why we never stop arguing. Our value differences may not be readily apparent, and they may be irreconcilable; but in productive arguments, informed by critical thinking, they are at least partially forced to the surface.

Arguments that have a normative component (whether moral, political, aesthetic or otherwise) tend to be more complex and harder to resolve. Facts may change, and different facts that are equally true (statistics being a notorious example) can be used to support opposing views. But our values are self-defined and stubborn; they do not change as easily as our factual understandings. Particular facts can sometimes be embarrassing to particular value-claims, but they seldom, if ever, change hearts or minds. We can survive a lot of embarrassment without reassessing the untidy basket of needs, desires, and ideals that largely make us who we are. Moreover, while “winning” an argument may serve my goals, it does not make me right, nor does “losing” mean I am wrong (just ask Galileo). It may only mean I have defended my views with greater or lesser rhetorical skill, or–as in Galileo’s case–that the “argument” was one-sided or pre-judged. And an unsound argument does not preclude the possibility of a sounder argument for the same conclusion.

The relevant facts, if agreed upon, should frame or guide such debate; but when values are involved, facts alone will not necessarily decide the matter. Political opponents argue

ceaselessly, but they are not ceaselessly converting one another. Why do we argue nonetheless? For a number of reasons: because arguing expresses who we are; because it may lead to short-term success; because it can clarify our differing views; because it sometimes produces limited or fleeting consensus; and because we cannot help ourselves. When we disagree, as scholars or citizens, arguing is all we have got.

8. Informal Logic, Continued: The Mental Quicksand of Fallacies, Blunders, Biases, and Blind Spots

A rigorous argument of any kind requires logic and clarity about facts and values. But there are other tools of critical thinking that belong under the rubric of "informal logic" as warnings against intellectual pitfalls–in arguments or otherwise. These additional tools can be broadly divided into two main categories: epistemic and psychological. Informal logic thus has rhetorical, epistemological, linguistic, and psychological dimensions, all of which figure in the various definitions of critical thinking that have been proposed [7].

The epistemic side of informal logic deals with the assessment of knowledge. It includes

- justifying factual claims;
- examining evidence and assumptions;
- distinguishing authoritative from non-authoritative information and biased from unbiased; and
- distinguishing propaganda or other forms of rhetoric from truth-seeking.

The pitfalls of a more psychological nature include the systematic biases, blind spots, and misperceptions to which the human mind is prone, and which we need to avoid in order to think clearly and well because they reflect ways in which our needs, values, or cognitive limitations cloud our judgment. There are dozens if not scores of common fallacies to guard against, as intellectual errors that do not involve logical contradiction. A mere handful of these will serve as examples [8]:

- *The Pathetic Fallacy*: attributing human traits to something else in nature;
- *The Intentional Fallacy*: divining an author's intentions or confusing the work with its author;
- *The Affective Fallacy*: Confusing the work with one's reaction to it;

- *Ad hominem*: attacking the person making the argument rather than the argument itself;
- *Hasty Generalization*: drawing a conclusion from a too-small sample of evidence, or ignoring important exceptions to the generalization;
- *Argument from Authority*: The flip side of *ad hominem*, where an argument is affirmed because of who is making it rather than on its merits;
- *Ad Populum*: appealing to prejudice or convention rather than to facts or reasoning about facts; and
- *Post hoc ergo propter hoc*, or "After this, therefore because of this," in which we infer that because A precedes B, A causes B. Sometimes B just follows A and is caused by something else. Just because I am older than you does not mean I am your parent.

A fuller catalog of recognized fallacies would fill an entire book. But even such a book would only partially map the territory we are navigating. So instead, we will look at two questions that form a useful segue to the final band of the spectrum of critical thinking. One is the question of appearance and reality–a useful distinction if ever there was one. The other is the mysterious art of questioning itself.

9. Appearance and Reality

One of the first things an infant learns is to distinguish itself from its mother and from the rest of the world. Another significant step comes several years later, when the child learns the difference between dreams and memories and between fantasy and reality: understanding, for example, when a story or a character is imaginary and does not actually exist. Developmentally, these distinctions are the very taproots of our critical capacity.

The sense of self and the sense of what is real do not prevent us from enjoying or learning through make-believe, art, or imagination. But they reflect the emergence of the mind's crucial triage function in evaluating the nature and quality of incoming information. The ability to discriminate between appearance (which, as we gradually learn, is sometimes unreliable and never complete) and reality enables the mind to transcend the here-and-now and to think abstractly. It is a precondition for developing the particular skills we use later in life to weigh

information generally and to identify lies, scams, rumors, urban legends, conspiracy theories, and the like.

The aim of critical thinking is not to suggest (à la Plato) that the world of appearance is innately flawed or inferior to something else. Everything *begins* with our perceptions. But looking beyond immediate perception is an essential critical function. Just as we must question and transcend binaries but cannot dispense with them, we must question and transcend appearances, but cannot ignore them, to organize the world successfully. To say that we can look beyond the immediately visible is simply to say that we can think.

Our limited and subjective perceptions of the world may or may not be accurate reports. Sometimes the problem is in mind, as the recipient and organizer of those perceptions; sometimes, it is in the limiting fact that we each have just one mind, in one time and place. But the human intellect affords a wider arsenal for understanding than "raw" perception (if there even is such a thing; it is more likely that all consciousness involves rational functions that organize our perceptions). That arsenal includes all the other things we do with our minds: reasoning, calculating, remembering, imagining, intuiting, inferring, generalizing and abstracting, distinguishing and connecting, discerning causes and effects, patterns and systems, contexts and implications. As part of that intellectual arsenal, we can think metacognitively to identify and counter mental limitations such as the fallacies enumerated earlier. More generally, what we can think and express with words depends on which words we choose and how we can use more words to express what fewer words cannot. Indeed, to examine words at all is to look beneath the surface of appearances and utterances.

And here is the rub: the greater the variance between appearance and reality, the more complex our understanding of the world becomes. Such divergence is, in fact, one way of defining complexity. It is a form of complexity that we encounter all the time and one that ultimately enriches our understanding and capacity for action. Humor and irony, for instance, celebrate unstated or unobvious truths about the world or human nature or truths that are cloaked as something else. Power is one example, as Malcolm Gladwell points out in his book *David and Goliath*. Strength can mask weakness and vice versa. The Bible [2 Corinthians 12:10] concurs: "For when I am weak then I am strong."

The ability to discern levels of reality and unreality, and alternate ways of representing them, also helps to explain the power and beauty of art. We, humans, are addicted to art because it straddles the boundaries of what we think of as real, and in so doing, offers new ways of thinking and seeing. We do not so much escape from reality through art as play with its boundaries. We can equally appreciate the true story of the whaleship Essex and Melville's *Moby-Dick*, a novel based on that event, from which we can arguably learn much more.

Critical thinking, then, is built on the understanding that there is more to the world than meets the eye; that what is usefully called "reality" goes far beyond what is evident, obvious, or material; and that learning of all kinds requires the ability to think abstractly, to think outside the box, and to be surprised. That is why art, imagination, and the capacity for wonder are crucial to early education. They are forms of play that teach us not just to compile or organize facts but to figuratively re-imagine the world and see it in ways that are more layered and complex–an important skill for would-be scientists, among others.

10.The Art of Questioning

Thinking critically means, above all, *questioning*: scrutinizing one's own thoughts and that of others. Questioning is the ultimate wellspring of metacognition and dialectical reasoning.

Where does this come from?

What happens next?

What fact or principle justifies this assertion?

How should we define this term or understand that idea?

What is related to what?

Why do we believe something to be the case?

Certain kinds of questions recur with regularity, but questioning itself is unbounded.

Plato's dialogues show us how to question by example. But even philosophers, who are forever questioning, seldom directly address the question of how to question. This is because interrogation has no rational limits other than coherence and relevance to the topic at hand. Questions do not arise out of nowhere or pop into our minds randomly; they arise from doubt, curiosity, uncertainty, and our vast stores of ignorance. They arise, that is, in a particular

context, as part of some larger fabric of inquiry. As D.Z. Phillips writes, “Questions arise about something; questions are occasioned” [9].

If we cannot define “intelligent questioning” in the abstract, however, we tend to recognize it and can make several general points about it. One is that framing questions is not a special skill apart from other kinds of critical thinking. Questions emerge as we reason about facts and find gaps in our understanding. We need to pose them in ways that drive the inquiry forward by giving it greater focus, broader context, greater clarity, as the case may be. And what “inquiry” means here is simply this: a cluster of related questions.

A related point is that questioning is subject to the same economies of reasoning as any other mental activity. To ask any question is to forgo or defer asking a different one. So our questions, except for simple or factual ones (*What is x? Is y the case? Can I buy you a drink?*), must be scrutinized for clarity and relevance. Good questions are formed when we know clearly what it is that we need to know.

Even questioning has its limits, however. We cannot navigate life effectively merely by questioning or by challenging everything. At some point, we need to make decisions, arrive at definitions, adduce evidence, and state beliefs about what is the case. And if we are critical thinkers, those assertions will properly reflect the level of confidence we have in our knowledge. Thus, an important part of the habit of questioning is knowing when to move on to the next question. Skepticism is central to critical thinking, but it must not blind us to the need for provisional truths, valid generalizations, or best practices, all subject to later revision. So, critical thinking means questioning–while acknowledging the limits of time and certainty.

The abiding questions first posed in a systematic way by the Greeks–about knowledge and truth, thought and action, freedom, and causality–are, like rationality itself, by their nature answerable in different ways and on different levels. They generally apply across many contexts, which is why they abide. Philosophers ask such general questions because that is their job. Likewise, historians ask one particular range and type of questions, mathematicians another. Psychology, literature, economics, and law have their own distinctive questions as well. In the pursuit of knowledge, there is no end to it. When questioning ends, learning ends, and thinking ends.

11.Analytic (Systemic) Thinking

Questioning forms a segue to the opposite end of the critical thinking spectrum from formal and informal logic. This third band is analytic thinking: the process of posing and answering questions both systematically, according to rules and reasons, and systemically. Analytic thinking explores how our concepts, and things in the world, relate to one another. Analytic questioning thus reflects the complexity, and the limits, of knowledge itself.

We know or can at least make a good pragmatic case for certain things - for example:

- that words and numbers exist, as mental devices;
- that time as we commonly understand it moves toward the future (although some physicists disagree);
- that gravity keeps things on the ground, and rivers flow toward the sea.

But we cannot "know" what beauty or justice is; these are normative issues that facts and logic alone are unable to resolve. We can only define and analyze those concepts at a high level of generality and argue about the rest.

Analytic thinking involves making distinctions and connections to model the world and seeing how things are both distinct and related. This, in turn, means seeing the world as the interplay of systems, i.e., phenomena that are composed of interrelated parts, such that the system as a whole can be usefully distinguished from those parts. Examples of systems include the human mind, the body, language, personalities, societies, economies, laws, games, conceptual systems, and nature at different levels: ecosystems, the weather, the galaxy, the universe.

We find systems wherever we look because structure, unity, distinctions, and connections are how our minds order and model the world. A pair of engineers sums up the systematic/systemic dichotomy succinctly: "Thinking systematically means employing a given thinking method consistently and thoroughly. Thinking systemically means thinking about systems and connections–the web of relationships within a system, the relationship of the system to other systems, and the larger system that contains all the systems" [10].

On the spectrum of critical thinking, all thinking is systematic, but not all thinking is systemic. Where they differ is in regard to the kind of connectedness to which they refer. Think of it this way: systematic thinking is mainly about *how* we think, linking our thoughts over time, space,

or logical or conceptual space by using common rules. Systemic thinking focuses on *what* we think about: how we discern structure in the world. Sophisticated thinkers need to do both.

Systemic analysis (or we could call it by its venerable name, *dialectic*) begins with the two nuclear mental functions: distinction and connection. They are the ultimate quanta of human thought–the cognitive equivalents of waves and particles. It does not matter whether we are talking about language in general, the concept of critical thinking, the history of commercial fishing, or the social patterns in ant colonies. "Our two most basic intellective functions," Robert Grudin observes, are "the perception of likeness and the perception of difference…." [11]. The Greek term *analysis* means "taking apart," but as a combination of distinction and connection, the analytic process also involves synthesis or putting together. The two functions work in tandem.

This process serves a number of core epistemic purposes for all thought:

- it is how we individuate "things" in the world in the first place;
- it is how we determine the (internal) essence of things and the (external) context of things–whether a person, a tree, an idea, a natural or social process, or a galaxy;
- it is how we relate eggs to chickens and individuals to families, communities, economies, religions, nations, etc.; and
- it is the process by which we make explicit what is implicit or what is otherwise obscured ("Obscured" here does not mean deliberately concealed; rather, that we cannot connect and distinguish at the same time, or with the same words, but must do so in succession).

As Robert M. Pirsig observes in *Zen and the Art of Motorcycle Maintenance*, analysis involves "the recognition of likenesses hidden under apparent divergences"–and correspondingly, the differences are hidden under apparent likenesses; it is an endless process of achieving intellectual breadth, depth, and clarity, because (as the philosopher Renford Bambrough observes) "Each of several different uses [of language] may be valuable for the light it sheds and dangerous because of the shadow it casts" [12]. The aim of dialectic, then, is to shed maximal light where there is darkness. It is a process of breaking down and putting together,

revealing the distinctions that connections invariably obscure, and vice versa–like a pair of lighthouses, each illuminating what is in the other's shadows.

12.Conclusion: Critical Thinking and Complexity

Any attempt to map or organize human thought may seem like a fool's errand, and yet, how can we not make at least limited attempts to do so? How can we exploit the full potentials of the human mind without trying to give some shape and structure to its most basic tools? There are many ways to do that. What I have attempted here is simply one schematic–and non-scientific, but also meta-scientific–approach, and surely a contestable one. At a minimum, I have tried to suggest that there are useful distinctions, connections, and assumptions that we can make to sketch the common intellectual landscape that is shared by scholars, scientists, and others. In summary:

i. we can and often must distinguish "practical" from "intellectual" or "theoretical" reasoning, but must also be prepared to relax or collapse that distinction; and

ii. "critical thinking" can be defined in various ways, but they all amount to basic forms of intellectual rationality. While every discipline has its own techniques and methodologies, all intellectual rigor is embedded within this web of rationality. Critical thinking, on any definition, comprises an essential (but diverse and imperfectly codifiable) set of intellectual skills. Collectively, these skills describe a spectrum of rationality that includes logic, the varieties of informal logic, and systemic or analytic thinking. This spectrum maps the human ability to inquire across all fields of knowledge and to organize, evaluate, and expand what we know. Even art is in important ways a rational process: like language, it is an attempt to communicate, to share ideas, perceptions, or ways of seeing, and thus to form communities. Similarly, religion has aspects and functions that are practically or intellectually rational, and so does political discourse, including propaganda.

Little of this is cut-and-dried, however. It is not a Rubik's Cube with a single solution. Beyond closed systems such as mathematics and formal logic, everything is more or less negotiable as long as we do not abuse language. We may disagree about the set of skills that define critical thinking, which are most important, or how to teach them. And we may argue about whether

basic “problem-solving” skills (or which among them) should be lumped under the critical-thinking rubric. It depends on the type of problem and who is doing the lumping. But problems are simply questions with relatively greater specificity or immediacy. How do you fix a leaky faucet, quell a child’s fears, balance a checkbook, choose a school or career, decide whom to vote for, win a round of “Jeopardy,” or send a spaceship to Mars? Being a critical thinker does not guarantee mastery of any of these skills (all of which, to be sure, require practical and experiential knowledge), and we cannot excel in all of them. But as students, scholars, and citizens, it is where we must begin.

A final point I wish to make is a nod in the direction of the concept of complexity. It is already familiar to most scientists–indeed, there is a science of complexity itself. But it is also exemplary of the important connections between scientific thinking and lay intelligence. Indeed, I believe the concept of complexity (by which I mean not just complexity *per se*, but the spectrum between the simple and the complex) is of particular value to non-scientists. Among other things, the simple-complex axis arguably helps to explain many areas of fundamental disagreement: areas of what philosophers call “essential contestability.” Differential tolerance of complexity underlies how and why we differ in our interpretive schemes, our worldviews, and indeed in our moral and political outlooks. And as we have seen, rationality and critical thinking are innately complex ideas.

Thinking more broadly, some scientists have theorized that the universe itself may be too complex for the human mind to understand. And so it may be; but we have no idea and seemingly no way of knowing. Indeed, it is not clear what it would mean to “know” that the universe is ultimately unknowable to us. Moreover, the over-complexity conjecture poses a further conundrum because the dichotomy or spectrum of complexity/simplicity is *our* idea. It is not a fact about the world but a tool for understanding those facts that are available to us.

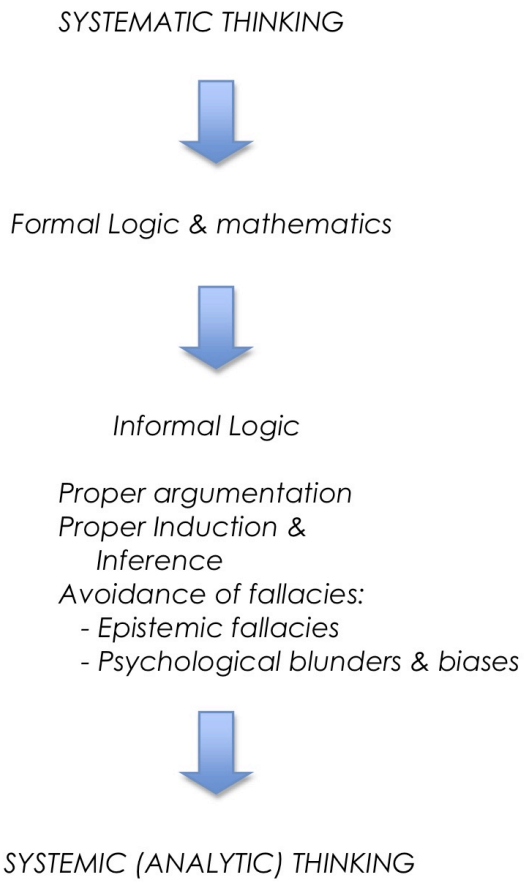
Some things are inherently or objectively more complex–to our minds. And our minds, and the tools we generate with them, are all we have or are ever likely to have for understanding what is out there and how it all works. Complexity, like simplicity, implies order; at the extreme, it verges on chaos, not on a level of complexity that lies beyond our minds or beyond artificial intelligence. So while there may, in theory, be truths about the universe or our place in it that

lie forever beyond our reach, I suspect (but I could be wrong!) that it is not because they are beyond our mental grasp. If that were the case, in what sense could we still call them “truths”? Scientists, meanwhile, are acutely aware of the universe’s complexity. That is something for non-scientists to acknowledge and appreciate, but not to envy or emulate for the sake of a spurious “scientizing” of their own disciplines. Like everyone else, scientists must exploit the concept of complexity in describing their natural slice of the world–and balance such complexity against the need to simplify in order to understand what they are seeing and explain it to others. We think critically by commuting between the simpler and the more complex–just as we commute between the general and the particular, between the binary and the non-binary, or between the distinct and the connected–not by clinging to either function alone. Thinking about the complexity axis and how to balance it is an important aspect of all critical or rational, or analytic thinking. It opens up a way of seeing the world (and of understanding how we see it differently) where the scientist, the social scientist, the humanist, and the ordinary citizen may find common ground.

Core Messages

- Science is a unified enterprise, as the study of nature, but it shares a common basis in rationality with other areas of inquiry.
- Rationality can be defined in various overlapping ways, including a) acting or thinking *systematically*, according to rules and reasons; commuting between the general and the particular, the binary and the non-binary, the simple and the complex; and relating things *systemically*.
- Critical thinking has been called the "educational cognate" of rationality, but practically speaking the distinction is insignificant.
- In addition to thinking systematically and systemically, on a spectrum that includes formal logic, informal logic, and analytic thinking, certain key concepts, such as causality, complexity, and language, transcend disciplinary boundaries and unify learning.
- As the source and paradigm of intellectual rigor, rationality is the constitution of the republic of learning.

Graphical Abstract/Art Performance



The spectrum of critical thinking

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References

1. Wood P (2012) Some Critical Thoughts. Chronicle of Higher Education. . chronicle.com/blogs/innovations/some-critical-thoughts/31252/.
2. Lepore J (2016) After the Fact: In the history of truth, a new chapter begins. The New Yorker:91-94
3. Wrightstone JW (1938) Test of Critical Thinking in the Social Studies. Bur Publ, Teach Coll, Columbia Univ
4. Novaes CD (2017) What is Logic? https://aeon.co/essays/the-rise-and-fall-and-rise-of-logic. Accessed Jan 12, 2017
5. Williams B (2006) Philosophy as a Humanistic Discipline.
6. Ferry L (2011) A Brief History of Thought.
7. Ennis RH (1964) A definition of critical thinking. The Reading Teacher 17 (8):599-612
8. Dobelli R (2013) The art of thinking clearly: better thinking, better decisions. Hachette UK,
9. Phillips DZ (1979) Is moral education really necessary? British Journal of Educational Studies 27 (1):42-56
10. Kuprenas J, and M. Frederick (2013) 101 Things I Learned in Engineering School.
11. Grudin R (1997) Time and the Art of Living. Houghton Mifflin Harcourt,
12. Bambrough JR (1965) Aristotle on Justice: A Paradigm of Philosophy. In: Bambrough JR (ed) New Essays on Plato and Aristotle. pp 162-165