The Logic of Scientific Discovery Study Guide

The Logic of Scientific Discovery by Karl Popper

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Plot Summary

The Logic of Scientific Discovery by Karl Popper is an analysis of scientific thinking through his particular view of epistemology. Popper is a well-known philosopher of science. In this work, he investigates where scientific findings fit into philosophy through examining what differentiates true knowledge from false knowledge. He claims this quest is far more than language analysis or reductionism, relying instead on the relationship of basic statements and the notion of "falsifiability" to sustain rational analytical processes in the growth of knowledge.

Science is about putting forward and testing theories. Falsifiability figures prominently as Popper's method for testing theories. He repeatedly shows that theories are never verifiable, only falsifiable. Concepts of universality and singularity help to define falsifiability. Singular statements, or occurrences, are subsets of universal events. Basic statements are particular types of singular statement that can serve as a basis to empirically falsify theories. They can be used to falsify a hypothesis "if two non-empty classes of basic statements exist such that one contains statements that would lead to rejecting the hypothesis while the other class contains all other basic statements." Using this approach, Popper labels hypotheses as either empirical statements or non-empirical statements depending upon the degree to which they are corroborated. Corroboration is based upon tests to a theory's basic singular statements. The demarcation between empirical and non-empirical theories is a key element in Popper's logic about what properly constitutes scientific methodology.

Popper directly and repeatedly rejects induction as a viable scientific method. The inductive method is one through which universal statements can be inferred from singular statements. In disputing the logic of deriving theory from induction, he shows how inductive reasoning leads to infinite regression or to tautologies. Popper finds inductive logic internally inconsistent. Instead, he supports deductive reasoning as empirically scientific. Deductive systems avoid many of the pitfalls of metaphysical thinking and psychologism by requiring continued testing for falsifiability.

Positivism falls under Popper's attack for lacking intersubjectivity and for circular, or tautological, thinking. Returning again to the merits of falsifiability, Popper shows how the positivist method to show verification of a statement's "meaningfulness" is inductive and should therefore be disregarded. Further, he takes on conventionalists. He claims they cling to the idea of simple basic laws of nature that are created in the human mind. These laws serve as the logical construction of nature from which humans can think about science. This basic difference in the premise causes Popper to refute conventionalism for inappropriately solidifying accepted scientific theories with ad hoc hypotheses that protect well-accepted theories unless they are actually falsified. Popper claims that conventionalism cripples scientific growth and discovery that would be better served by the premise of empirical falsification.

Popper tests the application of his principles on problems associated with probability. While stating that probability statements cannot be falsified, he suggests that excluding statements of extreme improbability will suffice for empirical results through what he calls "reproducible physical effects." He also applies falsifiability to problems of simplicity and quantum theory in an attempt to test his ideas and stretch the applicability of his theoretical constructs. In the appendices to this book, Popper further develops mathematical solutions in support of his theories. He also shares some of the correspondence and criticisms he has received about his ideas, including one from Albert Einstein.

Part I: Chapter 1, A Survey of Some Fundamental Problems

Part I: Chapter 1, A Survey of Some Fundamental Problems Summary and Analysis

The Logic of Scientific Discovery by Karl Popper is an analysis of scientific thinking through the particular view of epistemology held by this well-known philosopher of science. In this first chapter he analyzes the methods of empirical science. He claims that metaphysical and philosophical ideas contribute heavily to the cosmology in empirical scientific endeavors. He believes there is far more to such endeavors than the language analyst's "linguistic puzzles" or other investigations about how scientific laws are arrived at and accepted. Equating rational attitude with critical thinking, Popper draws a clear line between two approaches to knowledge, common sense and scientific thinking.

The problem of epistemology lies in whether problems are logically approached inductively or deductively. Popper overtly dismisses inductive methods by denying the existence of inductive sciences, procedures or inferences. He claims induction is not a rational, empirical scientific method. It is metaphysical. Popper challenges what he terms "the problem of induction," claiming there is no logical justification to suggest that universal statements may be drawn from singular statements. Further, he claims that using induction to suggest probability for a given event occurring results in a loop from which one cannot logically escape. He calls this loop an "infinite regress." He sees most uses of the concept of simplicity as part of the framework of induction.

Popper claims that confusion between the psychology of knowledge and the logic of knowledge lies at the heart of the problem of induction. Psychologism concerns itself with questions of fact whereas logical analysis of scientific knowledge is concerned with questions relating to justification or validity. The concept of demarcation between metaphysical and non-metaphysical knowledge is central to Popper's developing argument against induction as well as his stance against positivists' and reductionists' adherence to dogmatic rules.

Popper champions deductive methods as the appropriate ones for empirical scientific inquiry. Deductive reasoning begins from the premise of testability. The goal of scientific statements is to attain a degree of probability that lies between the boundary conditions of truth or falsehood. It is not science's goal to confirm statements as either truthful or false. Therefore, there are no ultimate scientific statements. However, each statement forming the basis of science must be objectively testable, regardless of whether or not it is ever actually tested. It is from testable statements that other statements can be deduced. Empirical science is what Popper terms synthetic (representing a possible, non-contradictory world). It is, by definition, not metaphysical.

Popper proposes four deductive tests for scientific knowledge. These are internal consistency from comparing conclusions, investigations of the logical forms of theories, comparing theories with other theories to determine whether or not the theory under consideration is a scientific advance, and empirical applications of the conclusions. These tests help to ensure that a theory is not tautological or self-contradictory, and that it can stand up to rigorous tests and comparisons with other theories and logic. Further, the procedure of testing is also deductive. Predictions are deduced from theory and then verified. Consistent with his dismissal of induction, Popper makes the argument that theories are never empirically verifiable, only falsifiable.

Part I: Chapter 2, On the Problem of a Theory of Scientific Method

Part I: Chapter 2, On the Problem of a Theory of Scientific Method Summary and Analysis

Epistemology should guide the choice of methods through rules that adhere to demarcation and ensure the testability of statements. Therefore, a theory of scientific method must be more than a formal logical structure of statements. Otherwise, metaphysics would emerge from elevating obsolete scientific theories to the status of truth. To emphasize this point, Popper says that dogmatically defending theories that are not conclusively disproved is an example of the degradation of the process of logically pursuing knowledge. In fact, according to Popper dogmatic defense is diametrically opposed to the critical attitude required of a scientist. Popper states that theories can never be conclusively disproved. Claims can be made that the experiments were unreliable or that the apparent differences in theory and practical application will disappear when one better understands the theory. Theories can, however, be falsified through using particular methodological rules.

Methodological rules are conventions. They differ from logical or deductive rules in that they are constructed to protect and ensure demarcation. Demarcation is necessary based on Popper's definition of empirical science. This philosophical basis, which he says contains fairly obvious conventions, guides methodological considerations about what counts as empirical scientific knowledge. Demarcation between science and pseudo-science as well as metaphysics is essential to Popper's development of a theory of scientific method for discovery.

Popper further considers his differences with positivists, making it clear that he sees positivism as narrow, limited and misguided. Positivists see only logical tautologies and empirical statements while dismissing philosophy and methodology. The one allowable arena for methodology for positivists is as a study of the behavior or procedure of science. Positivists investigate how scientists work and how science works by using an inductive approach to the theory of science. Popper rejects their approach as inconsistent. It is neither critical nor testable. By showing the ease by which a problem may be labeled "meaningless," if one creates a very narrow view of meaning as he claims positivists do, Popper accuses positivists of relegating philosophy to puzzles that fall into either the statement category of empiricism or that of tautology. Circular statements and observational statements that are not considered intersubjectivity do not conform to Popper's logic for scientific inquiry.

Popper elaborates on the never-ending question of the existence of philosophy, digressing into further attacks on the 'naturalistic' view through which positivists agree upon conventions when they think they are discovering facts. Such an approach establishes unassailable dogma, thereby constraining critical thinking. The resulting inconsistencies further support his developing argument against inductive thinking.

BOOKRAGS

Part II: Chapter 3, Theories

Part II: Chapter 3, Theories Summary and Analysis

Systems of theories comprise empirical science. Therefore, a logic of science is a theory of theories. Theories are used to capture and explain the world. These theories or natural laws are continually being refined to become better explanatory tools. Scientific theories are universal statements. Popper says that the frequently-made distinction between universal statements and singular statements, that theories are universal while singular statements are concrete, is not a useful distinction. He finds this distinction less than useful because it seeks to constrain theories under a label of their instrumental uses. Instead, the goal is to look for universal theories and a coherent theoretical system. Theories are guides to explanations of the world and its phenomena. Further, theories are often looked to for predictions.

Issues surrounding causal explanations arise when considering predictions. Causality depends upon both universal and singular statements. Singular statements are deduced from universal ones. The principle of causality asserts that any event can be deductively predicted. If it is always possible to construct causal explanations for events or initial conditions that lead to the explanation, such an approach is tautological, and therefore rejected by Popper. In addition to the tautological argument, Popper neither adopts nor denies a principle of causality because it is not falsifiable. He therefore excludes it from science, calling it metaphysical.

The concept of numerical universality also contains problems for Popper. He challenges the convention and agreement to what he calls "singular numerical statements" by those who subscribe to inductive methods in science. First, such statements are conventions. Second, they are not universal, they are singular. This is fundamentally important because of the scientific importance placed upon inference from the universal to the singular. Popper draws an analogy between the problems of induction and the problems of universals. He explains that attempts to identify an individual thing by its universal properties alone fail to define the thing, but to instead put it into a class of things with those same universal properties. Popper gives numerous examples of ambiguities and misunderstandings that come from a misuse of the concept of universality. Some scholars characterize universals as statements in which individual names do not occur. Popper shows this is not logical. Further, naming universal things with the help of individual names becomes a fruitless exercise. He makes clear the close connection of using singular statements to derive universal concepts with induction. Neither is defensible to Popper. These problems of universal and singular statements are similar to the immense confusion among those working in symbolic logic. Problems cannot be solved by using symbolic logic which confuses the distinction between universal and individual names with the distinction between classes and their elements. Using symbolic logic may even exacerbate the problem under investigation.

Popper addresses these ambiguities by approaching theories from a different starting point. Useful natural laws and theories of natural science are in the logical form of universal statements that are negations of existential statements. These take the form of "there is no" or "there is not," denying the existence of something rather than affirming that something exists. Because they rule things out instead of including more things, they are falsifiable. By prohibiting a particular thing they become logically useful statements in accruing knowledge. In contrast, a strictly existential statement like "there are," is not falsifiable. There is no singular statement that can disprove that the thing could be in existence. Therefore, according to Popper, existential statements are metaphysical. They are non-empirical and non-testable.

Theories change, rendering other theories obsolete. All new modifications revise the system of science. This is necessary if science is to form a rigorous system of theories. A theoretical system arises from axioms. Axioms may be seen as conventions or as scientific hypotheses. Conventions tie down fundamental ideas. They cannot be falsified and therefore are not empirical. They are at the highest level of universality. Because of the difficultly in arriving at axioms, it is only at the level of branches of science that well-constructed systems of theories arise from axioms. Even these branches of science only have the derived systems temporarily until some unit of them has been overthrown by newly tested theories. Hypothesis testing can falsify part or all parts of systems, even those based on axioms. Still, Popper finds axiomatic systems to be useful constructs in advancing scientific knowledge. Systems of axioms adhere to a set of rules. They must be free from contradiction. The system must not be able to be deduced from the rest of the system. Axioms must be sufficient for deducing the theory's body of statements. They must contain no extra assumptions that are unnecessary to performing their purpose in the system. These conditions are important in analyzing falsifiability. For example, in some cases parts of the system may be falsified without jeopardizing the entire system.

Part II: Chapter 4, Falsifiability

Part II: Chapter 4, Falsifiability Summary and Analysis

Popper's use of falsification as criteria for deciding whether or not a theoretical system is empirical, and therefore scientific, is challenged by conventionalism. Conventionalists see natural science as a logical construction of nature, not what nature is. For them, the laws of nature are simple. The construction of those laws determines the properties of the natural world. In fact, the laws are required in order to determine our observations of the world, especially scientific measurements like clocks for measuring time. Conventionalists explain inconsistencies by suggesting that greater mastery will yield more complete results, or by questioning the validity of particular measurements or instruments for measurement. Conventionalists see Popper's arguments about the underpinnings of new discoveries through deduction as a collapse of science. They see the only approach as selecting the simplest system from all possible systems. Any other approach, including falsifiability, undermines the principles of science, jeopardizing its very existence.

Popper sees this disagreement as a dispute about the very purpose of science. Giving credit to conventionalism for linking theory and experiment, Popper nonetheless discredits it by suggesting that adapting conditions can make any hypothesis agree with the phenomena under investigation. He proposes creating rules to guard against conventionalism, including retesting systems that seem to have fallen under conventionalist influence. Further, he cautions against blind acceptance of auxiliary hypotheses unless these hypotheses do not diminish the testability of the system or the potential degree of falsifiability. Otherwise these hypotheses might serve conventionalism by creating artificial agreement between theory and experiment. As an extension of this idea, Popper requires that all modifications to theoretical systems, including those higher order changes that affect lower order items, must be re-examined as if a whole new concept was being introduced each time there is a change. At each level, the integrity of testability must be maintained, including rules about the competence of the experimenter or theoretician, by test/retest methods.

For an empirical theory to be falsifiable, basic statements must satisfy two conditions. First, the theory must point to a class of basic statements with which the theory is inconsistent. These statements could potentially falsify the theory. The theory must also contain "a criterion for the empirical character of a system of statements that are to be accepted as basic statements that could contradict the theory." These logical relationships between the theory and classes of basic statements must be consistent and non-tautological. Further, falsifiability must be distinguished from falsification. Falsification is a reproducible effect which refutes the theory. The role of basic statements is to provide logically possible options and to be the basis for contradicting a theory if, and only if, they support a falsifying hypothesis.

Occurrences, or singular statements, are subsets of events. They exist at a particular time in space. Events denote what is universal about an occurrence. This concept is critical to the practical application of falsifiability. A theory is falsifiable if it prohibits at least one occurrence. Through this method, Popper contends that one can learn about the world of experience. If no prohibited occurrences exist, there is no learning. Groups of potential falsifiers must be identical to those of basic statements. Popper favors falsification over verification. One can verify an instance, but falsification applies to classes of events through falsifying basic statements. This means an investigator need not look at every event to falsify a theory. It is impossible to test every occurrence, but falsification is transferrable to other occurrences that fall within classes that have been falsified.

Popper reiterates that empirical systems must be consistent and falsifiable. Consistency divides the statements into those which a theory contradicts and those which a theory supports. It is the most general requirement of all systems. Consistency is generally a prerequisite for falsifiability in that statements which do not conform to the principles of falsifiability also do not differentiate between the two classes of statements required for consistency.

Part II: Chapter 5, The Problem of Empirical Basis

Part II: Chapter 5, The Problem of Empirical Basis Summary and Analysis

Singular statements are important to Popper's argument for a logic of science. In this chapter, he considers the kind of singular statements that are also basic statements. Basic statements allow for considerations of whether or not a theory is falsifiable (empirical) and for corroborating falsifiable hypotheses. Popper investigates the chain of logical reasoning by breaking the process up into many small steps. He claims that these steps are easily checked by those with mathematical or scientific expertise. He suspends judgment if proof cannot be found, but does not deny existence if proof is not evident in tests. If a problem is not testable, then, Popper says that the best contribution such a statement can make is to suggest a problem.

Popper rejects perceptions as the basis of empirical science, tying the proposition to inductive principles. While observations can give information about facts, they cannot justify or establish the truth of a statement. Reiterating his earlier discussion of the confusion of psychology and logic in epistemological discussions, he considers the Fries' trilemma of dogmatism, infinite regress and psychologism. For Popper, universals cannot be reduced to a class of experiences. He appears to weigh in on the trilemma on the side of psychologism over dogmatism or infinite regress, as does Carnap and others whom he cites, but with a twist. Popper distinguishes between objective science and "our knowledge." Scientific statements must be tested by their deductive consequences. Ultimately, Popper refutes all three sides of the trilemma. He rejects dogmatism because one cannot test dogmatically held views. He denies infinite regress because within it there is no intention to use a given theory to prove the statements. Finally, he rejects psychologism because while perceptions and experiences are useful for gathering facts, they do not allow for justification of basic statements through these experiences, especially perceptual experiences. In science it is required that one set points at which one is agreed to be satisfied with the results for the time being. These points generally are set at the level of a fairly simple and easy test. However, the point is not set at the level of perceptions because intersubjective testing of perceptions is very difficult.

Basic statements must take the form of singular, existential statements. They may indeed contradict a theory. They must be observable and inter-subjectively testable by observation in space and time. Popper claims this process is not psychologism because while observations may be psychological, observability is not. He calls observability a "primitive term" meaning it needs no definition but is learned by the epistemologist in the same way they learn and use the word "symbol" or physicists use the term "mass point."

Popper explains his theory of experiment, stating that to test a theory an experimenter attempts to screen off sources of error and limit variables after the theoretician has posed a sharp, clear question. The order of these events is important. Theory guides experiment throughout the process. Popper cites Broglies' prediction of the wave-character of matter as an example of his point. Falsification feeds back to help realign or redefine accepted theory. A theory survives by how it holds its own with other theories, rather than by experimental justification. A good theory is testable in a most rigorous way. It depends upon the basic statements and the relationships of those statements which are made by decisions. From this point of view, decisions ultimately hold the fate of theories.

Popper again challenges conventionalists for believing that simple systems are superior to complex ones. Instead, Popper suggests that the selection should be made on the basis of the severity of the test under which the theory survives. The quality and appropriateness of basic, singular statements in the theory are the vital elements. He also reiterates his challenge to positivists that basic statements are not justifiable by immediate experiences but instead accepted by free decision reached by a procedure governed by rules. Popper uses the example of a jury trial in explaining how such decisions are properly made. Such processes can leave room for subjectivity, a precondition for rational consideration. Where his opponents see that the basis of scientific theory is a system in which universal statements are justified by empirical experience, Popper argues that decisions about singular basic statements in a theory are reached through a process of rules and that those statements will continue to be subject to testing.

Part II: Chapter 6, Degrees of Testability

Part II: Chapter 6, Degrees of Testability Summary and Analysis

In selecting a theory, the degree of testability is a most significant factor. Testability is directly linked to falsification. This chapter investigates comparisons of classes of potential falsifiers to be used in testing theories. Popper states that the amount of empirical information conveyed by a theory increases with its degree of falsifiability. The number of possible events, permitted or not, is infinite. Therefore the aim of theoretical science is to obtain theories that have a narrow range of basic statements that are not forbidden and are easily falsifiable. These theories hold the greatest promise to advance scientific knowledge because they offer the greatest precision in what is actually encountered and observed.

Popper considers the argument made by many theorists that precise meaning is given to classes of events through the power, or cardinality, of the class. He also examines the utility of class dimension, extending through subclasses of events. He dismisses cardinality because falsifiers are shown to be equal in issues relating to power of classes. Dimension shows greater promise. Popper gives examples from geometry to make his argument. More points exist in a geometric shape of greater dimension. Therefore, these classes of events will have more relationships with other events. Basic statements can be combined at junctures to make more basic statements. Finally subclasses are considered if and only if one class includes the other. Otherwise subclasses have limited utility in comparing falsifiers. Popper shows this graphically by using examples of numerical and geometrical explanations of subclasses and logical probability in subclasses to show how empty classes of statements such as those in tautological and metaphysical theories appear everywhere and so cannot be numerically depicted. Empty classes cannot be singled out; they are all equal and therefore not subject to the rigors of scientific empirical scrutiny.

Next he explores the concept of logical probability. By using tautology and contradiction as the boundaries and assigned values of 0 and 1, the fractions in between 0 and 1 represent degrees of falsifiability and therefore logical probability. Probability is complimentary to the degree of falsifiability. The better testable statement has a higher degree of falsifiability and is therefore less probable. Less testable statements are more probable. This holds for universal as well as for singular statements and therefore for theories in conjunction with initial conditions. Since the goal is to find the highest empirical content, statements that forbid more say more about the world of experience. If any two statements have equal logical content, they also must have equal empirical content and other logical comparison conditions if they are to exclude metaphysical statements.

High empirical content is often considered valuable. Popper compares degrees of empirical content by the relationships points of content that fall between contradiction and tautology. By including synthetic statements, which he claims must be empirical, he negates positivist notions that synthetic statements are meaningless. For high empirical content, one seeks the highest degrees of universality and precision. So theories with more universals have a higher degree of testability and a greater logical and empirical content. Both universal and singular statements can be considered as universal conditional statements. This shows which statements can be derived from more universal ones. Information about precision comes from examining ranges, or degrees of freedom. In this way, differentiation is possible between theories whose differences are small and difficult to calculate. Theories with high testability allow for a narrow range and are therefore more precise. There is never a final point of measurement, only a range, however narrow. This gives a background for the statistical theory of errors.

Popper clearly prefers quantitative over qualitative methods. To strengthen his point on this issue, he uses examples such as Plank's conservation of energy formulation as an example of how theories can easily become tautological without some measurements to determine initial conditions. Discovering the degree to which basic statements are composite from other basic statements can be difficult. Understanding this degree has a bearing on showing falsifiability. There must be a minimum degree of composition if a basic statement is to be able to contradict a theory, or else it would automatically be permitted by the theory. Establishing some quantitative values provides a framework for the process of discovering composite statements

In a look at the dimensions of theories using geometry, Popper considers the value of reducing the dimensions of a curve to achieve greater falsifiability. Geometrical procedures only work if the coordinates are of similar theory that can be representing on a graph. Each point is one atomic statement when represented on a graph. He stresses in an addendum (added in 1972) meant to clarify points in this chapter that the content of a theory may have degrees which may make falsifiability relative. He also says the aim of science can be equated with the growth of the content of theories.

Part II: Chapter 7, Simplicity

Part II: Chapter 7, Simplicity Summary and Analysis

Many philosophers emphasize the importance of simplicity. Popper claims they do this without recognizing the difficulties that arise by this emphasis. Without further explanation, he finds simplicity as it is normally applied untenable. First he eliminates the pragmatic and aesthetic meaning of simplicity in his application to epistemological questions. Conventional theory holds that simplicity is expected to achieve a law-like regularity of events as it is considered within epistemology. For Popper, this does not hold up under scrutiny.

Simplicity is suspect to Popper because it plays a special role in the theories of inductive logic. It is used in arriving at natural laws by making generalizations from particular observations. Popper cites Wittgenstein, Schlick and Feigel's call for simplicity as a basic law. He believes their approach logically misses crucial points in the argument. This is an example of injecting metaphysics into scientific theory. He responds to others' explanations for using simplicity as a basic law by invoking his call for falsification. Popper dismisses Weyl's appeal to using mathematical simplicity because Weyl fails to define mathematical simplicity, and more importantly does not outline the advantages of a simple law over a complex one. Popper instead equates simplicity with falsifiability, reiterating that theories with lower dimensions are more falsifiable. He posits that the degrees of universality and precision therefore increase with the degree of falsifiability. Popper objects to the authors' methods rather than to their conclusions. Of the group he argues against, only Feigel explains why simplicity is desirable. To Feigel, Popper responds that instead of appealing to an economy of thought,it is more appropriate to say that simple statements are preferable because they reveal more empirical content and can be better tested.

Popper returns to geometry to explain his views of simplicity. The value of simplicity lies in the testability of simple systems. Using geometrical curves requires that one not change the number of changeable parameters or the displacements of groups of points. Euclidian geometry shows higher degrees of simplicity than any competing hypothesis. Popper gives the example of Euclidean light-ray geometry to make his point. These simpler structures are more easily testable, hence falsifiable. Conventionalists and Popper agree that no theory is unambiguously determined by experience. But conventionalists define simplicity arbitrarily as both aesthetic and practical, giving it a falsifiability factor of zero. For conventionalists, simplicity is arbitrary and hence not allowable for Popper. In his 1972 addendum to this chapter, Popper directly asserts that assuming a meaning for simplicity that takes into account testability would be useful. Popper says that he does not quarrel over words, but philosophical issues. He see the concept of simplicity as a philosophical issue.

Part II: Chapter 8, Probability

Part II: Chapter 8, Probability Summary and Analysis

Discussions of probability can be applied to many subjects. Popper limits his discussion in this chapter to the probability of events and associated problems,as shown in games of chance and with the probabilistic laws of physics. He begins with a basic problem with probability: although probability statements play a vitally important role in empirical science, they turn out in principle to be outside the concept of falsification. His goal in this chapter is to test his theory against this problem. He does this by providing a new foundation for the calculus of probability as a new frequency theory, and by exploring the relationships between probability and experience.

First he distinguishes between two types of probability, numerical and non-numerical probability. Numerical probability involves considering the number of favorable cases divided by the number of possible cases. Non-numerical probability statements cannot be converted into numerical problems without distorting their meaning. Popper is interested in exploring three interpretations of numerical probability. First, numerical probability is often open to subjective interpretation, such as looking at a normal law or error or a mathematical expectation. Popper sees these interpretations as psychologic measures of doubt from assumptions or conjectures. Other numerical probability statements are logical proximity statements whose extreme ends along the continuum are derivability and contradiction. Popper finds this approach to be non-empirical and tautological. Subjective theories can offer a solution to how to decide problem statements and in a similar way can be used in deciding what questions to pose. However, they do not result in empirical solutions and are internally self-definitional, hence tautological. A third interpretation of numerical probability is the objective interpretation, in which probabilities are only expressed as frequencies by using a sequence of events. Popper supports the objective interpretation with some modifications. These modifications turn out to be significant and form the basis of his theory of probability which he calls a modified frequency theory. He begins by exploring the fundamental problem of the theory of chance. Popper calls this theory the most important application of the theory of probability.

The theory of chance is based on chance-like random events. What he means by chance-like becomes evident as he develops his case. Using both mathematical and narrative approaches, Popper first eliminates the axiom of convergence from common frequency theory. He then analyses the assumption of frequency and moves from singular occurrences to supported concepts of regularity and stability of frequencies as the basis for his new theory.

Beginning by explaining von Mises' theory of frequency by using the example of throwing dice, he then uses the coin-toss example to show a simple alternative. As event sequences become longer, according to axioms of randomness and convergence as expressed by von Mises, they approach the same limit as frequencies for all possible events. Cautioning against using these principles in popular realism in the same way they are used in scientific circles, von Mises infers "collectives" through his calculus of probability. These collectives are derived from certain initial probabilities and distributions. Popper criticizes the ways in which the collective is defined by von Mises. First, he finds that one may not apply a mathematical rule like the axiom of convergence to a sequence which by definition of being random is not subject to numerical law or rule. He also finds the need to improve the axiom of randomness, which he sees as a mathematical problem. In its relation to the idea of von Mises' collective, Popper finds the axiom to be self-contradicting. Further, it demands more than is required to be considered "necessary," one of the basic tenets of Popper's approach. By substituting the concept of absolute freedom for von Mises' axiom of randomness, Popper excludes more from the requirement and makes it more testable.

Popper sees the need to eliminate the axiom of convergence which he says is of "concern to epistemologists." He begins by categorizing a frequency theory for finite sequences, one for infinite sequences that eliminates the axiom of convergence, and finally one for objective probability under his new system. He begins with a discussion of calculating frequencies of events.

Frequency in finite sequences starts with a discussion of why selection is critical, methodologically, to operations performed on a finite class of events. This position is used as a basic argument for sample selection in scientific research. He explains the differences in selection by ordinal numbers (i.e. sequenced events by number) and selection according to an event's "neighborhood" or relationship to certain parameters of other nearby events. These may, for example, be the relationship of an event in sequence relative to other events under investigation. Selection according to neighborhood allows for a mathematical definition of sensitivities and insensitivities to an event relating to other events around it, and to combinations of other nearby events. Pairs of processes of nearby events can enable a prediction of the property of the element in question by giving it the initial conditions for deciding a prediction. Such regularity can contribute to probability-based predictions. Not all sequences show these regularities. By extending a sequence that does not show patterns of reliance on other elements and is thereby insensitive to selection according to these parameters, an event can be shown to be free from influence. The larger the sequence in which this remains true, the larger the number of its freedom from influences. Popper mathematically takes this argument through the first binomial, or Newton's Formula.

Next he explores infinite sequences. Infinite sequences are hypothetical estimates of frequency. One area of concern in these frequencies is linking empirical and mathematical rules. In cases in which one can replace an empirical rule with a mathematical one, the limits imposed by the restriction of relative frequencies amounts to an axiom of convergence. The idea that a mathematical sequence will approach an empirical one is hypothetical, but according to Popper this does not affect how to calculate their frequencies. In finite classes, it makes no difference how frequencies are obtained from which to calculate—by rule or by invention. For the purposes of calculation, then, no problem exists by making frequencies a "given." However, this arbitrary assignment is an issue within probability theory.

For infinite empirical sequences, Popper states two main sources of hypothetical estimates of frequencies. The first is the "equal choice hypothesis," shown in the dice example. It asserts equal distribution, normally based on considerations of symmetry. The second is an extrapolation of statistical findings. He claims inductivists ignore the hypothetical character of statistically derived estimates, confusing basing assumptions on statistical extrapolation with empirical sources. He claims there is no justifiable basis for a claim that estimates of probability can be derived from past empirical occurrences that do not stand the test of his theoretical rigor. The result of doing so, he says is advancing non-verifiable hypotheses by a conjecture that frequencies will remain constant. Even equal chance derivatives can be subject of the problem of indicative logisticians' belief in constant frequencies. Confirming predictive estimates always involves pure conjecture.

Moving next into objective probability, Popper shows how he can work with Bernoulli's probability theories without the axiom of convergence. This is a basic contribution Popper makes to the logic of the theory of probability. He begins by mathematically addressing how the theory works for adjoining as well as overlapping segments. He does this by using the third binomial formula to show that from absolute freedom (insensitivity to neighborhood as earlier described) follows insensitivity to ordinal selection as well. Popper describes how while most short segments show great fluctuations, greater samples show smaller fluctuations in what is called "quasi-convergent behavior." However, he considers the law of great numbers not as a trivial axiom of convergence as might be inferred from his argument at this point. To make his argument, he deduces Bernoulli's theorem without assuming an axiom of convergence. Popper begins with the concept of relative frequency and introduces the concept of a middle frequency within a sequence. This does not require the limits set by convergence in frequency calculations. This different premise requires Popper to overcome the problem that middle frequencies are not unique. Failing to address this issue would return his argument to the axiom of convergence. Popper introduces a requirement for uniqueness for middle frequencies. This requirement is set as a last step after a sequence is absolutely free. First, under the requirement of randomness, there must be at least one absolutely free middle frequency—its objective probability. Second, under the requirement of uniqueness, one and only one probability can exist for the same chance-like alternative. These, without convergence, allow Popper to logically deduce Bernoulli's theories.

The theory of chance is then solved by expressing irregularities in terms of hypothetical assumptions of the occurrence of only one of the middle frequencies in any selection so that no after-effects result. Certain regularities appear in very large sequences. This explains the statistical successes of probability predictions in science. Popper explores how this success is shown through a discussion of decidability. In this discussion, he explains that, far from needing a new system of logic, the current success is logically discernable through the concept of possibility and the relationship of probability estimates to basic statements. The requirement of uniqueness alters probability statements to allow them to contradict one another, conforming to fundamental logical relations like derivability and equitability inherent in any universal statement of theory. Popper singles out a falsifiable theory as an example, in keeping with his basic theme.

Finally, Popper specifically looks at physics and the importance of probability statements in interpreting macro laws which are not observable as micro events. He advises using caution in how this is accomplished to guard against allowing speculative metaphysics "to explain any regularity we please." He invokes the rule that extreme improbabilities must be neglected according to agreement with scientific objectivity. This is accomplished by adhering to the reproducible physical effects rule. In discussing physicists' use of probability theory, Popper shows examples of gas pressure. The methodological rule according to demarcation forbids reproducible occurrences of deviations or segments by agreement of what is testable and reproducible.

After developing his theory of probability, Popper discusses his view of chance as a circumstance in which knowledge is insufficient for making a prediction. Without knowledge of the required initial condition, predictions become impossible. Therefore, something is "chance-like" if laws and initial conditions for it have not yet been discovered rather than it being unknowable. The probability of singular events depends upon the class in which the singular event fits, and the characteristics of that class. Popper offers the example of the question about when a man is going to die. It depends upon his age, health and other factors. Subjective statements about singular events attest to the lack of knowledge about the event.

Part II: Chapter 9, Some Observations on Quantum Theory

Part II: Chapter 9, Some Observations on Quantum Theory Summary and Analysis

In this chapter, Popper tests his probability theory on some basic questions in quantum physics. Popper cites quantum physics as one of the premier scientific achievements so doing this is a true test of his own theories. Taking on Heisenberg's Uncertainty Principle, he seeks to show how it contains probability statements that must be interpreted statistically to be useful. He also suggests that some of Heisenberg's assumptions actually contradict quantum principles if they are statistically interpreted. In this exercise, he uses no mathematical arguments and only a single mathematical theorem.

Heisenberg's attempt to eliminate unobservable events to answer criticisms of Bohr's work with the electron is compared to Einstein's issues of hiding unobservable events. At the atomic level, the energy exchange between an object and the measuring apparatus which includes the observer alters the object being measured. Therefore, measurement cannot be a basis for predictions. Heisenberg explicitly prohibits simultaneous measurement of position and momentum. Popper writes that those dealing with uncertainty regularly vacillate between the subjective and objective approaches and that Heisenberg has been unsuccessful in purging atomic science of metaphysical influences.

Heisenberg begins with particle theory where Schrödinger begins with wave theory. These were mathematically equivalent theories. Born interprets the equivalence statistically which is a basis for Popper's assumption for a statistical and objective interpretation of uncertainty relations. Claiming that experimental results do not agree with Heisenberg's interpretation, Popper develops a formula for statistical scatter relations that states there is no aggregate of particles more homogenous than a pure case. He assumes that quantum theory formulae are probability hypotheses. Therefore, they are statistical statements. Using his probability theory that shows single statements logically unable to contradict theory, he claims that exact measurements of position and momentum, if carried out, would not contradict quantum theory. Placing limitations on an attainable precision is dogma, according to Popper. He further claims that by statistical scatter, a particle's path can be predicted and measured, in opposition to general quantum theory.

Popper finds Heisenberg to show influences of positivism in his discussion of non-observable magnitudes and in rejecting a concept of path. Using his concept of falsifiability, Popper refutes any notion of rejecting a concept of a path. Purporting that uncertainty relations are formally singular probability statements, he similarly dispatches the argument of subjective and objective interpretations. He contends that intersubjective objective testability must be applied to statistical statements of quantum theory rather than relying on the subjective statements of quantum theorists whether they come from Heisenberg, Schrodinger or Einstein.

The physical basis for uncertainty theory is undermined by obscuring a logical connection between statistical and non-statistical interpretations. Popper addresses Heisenberg's prohibition against making exact singular prediction by logically linking Heisenberg's statement with the hypothesis that predictive measurement and physical selections are inseparably linked. Without the application of such logic, and without statistical testing, Popper finds Heisenberg's approach to causality particularly disturbing because it is metaphysical. Calling the approach "indeterminist metaphysics," Popper finds causal principles or laws to be dangerous for research. He calls them "crippling," saying Heisenberg is guilty of attempting to give causal explanations for why causal explanations are impossible. Finally, Popper cautions that attempts to demonstrate the uncertainty principle closes off areas of research in the same way that the principle of constant light velocity closes off potential questions by forbidding other options. Returning to the problem inherent in the probability of singular statements when there is insufficient knowledge of initial conditions, he claims that with atomic science, probability takes the place of strict laws and opens the door for untenable theories that actually limit research.

Part II: Chapter 10, Corroboration, or How a Theory Stands up to Tests

Part II: Chapter 10, Corroboration, or How a Theory Stands up to Tests Summary and Analysis

The central question for Popper is how a theory stands up to tests. Popper finds that traditional inductivists working in probabilistic logic and seeking to determine how probable a hypothesis is do not ask the right questions. He equates this issue to the confusion between psychological and logical questions. His goal is to see if a theory is corroborated, and to what degree, by its ability to survive rigorous tests.

The scientific theory arguments he uses to underpin his explorations are these. Theories are not verifiable. They are not falsifiable, either, as far as their logical form is concerned. Showing that a result of the theory or a prediction is verified does not make the theory itself verifiable. Old experiments do not yield new results. Rather, new experiments refute portions of old theories. Parts of the old theories that are successful are retained as regularities. Science presupposes the principle of the uniformity of nature. Popper sees regularities as expressions of metaphysical faith in regularities, but specifically opposes the notion of the principle of the uniformity of nature. He strengthens this point through considering that importance of the non-verifiability of theories.

Like the law of causality, the principle of the uniformity of nature suffers from the metaphysics of induction. Inductivism shows that probability can be regarded as a generalization of the concept of a singular truth. This is at odds with Popper's premises regarding probability and frequency measurements. Logically, looking at probability in this way is, as Popper puts it, hopelessly subjective. Setting hypotheses apart from the sequences of singular statements, he argues convincingly against attempts to identify the probability of a hypothesis with the probability of events. Popper claims that hypothetical assumptions can never be probable, but only can be evaluated by how they function under testing, that is, how they are corroborated.

Probability statements are metaphysical unless it is decided to make them falsifiable by accepting a methodological rule to do so. This is in contrast with the naturalistic view of probability that depends upon inductive logic, which Popper argues leads again to infinite regress. He gives as an example of infinite regress the appraisal of the probability of Schrodinger's theory being 'true' or 'false' according to inductive logic. Since for Popper, corroboration is the goal in assessing theories, he investigates how to determine corroboration. Corroboration goes beyond whether or not a statement is considered to be true. A statement must be corroborated with respect to a system of basic statements accepted at the point of the test. Therefore, corroboration does not equate with truth. It is, instead a logical appraisal of relations.

Charging that it is the severity rather than the number of tests that shows corroboration, he shows how the severity in turn depends upon the simplicity of the hypothesis which determines its testability and falsifiability as the one which may be corroborated at a higher degree. To this effort, Popper states some rules. First, a theory which has been falsified by an inter-subjectively tested experiment will not be continued to be considered highly corroborative. This means the theory will be changed or possibly disregarded relative to the given test. This test is generally considered final if it is a well-constructed test. This is a direct example of the differences in how falsifiability and verifiability are considered. While something can be continually verified, showing a single instance of falsifiability in the appropriate way makes a change in the acceptance of the theory. This goes back to the relationship between accepted basic statements and a particular theory. Greater corroboration is accorded to more universal theories that are falsifiable to a greater degree. So when a theory is highly corroborated, additional instances do not raise its level much unless they corroborate the theory in new fields of application.

Those who subscribe to logical probability take an opposing position, according to Popper. They suggest that the probability of a hypothesis decreases with testability rather than increases. This is because, for them, scientific significance is accorded to hypotheses relative to their justification by experience. Popper believes that this reliance on the logical proximity of theory to empirical statements significantly limits the theory. He sees induction as counterintuitive to generalizations of any kind.

Popper concludes this work with a discussion about the path of science. He calls it a series of inductive directions from theories of a lower level of universality to theories of a high level. He is clear that this is not an endorsement of the inductive method. Instead, this quasi-inductive process is based on deductive testing at each lower level. Looking at science from an epistemological perspective, he marvels at the system of methods of scientific research based on everything to which scientists have previously agreed. Scientists form their experience by being willing to risk refutation and offer ideas up to severe scrutiny. It is the quest for knowledge not the possession of it that leads to scientific advances. The job of scientists is to tentatively accept theories while attempting to refute them.

Characters

Popper

Popper is a highly influential twentieth-century philosopher whose views on how scientific knowledge is discovered have remained important concepts in the development and evolution of scientific thought. His denial of the long-standing principle that scientific knowledge is arrived at through induction led to new ways of viewing what can be counted as scientific knowledge. Two major contributions are his considerations of what science is and how scientific knowledge emerges. The lines he draws between science and non-science refute induction in favor of falsifiability as the basis of scientific knowledge.

Creative imagination plays a key role in Popper's view of the growth of scientific knowledge. However, creative ideas must be subject to rigorous and repeated tested as described in his doctrine of falsifiability. For Popper, distinguishing science from pseudo-science means coming to terms with metaphysics. His disagreements with Heisenberg and other quantum physicists are consistent with his requirement of testability of statements and the ways in which theories stand up to tests.

Publishing the first edition of The Logic of Scientific Discovery in 1934, some revisions appear in the first English edition in 1959. He adds new footnotes and addenda in 1972 to several chapters. These additions clarify or expand concepts in certain chapters about which he had received feedback after the book's publication. For example in chapter 5, "The Problem of the Empirical Basis," he explains that his use of the term "basis" is not solid as it is never beyond being tested and that his "basic statements" are indeed test statements. He further elaborates on his definition of simplicity in chapter 7, and further explains his use of the term "degree of corroboration" in the final chapter and its relationship to his reliance on falsifiability. Popper's theories and ideas, while still grounds for philosophical debate, continue to heavily influence the nature of scientific research and discovery.

Kant

Kant is a philosopher who puts forth the idea that science must be justifiable. As an epistemologist, Kant uses scientific discussion as a major tool to explore scientific problems, theories and procedures. His epistemological approach to the analysis of scientific problems includes the belief that scientific problems are related to common-sense knowledge. His theory of objectivity is the precursor for subsequent theories about objectivity and relativism by Weyl and other philosophers.

A particular thing, to Kant, can only be knowable or understood through its appearances. Appearances are interactions between that thing and the human observer. He further suggests that it is man's own intellect that imposes its laws upon nature. This leads the way to Kant's view of induction as "a priori valid." From this position he postulates the idea of universal causation.

Kant's idealism comes from not adhering to demarcation. The "a priori validity" in Kant's principle of universal causation fails to solve the problems inherent in inductive reasoning. His view of simplicity is at the core of more modern conventionalism although conventionalists expand his premise of making the laws of nature simple to making nature itself simple.

Kant's problem about the limits on scientific knowledge is related to this lack of demarcation. Much of what comes from this type of empirical discovery turns out to be false or cannot be corroborated to a degree in which it is considered probable.

Hume

Hume is an epistemologist who questions the logical justification of universal statements about reality. These questions about the value of induction create a dilemma for Hume. As a positivist, Hume sees knowledge as derived from the observable. However, he reduces the metaphysical to nonsense and hence finds problems with the inductive method. The inconsistencies Hume finds in the principle of induction—that it is impossible to show the validity of natural laws by observation or experiment—may be addressed by demarcation according to Popper.

Carnap

Carnap promotes the value of both inductive and deductive logic in science. He agrees with Popper that there is a distinction between justification and discovery, but takes a different approach to understanding that distinction. He claims that all philosophical investigations speak of the forms of speech so therefore the logic of science must investigate scientific language and its forms. He calls sentences which represent experiences "protocol sentences" in distinguishing between empirical and theoretical laws. Therefore, scientific sentences can only be compared with other scientific sentences, not with experiences. Still he is translating experiences into forms of speech, retaining a psychologistic approach. He claims that science should stop at the point of perceptions, even though intersubjective testing is difficult at these points.

Bernoulli

Bernoulli is the developer of a theorem for the first "law of great numbers." This mathematical theory of probability states that large samples, approaching infinity, only deviate from the frequency value of the all possible samples by a fixed, small amount. By showing the statistical stability of random numbers, he significantly contributes to the concept of mathematical probability.

Keynes

Keynes is a proponent of probability theory based on the logical proximity of events. He defines probability as "the degree of rational belief."

Wittgenstein

Wittgenstein is a positivist philosopher who advocates for the definitive and unassailable tenants of science.

Poincare

Poincare, whom Popper places alongside Duhem and Eddington, is one of the major proponents of conventionalism

Kepler

Kepler is a philosopher who developed an easily falsifiable circle hypothesis which helps to formulate Kepler's Laws of planetary motion. His methods correspond to the method of elimination which can be used only if a theory is sufficiently easy to falsify.

Schlick

Schlick posits that the contradiction between empiricism and the lack of validity of inductive thought can be solved by seeing natural laws as rules for transforming statements rather than as genuine statements themselves.

Richard von Mises

Richard von Mises develops a frequency theory that provides a foundation for the principal theories of the calculus of probability. He develops the "axiom of convergence" and the "axiom of randomness" that underpin standard probability theory.

Fries

Fries is a German philosopher who states that if scientific statements are not to be accepted dogmatically, they must be justified by reasoned argument leading to a "predilection for proofs." Faced with the trilemma of infinite regress, dogmatism or psychologism, he embraces psychologism in his adherence to the value of immediate knowledge gained from the sense-experience. This experience is then mediated through symbols of language into scientific statements.

Objects/Places

Inductive Method and Logicappears in non-fiction

Inductive methods rely on experiences as the source of scientific theories, inferring universal statements from singular statements. Popper does not believe induction is a scientific method. Much of this book involves refuting inductivist methods even when used by epistemologists with whom Popper may otherwise agree.

Empiricismappears in non-fiction

Empiricism relates to our experiences. Empirical sciences are based on sense perceptions, or our experiences. While Popper finds empiricism useful in some aspects of scientific inquiry, he claims that inductivists inappropriately use these experiences as sources from which to derive theories.

Deductive Method and Logicappears in non-fiction

Deductive methods are those used to derive singular statements from one or more universal statements together with initial conditions that apply to the statement in question.

Metaphysicalappears in non-fiction

Metaphysical is non-empirical. Positivists extend this definition to include meaningless and nonsensical. Popper considers the fallacies of inductive logic partially a result of their reliance on metaphysics.

Positivismappears in non-fiction

A positivist is one who approaches scientific questions from the point of view that everything that counts as knowledge lies in empirical statements. Popper claims that this limits the possible world of scientific exploration to empirical knowledge while also disallowing philosophical theory as meaningful.

Probabilityappears in non-fiction

Probability is described by Popper as frequencies that can be explained by series of events. He develops competing theories of probability and posits a new calculus of probability based on the concept of middle frequencies.

Cosmologyappears in non-fiction

Cosmology is the study of the universe. Popper claims every person is interested in the place held by an individual in the universe.

Conventionalismappears in non-fiction

Conventionalism is a theory that clings to the idea of simple, basic laws of nature. These laws are created in the human mind and serve as the logical construction of nature from which humans can think about science. Conventionalists rely on inductive methods and ad hoc theories to sustain these basic laws. Popper rejects conventionalism as metaphysical and frequently tautological.

Epistemologyappears in non-fiction

Epistemology is the study of the logic of scientific discovery. Popper holds that epistemology involves rational thinking, and that epistemology and related ideas of growth of knowledge are the primary philosophical problems to be investigated.

Tautologyappears in non-fiction

Tautology is a loop from which one cannot logically escape. Terms in a tautological argument define one another, leading to a lack of testability. Inductivist logic is often tautological which can, in more extreme instances, lead to infinite regress.

Demarcationappears in non-fiction

Demarcation is the separation of the empirical from the non-empirical. It is a key feature in Popper's tests for scientific logic.

Fries Trilemmaappears in non-fiction

Fries trilemma is the problem faced by epistemologists in attempting to account for empirical knowledge. The trilemma psychologism, dogmatism or infinite regress is considered in Fries' "predilection for proofs."

Psychologismappears in non-fiction

Psychologism is the doctrine that statements can be justified by perceptual experience as well as by statements

Dogmatismappears in non-fiction

Dogmatism is the adherence to certain laws or statements as certain, irrevocable truths.

Infinite Regressappears in non-fiction

Infinite regress is the result of inductivists' attempts to logically justify statements within a theory by using other statements in the theory. This loop does not allow for intersubjective testability of statements.

Heisenberg's Uncertainty Principleappears in non-fiction

This principle includes statements about ranges of uncertainty due to the limits of precision in measurements. This basic principle is a precept for quantum theory, stating it is impossible to simultaneously measure an object's position and motion in the quantum universe.

Themes

Science is Deductive, not Inductive

Popper is critical of those who follow inductive theory for believing that scientific theory starts with stray elementary perceptions. These perceptions are metaphysical and lead to infinite regression. They do not allow for explorations of the regularity of theories. A theory should lead to deducing more empirical statements than the number that can be deduced from the initial condition without the theory.

At critical junctures in each argument, Popper described how inductivists use a term, theory or process and why that approach is suspect. For example, the fact that inductivists see statistical stability as a fundamental law of nature not reducible to a simpler statement is for Popper a logically unacceptable tautology.

He is clear that deterministic positivist assumptions are not tolerated in his approach to probability. In particular, he takes issue with logical probability which relies on the proximity of theory to empirical statements. Because of justification by experience, this leads to the exact opposite conclusion from Popper's: that the degree of probability of a hypothesis decreases with its degree of testability.

In testing his own theory of falsifiability in examples ranging from the properties of gasses to quantum physics, Popper contrasts his own approach with that of inductive reasoning. He repeatedly shows how assuming the existence of natural laws from which theories may be developed is a flawed, circular argument that fails under his definition of scientific empirical reasoning. Acknowledging the contributions of early philosophers like Hume and Kant to observational testing of ideas, he faults prior acceptance of laws or assumptions not testable under his definitions. In this way, he defines a lack of demarcation between the empirical and the non-empirical as one of his basic problems with inductive theory.

Falsifiability is the Correct Way to Approach Problems of Sc

Theories can never be verified, only falsified. Each instance in which a theory is shown to be true cannot counteract a finding which shows the theory to be false at the level of basic statements of that theory. It is important to note that instances in which is theory is observed not to work does not necessarily mean the theory has been falsified. Whether or not it is falsified depends upon the nature of the basic statements of that theory, not whether or not specific instances have been empirically observed that do not fit the theory.

Basic statements are particular kinds of singular statements. Possessing one or more basic statements is one of the logical characteristics of falsifiable systems. Theories that have more basic statements to test are considered to be stronger theories. Positivists and other inductivist thinkers assume the opposite is true, believing that fewer statements lead to stronger theories on the basis of traditional ways of viewing simplicity. Popper's definition of basic statements become the basis for his premise of probability and for the logical basis for deductive over inductive reasoning in scientific logic. Falsifiability is the antidote to the inductive use of dogmatism, infinite regress and psychologism. Through refuting an idea, a context is created through which imaginative thought may spawn a new discovery.

Probability as the Measure of the Value of Popper's Approach

Probability as it is applied to making predictions is one of the most widely used aspects of scientific logical thinking. Popper describes probability as frequencies that can be explained by some series of events. Through a discussion of probability in games of chance and physics, Popper takes the opportunity to refine and test his use of falsifiability. He develops a new calculus for probability using what he calls "middle frequencies." This is his answer to basing probability on a frequency theory, but without relying on von Mises' axiom of convergence. He does invoke a somewhat weakened version of von Mises' other axiom, the axiom of randomness but changes some of the premises.

By showing the usefulness of falsifiability in probability, he distinguishes probability from chance. Using dice throwing as an example, Popper labels the common concept of chance as subjective, saying that it is a situation in which there exists no knowledge of initial conditions. It is only through corroboration that regularities can be established, not through metaphysical assumptions or dogmatic adherence to laws that cannot be challenged. Within the context of logical assumptions about law and chance, he examines probability sequences as "chance-like," explores the theory of ranges, issues of decidability and the interpretation of probability statements.

Style

Perspective

The perspective of this work is that of a philosopher who makes expert logical arguments to support his case. This perspective is explicitly stated as Popper develops each of the basic concepts that underpin his logic. The reader is led to accept his expert status through his use of examples from a variety of disciplines, and his refutations of specific logical tenants held by other philosophers across different time periods.

Popper's method is to first make the opposing argument and then to expose its weaknesses using a counter argument. This method repeatedly returns the reader back to Popper's main philosophical arguments, especially the importance of falsifiability. In the attempt to show the solidity of his argument, Popper tests it in ways which reveal weaknesses in his own argument. He does this to perhaps show that his methods, while imperfect, are still preferable to inductivist and positivist arguments he directly opposes, such as those held by Fries, Wittgenstein and Schlick.

By maintaining the developing argument within the boundaries of philosophical discussion, Popper maintains a distance from the non-theoretical applications except when he uses particular examples to illustrate a point. This approach also allows him to be gracious in his discussion of the contributions made to science by even his most adamant detractors and by those whom he severely criticizes for flaws in their theories or logic.

Tone

Initially, the author's tone is one of leading the reader through an exploration of the common beliefs about scientific theory, where they came from and why one might question some of the basic tenets. He offers appreciation to those who have gone before him, like Kant, Hume, Kepler and others, while gently pointing out how he has built on their contributions. For example, learning how to empirically test theories is a valuable contribution.

As he develops his theories, Popper becomes more pointed in his criticisms of positivists and conventional scientific thinking. Their approaches are flawed and unscientific. They confuse empiricism with metaphysics. Occasionally returning to earlier contributions such as the one made by Euclidian geometry to the concept of simplicity, he carefully sets the stage to show how and why such concepts have become improperly used in the service of inductive reasoning. For example, he debunks the assumption made by thinkers who state that simplicity is innately preferable to complexity.

In considering probability, he expands the methods he uses to attack approaches that do not conform to his ideas of falsifiability or those that have metaphysical leanings. He employs a combination of mathematics and narrative to attempt to discredit appeals to inductivist reasoning and positivism. While giving credit to Bernoulli for his law of great numbers and some other contributions by fellow philosophers, most of the emphasis is on showing why positivists begin from misguided assumptions that limit knowledge, and that anything with metaphysical undertones is overtly suspect. He falls somewhat prey to his own argument when he admits that probabilistic statements are not testable, but stays strong in his overall convictions.

Popper adopts an even more highly critical tone when considering quantum physics. In particular, he attacks Heisenberg for placing limits on what can be known and for having positivist tendencies. He also considers Einstein and others suspect in their logic, claiming that even to ask the question of whether or not the natural world is ruled by strict laws is metaphysical. He further develops and supports this stance in appendix vi. In the final chapter, he returns to his more conciliatory tone in discussion corroboration, but not without some final shots at inductivists, positivists and conventionalism.

Structure

This work is comprised of two parts and ten chapters. Part One contains two chapters and Part Two contains eight chapters. Chapter lengths vary from twenty pages long to over seventy-five pages long. Each chapter has a name that refers to the content of the chapter. The entire work is broken into consecutively numbered sections that continue throughout each chapter from the beginning of the work until the end. The author references numbered sections throughout the text, when indicating something that has already been covered or something which he will explore further in a later part of the work. The text contains extensive footnotes. Some chapters have addendums added by the author several decades after the original publication of his work. Seven appendices are part of the original work, with another twelve added by the author twenty years after the original publication. These appendices primarily go into greater detail about the points raised in the chapters, including more in-depth mathematical arguments in support of Popper's theories. The final appendix also includes correspondence by Albert Einstein that responds to Popper's comments on quantum physics.

Popper's major concepts are introduced in earlier chapters and developed more fully in later chapters. Examples of this manner of concept development include Popper's treatment of inductive vs. deductive reasoning, falsifiability and probability. Some chapters, like chapter three on the logic of theories, are departures from this approach and explore deeper theories of philosophy. These sections seem to take the reader away from the basic arguments and become somewhat obtuse and difficult.

Overall, the author's points are developed logically and understandably. Given the depth of philosophical thought and argument involved, it is surprisingly readable and comprehensible. Popper leaves most of the mathematical explanations that support his points to the appendices so that those who wish to examine the mathematical arguments can do so without overburdening the text with pages of equations. The few equations that do appear within the body of the work are well explained in ways that a non-mathematician can comprehend.

Approaching the end of the work, Popper appears to abandon caution in his attempt to show that he is willing to put his theories to the test and abide by his own precepts of placing theories under rigorous tests. Disputing scientists like Heisenberg and even some of the ideas of Einstein is no small test. This makes for an interesting section from the reader's viewpoint, if not wholly satisfying from a logical one. In the final chapter, he returns to his themes using corroboration through inter-subjectivity to complete his argument for rationality based on deductive reasoning.

Quotes

"The theory to be developed in the following pages stands directly opposed to all attempts to operate with the ideas of inductive logic. It might be described as the theory of the deductive method of testing," or as the view that a hypothesis can only be empirically tested—and only after it has been advanced," Chap. 1, A Survey of Some Fundamental Problems, pp. 6-7.

"The empirical sciences are systems of theories," Part II, Chap. 3, p. 37.

"The negation of a strictly universal statement is always equivalent to a strictly existential statement and vice versa. For examples, 'not all ravens are black' say the same thing as 'there exists a raven which is not black,' or 'there are non-black ravens,'" Part II, Chap. 3, p. 47.

"A nice adaptation of conditions will make almost any hypothesis agree with the phenomena. This will please the imagination but does not advance our knowledge," Part II, Chap. 4, pp. 61-2.

"Whilst tautologies, purely existential statements and other nonfalsifiable statements assert, as it were, too little about the class of possible basic statements, self-contradictory statements answer too much. From a self-contradictory statement, any statement whatsoever can be validly deduced," Part II, Chap. 4, p. 71.

"For we can utter no scientific statement that does not go far beyond what can be known with certainty 'on the basis of immediate experience," Part II, Chap. 5, p. 76.

"There is only one way to make sure of the validity of a chain of logical reasoning. This is to put it in the form in which it is most easily testable; we break it up into many small steps, each easy to check by anybody who has learnt the mathematical or logical technique of transforming sentences. If after this anybody still raises doubts then we can only beg him to point out an error in the steps of the proof or to think the matter over again," Part II, Chap. 5, p. 81.

"Thus it can be said that the amount of empirical information conveyed by a theory, or its empirical content, increases with its degree of falsifiability," Part II, Chap. 6, p. 96.

"Now this sheds some light, I think, on the superiority of methods that employ measurements over purely qualitative methods," Part II, Chap 6, p. 110.

"The logical probability 1 corresponds to the degree 0 of falsifiability and vice versa. The better testable statement, i.e. the one with the higher degree of falsifiability, is the one which is logically less probably and the statement which is less well testable is the one which is logically more probable," Part II, Chap. 6, pp. 102-3.

"We can compare theories with respect to testability only if at least some of the problems they are supposed to solve coincide., Part II, Chap. 7, p. 132.

"Thus I declare my faith in an objective interpretation; chiefly because I believe that only an objective theory can explain the application of the probability calculus within empirical science," Part II, Chap. 8, p. 137.

"I do not attach much importance to these questions about the origins of 'sources' of our estimates. It is more important, in my opinion, to be quite clear about the fact that every predictive estimate of frequencies, including one which we may get from statistical extrapolation—and certainly all those that refer to infinite empirical sequences—will always be pure conjecture since it will always go far beyond anything which we are entitled to affirm on the basis of observations," Part II, Chap. 8, p. 158.

"My contention is that the relation of probability estimates to basic statements, and the possibility of their being more, or less, well 'confirmed,' can be understood by considering the fact that from all probability estimates, existential hypotheses are logically deducible. This suggest the question whether the probability statements themselves may no, perhaps, have the form of existential hypotheses," Part II, Chap. 8, p. 185.

"The belief in causality is metaphysical. It is nothing but a typical metaphysical hypostatization of well justified methodological rule—the scientist's decision never to abandon his search for laws," Part II, Chap. 9, p. 245.

"[Hypotheses] are not verifiable because they are universal statements, and they are not strictly falsifiable because they can never be logically contradicted by any basic statements," Part II, Chap. 10, p. 259.

"The old scientific ideal of episteme—of absolutely certain, demonstrable knowledge, has proved to be an idol. The demand for scientific objectivity makes it inevitable that every scientific statement must remain tentative for ever," Part II, Chap. 10, p. 280.

Topics for Discussion

Discuss induction and deduction. Is science inductive or deductive? Is Popper's logic sound? For what kinds of investigations should inductive methods be used? Deductive methods? A combination?

Discuss falsification. Does an insistence of falsification negate types of knowledge that enhance knowing about the world? Does falsification constrain thought, or give it a structure upon which to build on earlier knowledge?

Is all metaphysical knowledge non-scientific? Within scientific theory, how does Popper account for the metaphysical? Is causality something to be set aside as metaphysical as Popper suggests, or are there different ways to approach causality that are scientific without falling into tautology?

Discuss Popper's solution to his admission that probability is not falsifiable. Is his response ad hoc? Does the act of excluding statements of extreme improbability avoid rendering probability statements non-empirical?

Explain why Popper believes that, in order to be useful, predictions must be risky. How does this relate to his concepts of simplicity?

Does Popper refute his own logic in using Bernoulli's law of great numbers? If not, why not?

Discuss the values and pitfalls of the concept of simplicity as used by Popper and under the argument made by conventionalists.

Is Popper convincing in his criticisms of the Heisenberg Uncertainty Principle? Do the assumptions made by leading quantum physicists regarding the observer effect at a quantum level mean that their logic is not rational?

Discuss the ways in which Popper constructs his arguments. Could Popper have made his arguments more simply? Does he fall into his own traps by trying to be overly elegant in his explanations, or is the complexity required to weave his principles throughout the development of his approach to scientific discovery?

Discuss Popper's reliance on corroboration. If a theory is improbable but is highly corroborated, is that theory valuable? Why or why not?