THE CRAFT OF THINKING

LOGIC, SCIENTIFIC METHOD, AND THE PURSUIT OF TRUTH

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PREFACE FOR TEACHERS

Work on this text began in 1980 at Morehouse College. Both authors felt the need for a more rapid and effective way to introduce students to the basic techniques of formal logic without getting them too bogged down in the cumbersome, calculus-like technicalities in many introductory philosophy and critical thinking texts of the past twenty-five years. We have used these materials in the classroom, continually revising and expanding the teaching strategies based on student performance.

This text seeks a compromise between two opposing trends in the teaching of critical thinking. At one extreme are the more traditional, formal logic methods, such as the standard text by Copi, *Logic* (first printed in 1953).[1] The advantage of this approach is that it develops precision in deductive reasoning, so that, at least in principle, after mastering the techniques, students can evaluate the validity or invalidity of arguments. This is an important goal. Students insecure in their ability to determine validity in arguments also feel insecure in their ability to evaluate others' reasoning. Consequently, they shy away from intellectual controversy, remain susceptible to authoritarian manipulation of their beliefs in all domains, and lack creativity and competence in problem solving. Learning the traditional methods of formal logic can go a long way toward alleviating this problem, but only if the student masters the complicated techniques. Although math, philosophy, and some natural science majors may do well in courses based on these techniques, others flounder and become utterly lost.

At the other extreme are more recent attempts to avoid formal techniques altogether, or to give them lip service without requiring students to actually solve deductive problems using the techniques. Within this second category are numerous texts. Some try to help students with personal psychological problems; others advise students on how to use "case study" methods developed by education specialists; and still others encourage students to articulate the assumptions they make in forming opinions, without teaching any precise way to determine confidently whether a given argument is deductively valid. Students in these courses fail to achieve the confidence to evaluate the validity of an argument—a skill needed in any intellectual forum, and crucial for becoming a creative and accurate problem solver.

The present text incorporates the advantages without the disadvantages of both approaches. Our teaching experience with the materials convinces us that we have accomplished this goal, not merely by changing the way the materials are packaged and presented,

[1] Irving Copi, *Introduction to Logic*, 9th ed. (New York: MacMillan, 1982).

but by developing new content. We have developed ways of streamlining formal logical techniques to achieve a system that requires minimum technical apparatus but retains the precision of the more complicated systems. In some cases, this has required developing simpler notations. In other cases, it has required developing ways of communicating the techniques to students without using many of the traditional, even archaic, technical terms of formal logic, such as "figure," "mood," "fallacy of the undistributed middle," and so forth.

In some instances, we have empirically validated the improvement in our students' performances. In the summer of 1987, one of the authors used a UNCF summer grant to develop a new method of teaching logical fallacies. The strategy was based on the observation that students grasp an abstract concept best when the concept is expressed in behavioral terms, i.e., in such a way as to state what the student can *do* with the principle. For example, the principle of *modus tollens* tells us that we can negate both terms and reverse their order; the fallacy of denying the antecedent tells us that we should not merely negate the two terms. After applying this technique the following semester, the seventy students' grades on the test on fallacies averaged fifteen points higher than the sixty-five students who were taught using the more traditional method the previous semester.

Several other advantages of our approach are not reflected in most recent textbooks. One major service to students is the extensive treatment of scientific reasoning in Chapters 8 and 9. Of the numerous logic and critical thinking texts available, few if any provide more than a cursory treatment of this topic. The reason is to be found probably in the traditional contrast in the agendas of two separate courses: Logic, which deals with deductive reasoning techniques thoroughly; and Philosophy of Science, which deals with inductive and scientific reasoning. The problem of separating these topics into separate courses is that students who are not philosophy majors—including math, natural science, and social science majors—seldom take more than one of them. Consequently, science majors are deprived of basic training in scientific reasoning, one of the main benefits they would expect from a critical thinking course. Moreover, in an age of increasing technology, when more and more social and political issues revolve around the assessment of cause and effect relationships, it is no longer acceptable for students not to be familiar with the basic uses and typical abuses of scientific reasoning.

For analogous reasons, we have included "Thinking Logically about Value Issues" in Chapter 7. Critical thinking texts seldom include such a unit, and when they do, they do not show how precise deductive reasoning can actually be used to evaluate the reasoning behind philosophical value assumptions; instead, they merely take philosophical positions as unquestioned premises, and discuss the ways that concrete, real life conclusions could be reached from those premises—if they were to be accepted in the first place. The problem with such an approach is that students cannot evaluate the premises themselves, which is by far the most important challenge of thinking logically about value issues. For example, what reasons are there for preferring a theory of distributive justice over a utilitarian theory as a premise for making political decisions? Our text provides tools and techniques for addressing these kinds of questions.

This text develops a system of syllogistic logic dealing with combinations of universal and nonuniversal statements that makes it continuous with *sentential* logic (which treats only universal statements). In this way, both types of logic are combined into one system, so that both can be learned easily and quickly. Most introductory logic courses cover only sentential logic, leaving syllogistic logic for a separate and more advanced course, which covers the most advanced contemporary way of treating syllogistic logic, or "predicate logic," as developed by Frege.[2] Thus, without taking the more advanced course, students still cannot handle such a simple example as 'No snakes are flying creatures; some flying creatures are mammals; therefore, some mammals are not snakes'. The way we handle this problem is to introduce a few simple syllogistic principles that can be *added on* to what the students already know about sentential logic, resulting in a short Chapter 5 on the logic of syllogisms.

Teachers should be aware that we have defined the relation of '*implication*' more broadly than most texts to combine both sentential and syllogistic logic into one system. We define the relationship of implication as including three types of situations: we say that '**p** implies **q**' whenever one of the following relationships obtains:

1.	If **p** then **q**	(where **p** and **q** are propositions)
2.	All **p**'s are **q**'s	(where **p** and **q** designate properties)
3.	**p** is a **q**	(where **p** is an individual and **q** designates a property)

Some systems of logic do not define the second and third types of relationships as implications, but instead deal with them by means of a completely separate system of syllogistic logic. We define all three types of relationships as implications to simplify and clarify logical analysis, without sacrifice of precision or problem-solving power. Logic texts usually treat implication as obtaining only when one *proposition* implies another *proposition.* But sometimes it is useful to think of a term *within* a proposition as implying another term within that proposition. For example, we can think of the statement 'All Spelman students are women', as asserting that the property of 'being a Spelman student' *implies* the property of 'being a woman'. That is, *if* someone is a Spelman student, *then* that person is a woman. Because of the 'if-then' relationship here, we can think of this statement as expressing an implication. Similarly, with 'Mary is a Spelman student', it is convenient to think of the statement as expressing an implication, because it asserts that the property of 'being Mary' implies the property of 'being a Spelman student'. That is, *if* someone is Mary, *then* that person is a Spelman student. Or, if we know that the individual who stole a briefcase is a Spelman student, we can let **p** stand for 'the individual who stole the briefcase', and **q** for 'Spelman student', and thus write this statement simply as '**p** → **q**'. The advantages of defining implication in this broadened way will become increasingly obvious as we proceed.

[2] Peter Geach and Max Black, eds., *Translations from the Philosophical Writings of Gottlob Frege* (Cambridge: Cambridge University Press, 1952).

No text should neglect the importance of using examples whose content is *interesting* to most students. For example, Chapter 9, "The Use and Abuse of Scientific Reasoning," focuses heavily on scientific issues that are interconnected with sociopolitical controversies, such as cause and effect theories about poverty, crime, Third World development, and other social problems. This pragmatic focus motivates students from a variety of backgrounds to be interested in logic, and to learn it more readily.

The explanations in the text make every effort to be simple, concise, and easily understandable. Teachers should be able to spend a minimum of classroom time explaining principles and techniques, and more time applying and illustrating them with actual examples.

INTRODUCTION

Human beings as a species possess one main advantage for survival—our ability to think. Other animal species are much faster or stronger than we are, and most have more discriminating senses. Humans survive by means of adaptability, complex processing of information, careful, long-range planning, and the ability to critically question our hypotheses about the realities facing us. One of the most important applications of these skills is in the development of strategies for socially cooperative activity in solving the problems we confront. As social, political, and technological realities become more complicated, the ability to think logically, critically, and independently becomes increasingly important.

It is crucial to distinguish between critical thinking, which is an active, questioning process, and the mere accumulation of information. Unfortunately, the more our educational systems emphasize the assimilation of ever-mounting masses of accumulated information, the less time is left for students to develop the critical, questioning functions necessary for logical analysis.

In recent years neuroscientists have become increasingly aware of the severe limitations of the learning that takes place through the passive absorbing of information. The brain is structured to operate by means of active searching for information and understanding, not passive absorption. We now realize that the human frontal lobe, whose comparatively huge size distinguishes our brains from those of other animals, is designed to facilitate formulating questions about the array of information with which we are presented—the focusing of attention, questioning of logical validity, and forming of hypotheses.[1] Moreover, because of the electrochemical pathways in the brain, the entire cortex, with all its thinking and memory functions, works more efficiently when activated by this questioning activity of the frontal lobe.

The "Learning to Learn" program, developed at the Harvard School of Education, used this new knowledge about the active, question-directed nature of the brain to help improve students' grades.[2] The main strategy was a very simple one: In the margin next to each paragraph in a textbook, the student is asked to write the question to which the

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[1]For further discussion of this aspect of brain functioning, see Alexander Luria, *Higher Cortical Functions in Man* (New York: Basic Books, 1980); Michael Posner and Mary Rothbart, "Attentional mechanisms and conscious experience," in A. D. Milner and M. D. Rugg, eds., *The Neuropsychology of Consciousness* (London: Academic Press, 1992); Antonio Damasio, *Descartes' Error* (New York: Putnam, 1994); Ralph Ellis, *Questioning Consciousness* (Amsterdam: John Benjamins, 1995); Natika Newton, *Foundations of Understanding* (Amsterdam, John Benjamins, 1996).

[2]Joshua Slomianko, "Learning to Learn," seminar presented at Atlanta University, August 1987.

information contained in that paragraph could constitute a possible answer. Within one semester, the grade point average of these students increased by an average of 1.5 on a 4.0 scale—a much greater increase than among students using other tutoring methods. And the improvement was just as dramatic in courses involving rote memorization as for those that stressed critical thinking.

Why would such a simple method work so well? Because students had to adopt an actively questioning frame of mind rather than a passive, receptive one. And we now know from the neurological work mentioned above that the frontal cortex is active when we ask ourselves a question—especially when we formulate a question for ourselves (as opposed to merely responding to someone else's questions); this is when the frontal cortex increases its level of electrical and chemical activity. And when the frontal lobe is activated, the rest of the brain quickly follows suit. We remember information more effectively when we ask ourselves questions about it during the learning process, and this formulation of questions is a primary aspect of making sense out of the information. The Harvard experiment dramatically emphasizes the usefulness of developing habits of critical thinking and questioning in any learning process.

Can logical ability be developed and improved, or are we simply stuck with the luck of a hereditary draw that determines our IQ? Increasing evidence suggests that intellectual skills are not just hereditary, but that we can develop them. In fact, it has now been demonstrated empirically that a course in logic or critical thinking, if it emphasizes the kinds of formal logical analysis covered in this textbook, dramatically increases a student's IQ. David and Linda Annis[3] have documented that a logic course structured in this way increased their students' IQ scores by an average of ten points (after compensating for the normal test-retest increase, which is about one to two points). To appreciate what a dramatic increase this represents, consider that, on most measures of IQ, the average college student falls within the upper 15 percent of the population. After the improvement reported by Annis and Annis, this same average student would fall within the upper 4 percent.

Still other empirical studies have shown that, by practicing our logical thinking skills, we improve the functioning of our brains. Kretch and his associates[4] have found that rats that participate in learning experiments throughout their lifetimes, and therefore must use their brains to actively solve problems, show alteration not only in the structure, but also in the chemical composition of their brains. Dissecting the brains of the rats at death, Kretch finds that they contain significantly more acetylcholine and a larger number of glial cells—factors known to be associated with enhanced learning and problem solving. Kretch also finds a significant increase in the sheer *mass* of the brains of the rats that must use their brains to solve problems.

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[3]"Does Philosophy Improve Critical Thinking?" *Teaching Philosophy*, 3, 1979, 2ff.

[4]David Kretch, Mark Rosenzweig and Edward Bennett, "Effects of Environmental Complexity and Training on Brain Chemistry," *Journal of Comparative and Physiological Psychology* 53, 1966, 509-519.

The method used in this book is similar to the one Annis and Annis used. The backbone of the strategy is to begin by consciously reflecting on the inference rules that we rely on in everyday reasoning; to abstract the patterns we normally follow so as to formulate rules of inference; to make sure that invalid rules are not followed (by considering examples that show that these invalid patterns of logic cannot be trusted to guarantee true conclusions from true premises); and then to consciously apply the rules to various examples to increase our skill at making reliably valid inferences.

In this way, we develop confidence in relying on certain rules of inference. We then feel confident enough of our own logical thinking that, when someone else's logic seems wrong to us, we can compare their arguments to the patterns of reasoning we have learned to rely on; if the other person's logic is found wanting by these criteria, we can then feel sure that it is the other person's logic that is faulty, not our own. Only by developing a reliable set of criteria for correct reasoning can we feel confident enough to evaluate arguments by applying those criteria, even in situations that may be unfamiliar to us or emotionally charged.

Many important questions in life depend more on the use of logical reasoning than on any other kind of knowledge. For this reason, logic is considered to be a branch of philosophy, whose purpose is to address questions that cannot be answered by means of empirical knowledge, that is, knowledge based on physical observation. Fields of empirical knowledge, such as physics, chemistry, and psychology, have become so important in modern cultures that we tend to forget that not all knowledge *is* empirical.

It is fairly obvious that many things are learned empirically, beginning with sense perception. Through the senses we become aware of the existence and qualities of individual things. We can also generalize from the characteristics of individual perceptions and build general knowledge based on our experience as well as that of others. In this way, we learn that crows are black, that canaries sing, that water quenches our thirst, and a host of other things. More complex than these generalizations is our theoretical scientific knowledge, such as Newton's gravitational theory, or the quantum theory. Scientific knowledge is derived from experience with the help of theoretical constructions called models or theories. We shall discuss the kind of reasoning involved in developing reliable scientific models and theories later in this book. The relationship of scientific knowledge to individual perceptions is no simple matter, but we know that the main function and importance of this kind of knowledge is directly related to the fact that it can be used to predict and often control events.

Empirical knowledge, then, is based on sense experience. My knowledge of the existence of the color yellow is a bit of empirical knowledge based on sense perception. My knowledge that canaries are yellow follows as an empirical generalization.

But certain kinds of knowledge are acquired by examining concepts in the mind. We learn, for example, that two things equal to a third are equal to each other by examining in our minds what is involved in the idea of equality. To acquire that bit of knowledge, we do not need to make a large number of observations, or to experiment; we need to understand the meaning of "equality." That two things equal to a third must be equal to each other seems to follow from the very nature of the idea of equality. Further, once we have seen this, we know that this statement applies to any objects whatsoever; there can be no exceptions.

Examples of the kind of knowledge acquired by analyzing ideas are:

> "237 + 2 = 239."
>
> "A whole is greater than any of its parts."
>
> "If the definition of a term in a proposition is substituted in place of the term, the meaning of the proposition will be preserved."
>
> "Let **a**, **b**, and **c** be three whole numbers: If **a** is greater than **b**, and **b** is greater than **c**, then **a** is greater than **c**."

These propositions are seen to be true simply by examining in one's mind the relationship between the concepts used in them. Knowledge of this type is not empirical. In philosophy, any knowledge acquired through the analysis of concepts in the mind is called "*a priori*" or "conceptual" knowledge.

A priori knowledge has two main advantages that enable us to rely on it with a great deal of certainty. The first is *necessity.* If we grasp the concept of equality, we know that two things equal to a third *must* be equal to each other, no matter what particular things we may be considering. This is not something that happens to be true of some objects. It is a universal and necessary truth about equality. *We cannot conceive of it being otherwise.* This characteristic of *a priori* propositions, that it is absurd or contradictory to think that they might be otherwise, is called *necessity*. *A priori* truths are *necessarily* true, not just frequently or in a number of observed specific cases.

The second characteristic of conceptual knowledge is *universality.* A conceptual proposition applies to all relevant cases without exception because conceptual truths are based not on particular examples, but on general concepts. We know that the above statement about equality applies to any objects whatsoever. Any two objects that are equal to a third must be equal to each other. There can be no exception, because this truth follows from the very concept of equality. An exception would be absurd. This quality of *a priori* propositions—that they apply to all cases without exception—is called *universality.*

It is important to notice that empirical knowledge does not have these two properties. For example, we know from overwhelming empirical evidence that crows are black and that cats meow. However, exceptions to these generalizations are not at all absurd or contradictory. It is possible that a white crow may exist. We cannot say that it is impossible. Empirical knowledge is not necessary or universal. Exceptions are always possible.

Logic and mathematics are *a priori* sciences. They study relationships between concepts, not aspects of empirically observable nature, as the natural sciences do. That is why the propositions of logic and mathematics have necessity and universality. We shall see in the next several chapters that the basic principles of logical reasoning can be discovered by examining the meaning of concepts such as implication, negation, and validity. For this reason, principles of logic can be relied upon as absolutely trustworthy instruments, and we can use them with utmost self-confidence as criteria for evaluating the logical validity of inferences and arguments.

In brief, conceptual knowledge provides knowledge of certain necessary relations between concepts. By means of conceptual knowledge we can learn that certain structures are not possible in the world. We also learn that certain structures necessarily imply the existence of other structures. But conceptual knowledge does not give us knowledge of *actual things.* Conceptual knowledge can be used to yield knowledge of actual things when it is supplemented by empirical knowledge. For example, we can prove that the area of a rectangle is given by the product of its two sides. This is conceptual knowledge. It is necessary and universal, but it does not of itself give us any particular knowledge about empirical reality. However, if I happen to be dealing with floor tiles, I can use that formula to find out the area of a tile. I have, on the one hand, the conceptual knowledge that the area of *any* rectangle is given by the formula just mentioned. On the other hand, I have the empirical knowledge that I am dealing with a tile that is approximately rectangular in shape, and that its sides measure 10 and 12 inches. Putting together the conceptual and the empirical knowledge that I have, I can figure out that the area of my tile is 10 X 12 = 120 square inches. *The combination of the two kinds of knowledge* produces the concrete knowledge of the area of the tile I am dealing with.

This book deals with the most basic principles of conceptual knowledge—the principles used in making logical inferences in all kinds of contexts. Our assumption is that, by becoming clear and precise in understanding these principles, we can develop them into reliable criteria for evaluating reasoning and confidently deducing our own conclusions from the information given. Only by being clear and precise in our understanding of the way these principles work can we feel confident enough to use them as criteria in evaluating the reasoning of others, and in drawing creative inferences from given information, even when these inferences lead us into uncharted territory.

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