VALUE-LADENNESS OF EVIDENCE IN SCIENCE

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By

Justrus Mathew

DEPARTMENT OF PHILOSOPHY

SCHOOL OF HUMANITIES

UNIVERSITY OF HYDERABAD

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INDIA - 500046

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This is to state that the research work embodied in the thesis titled "**Value-ladenness of Evidence in Science**" submitted to the Department of Philosophy, University of Hyderabad, for the award of the degree of Master of Philosophy in Philosophy is original and carried out by me under the supervision of **Dr. Prajit K. Basu, Professor, Department of Philosophy, University of Hyderabad.**

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Date:

Place: Hyderabad

Prof. Prajit K. Basu

(Research Supervisor)

Dean

School of Humanities

Head

Department of Philosophy

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CONTENTS

INTRODUCTION

Science can be identified at two levels; science as a practice and science as body of knowledge. Usual accounts of science gives no consideration to the practical aspect of science. Considering science as a body of knowledge, we might say that science is objective, truth conducive and the justification of the theory is given by a set of reasonable evidence. This ignores how a scientist enhance a theory through his/her understanding and observation .Traditional, logical positivist and logical empiricist accounts of scientific rationality expected science to be consisting of rational method of enquiry, which enables to establish truths about nature. Science as a body of knowledge represents the set of propositions, descriptions which are justified.

By the emergence of 'Historicism', science was analysed through the history and the conception of science began to change. These philosophers in the Historicist tradition started identifying science as a practice. Soon after, the conception of science began to change. Science no more seemed to be operating in a strict algorithm governed by strict rational logical methodology. It started pointing towards the limitations in obtaining scientific knowledge. People started to see that the set of rational descriptions was not adequate to explain the practice of science. At times where same set of evidence supports multiple theories, there are uncertainty created by the problem of induction in scientific practice. This logical step reaches a saturation factor from where the logical methods cannot lead us further in justifying a theory. In that case how is the scientist able to proceed further? All this shows why the analysis of science at the practical level is important. This thesis analyses the practical side of science.

There are two ideals which philosopher tries to identify in connection with science. The value-free science and the value-laden science. Often, science is considered to be value-free. Especially the traditional accounts of scientific rationality including those suggested by the positivists identify science essentially as value-free. This thesis analyses the main question;

whether science is value-laden or not specifically in context of appraisal of evidence and tries to figure out the nature of value-ladenness of evidence in science

There are many choices that need to be made in scientific practice and a choice requires a value judgement. In a science and value discourse, values are defined as the standard based on which a choice is made. The practice of science can be defined into three phases; pre-epistemic phase (appraisal of topic of research), epistemic phase (appraisal of evidence) and post-epistemic phase (application of the theory). The value-free science is defined as science which is governed by epistemic values and the value-free ideal concentrates only on the epistemic phase. The other two phases are granted to be influenced by the non-epistemic values. In general, epistemic values are defined as truth-conductive. Even though there is no conclusive list about epistemic values, simplicity, unifying power, consistency etc. are considered to be examples for epistemic values. In opposition to this, non-epistemic values are defined as values which are not necessarily truth-conductive. The examples for non-epistemic values are political values, cultural values, etc. So, a value-laden science means, if a choice is made based on non-epistemic value then the science is said to be value-laden.

In chapter 1, instead of identifying epistemic values with particular values, an attempt is made to define epistemic values based on their necessary features. The value-free science is identified with the features of epistemic values which are truth-conduciveness, objectivity and priority of evidence. Value-free science necessarily presupposes that the concept of objectivity and priority of evidence to be maintained. Chapter 1 further goes through the definitions of objectivity and truth (in connection with the arguments for and against scientific realism). It tries to explicate the practical difficulties in attaining the concepts of truth and objectivity which include the problem of inductive risk and under-determination of the theories.

Chapter 2 in detail analyses the notion of how the priority of evidence is attained at the practical level. In the procedure of setting priority of evidence, it constitutes observation, interpretation of the observation and the qualification of observation as evidence. The first part of this chapter provides the basic characteristics of observation as given by Dudley Shapere and Stephen Jayard. In the following section, definition of evidence is given along with different accounts which tries to explicate a formal relation between the theory and evidence. But such a relation cannot be maintained practically. The practical features like the epistemic context in which the theory is proposed, etc., necessarily influence the appraisal of evidence. The problem of inductive risk and the under-determination of theory show that there cannot be a necessary relation between theory and evidence. In absence of such a relation, how does the evidence establish the confidence over a theory? In value-free science, the evidence must be able to support the theory independently of the theory. The evidence should not be manipulated according to the theory. Rather, the evidence must be able to justify a theory independently. This takes us to the discussion on theory-ladenness of the evidence. Logical positivists envisioned a science which starts with theory independent observations and through induction, theories are inferred. However history of science shows this is often not the case.

The following part of the chapter analyses this theory-ladenness of evidence, its affects and how it effects the priority of evidence. Three experiments from the history of science is analysed, namely;

1. Cathode rays experiments by Henrich Hertz and J. J. Thompson which show the same observation can be made to be evidence to two opposing theories. Also, how the theory preference of the scientist influenced the design the experiment (mainly considering the effect of vacuum in the experiment).

2. Eddington expeditions to prove general theory of relativity which essentially shows the theory-ladenness in interpretation of observation and qualification of observation to evidence.
3. Gravitational wave experiments shows the theory-ladenness effect in the choice of methods for analysis of experimental data and evidence.

Analysis of these experiments and the procedure in which the evidence for the theory is obtained shows the theory-ladenness of the evidence and how this theory-ladenness affects the interpretation of the observation, qualification of the observation to evidence. We can see that instead of the keeping the experimental results independent and analysing its match with theoretical value, the experimental results were manipulated towards the theoretical value. Consequently, instead of evidence getting priority over theory, theory gets priority over the experimental results. But despite all this, these theories got accepted. The further analysis of these experiments explicate the role of consensus among scientific community in acceptance of a theory (justification). Along with this, we will be able to see how objectivity and consensus of the scientific community is related. When we say that a theory has been accepted by the scientific community, it does not mean that each and every member in the scientific community is ready to accept it. This means the consensus of the scientific community is not unequivocal. Yet the acceptance is given for theories (even in cases where the experimental result did not match with the theoretical value).

The next section in the chapter attempts to explain the relation between theory-ladenness and value-ladenness. This consists of analysing the factors which make a theory dominant and how it gets connected to value-ladenness because not every theory gets dominance. The analysis shows that personal preferences of the scientist is an essential part of theory-ladenness. These preferences essentially influence the appraisal of evidence through theory-ladenness. In other words, the values which influence the appraisal of topic (pre-epistemic phase) can influence the justification of theory through theory-ladenness of evidence which enables us to conclude the value-ladenness of evidence in science. This essentially makes the science, value-laden.

Science fundamentally possesses a deficiency due to the limitation of the epistemic features to lead us to certainty. No theory is proven conclusively and with certainty. There is always a limit to which the epistemic features can make us confident about the theory and evidence. Beyond that, there is a leap of faith which every scientist has to take, which is not epistemically driven. In that case it is the non-epistemic values which fills that gap of uncertainty.

CHAPTER – 1

What is it to be Value-laden in Science?

Introduction

This chapter intends to explicate the notion of value-ladenness in science. The chapter starts with an account from the history of science on which happened at Germany in context of the spirit of anti-Semitism. This shows an instance of how social values can affect science. There are two ways in which science can be conceptualized. Science as a practice and science as a body of knowledge. For the purpose of this thesis science is identified as a practice. The following section of the chapter discusses the concept of truth and realism in science. This particular discussion analyses the arguments given by the realist supporting their position and the argument given against the realist argument. It tries to argue that neither the position of realism nor the constructivism is applicable to science. This discussion also tries to show the difficulty in an absolute conception of truth because of the absence of a self-evident principle as the criteria for truth.

The next section of chapter discusses the concept of objectivity in science which is very important in understanding the value-ladenness of science and identities the connection between value-ladenness and objectivity. This will be explained in detail in the later part of the chapter. The notion of values, epistemic values and non-epistemic values are defined. The chapter also goes through the definitions given by various philosophers for the above mentioned concepts. From my analysis of these concepts and examples of epistemic values, the epistemic values is identified with three necessary conditions

1. Truth conduciveness
2. Priority of evidence

3. Objectivity

The analysis enables me to identify the concept of value-free science in terms of these three conditions and the deviation from these ideals during scientific practice make science value-laden.

The chapter ends with the definitions of the problem of inductive risk and problem of under-determination of theories which hinders the attainment of the above mentioned ideals and is considered as a threat to value-free science. How these concepts adds to the value-ladenness of evidence will be discussed in the second chapter. In light of the analysis given in this chapter, I define the notion of value-ladenness in science as the non-attainment of the ideals of objectivity, truthfulness and priority of evidence during the course of a scientific practice.

1.1 Science and Society

In 1920s after the defeat of Germany in World War 1 the spirit of anti-Semitism that existed in Germany during that time was not just about deprivation of certain scientist (similar incidents were also observed under the rule of Stalin in Russia and at other instances)[1]. At least in Germany, anti-Semitism prescribed the way science must proceed. After the publication of the theory of relativity and in spite of the popularity in acceptance among the Europeans, German academia was not very interested in the theory of relativity. One of the most important factor which led to the rejection of the theory was Einstein's Jewish lineage. By the beginning of 1920 Einstein and his theory of relativity faced criticism based on racial grounds. In 1933, the spirit of anti-Semitism reached its peak. As a result, books authored by Jews including works of Einstein were set on fire. It is surprising to note that the list of opponents to the theory that

[1] In 1943, Russian scientist Nikolai Ivanovich was sent to prison by Joseph Stalin. Nikolai was blamed as the reason behind the failure of the collectivist agricultural program. In reality, the contributions made by Nikolai in the field of genetic crop development actually helped to lessen the food scarcity that existed in his country. But when Soviet Union became convinced that his genetic theory was not in accordance with the Soviet Union values, Nikolai became the scape goat for the failure of their agricultural policy (Elliott, 2017).

was considered the best among scientific theories didn't comprise of just laymen who had no idea of science but also scientists. Of which was Nobel laureate Lenard, a prominent experimentalist who was awarded on his work on cathode ray radiation in 1905. Lenard being less equipped with mathematics had criticized relativity in 1910 itself, emphasizing on the fact of physics being deviated from experimental nature. He went to the extent of calling the theory of relativity a Jewish way to pollute academia. In 1920 when the racial discrimination became prominent Lenard joined the party. Later analysis tried illustrating the personal dislike and jealousy to be factors in the objections raised. Similarly, responses from the laymen were interpreted in terms of the metaphysical divergence which the theory proposed along with the highly charged political atmosphere of the period.

Einstein's critics could disagree with relativity for a number of reasons: either they maintained a belief in the ether, or in the absolute nature of time. According to Wazeck, the success of the theory of relativity marginalized those academicians that had different ideas and opinion. Scientists like Gehrcke and Lenard, would find themselves on the margins of their profession, as they would be easily overlooked and their institutional desires would less likely to be fulfilled. Scientist likewise would find it even more difficult to get ideas published in respected journals, or be awarded speaking time at scientific meetings. Modern science, most prominently represented by Einstein's mathematical physics, would side-line them. Thus, anti-relativist scientists like Lenard were only trying to defend their own ideas and social status as scientists (there are even more reasons to be said about Lenard's personal jealousy in the anti-relativity campaign). Moreover, the acceptance which Einstein's theory got in Europe added to the grudge of the anti-relativity campaign.

This account from history shows, how social judgements can influence a scientific judgement in accepting a theory. In the history of science, this episode is not given much importance as the opposing arguments of relativity were lame and the theory of relativity prevailed as a dominant theory in physics. One attributing reason for its success is the importance the theory gained in the European academic circle. But hypothetically, had it been the case that the Germans had the power to accept or reject the theory of relativity, the plight of the theory would have been very different. This goes on to show how social ideas can interact with scientific decision making.

1.2 Science as a Practice

There are two senses in which the term ‘science’ can be identified. Science may be regarded as collection of propositions ranging from reports of observations to the most abstract theories accounting for these observations. This conception of science focuses on the end product of scientific practice. The image of science which we get when we read a science text is this, that which has no description about the practical aspect of science as in how these discoveries were made or why certain theory got accepted. It serves us with a set of approved description which are considered to be about the hidden principles of nature and which are true (the concept of truth is not a fixed one). The second conception includes the various practical aspects the scientist goes through in enhancing a theory through his/her observation and understanding. This aspect of science tries to analyse various notions which affect the scientific decisions at various stages. This conception includes all the stages of science which underlies the reported form of science as theory. In short, this second conception tries to include all steps the scientist takes, factors that affect the scientific enquiry to produce its result.

Considering S1 as the first conception and S2 as the second conception, S1 is usually considered as the measure of achievement made by the scientific enquiry. To conceptualise S2 is not as easy as conceptualizing S1. In that sense, S2 might be vague when compared to S1. “In the permanent record of the textbook, it is S1 that figures, and usually in an artificial form that gives practically no clue to the real sequence of events and considerations. S2 is, for the most part, is soon forgotten. Indeed, even to begin with, much of it may never have been made explicit. The interest of S2 is only this, that in a very definite sense it serves to explain how S1 came to be formulated in the first place" (McMullin, 1970). Science is identified with S2 in this chapter.

Science is certainly an empirical study which tries to conceptualize nature with the help of observations and various other techniques to suit our needs. When a theory is proven for the time being, it doesn't mean that it is right for ever. Also, it would be wrong to say that the theories explaining the phenomenon is in exact correspondence with phenomenon (in that case the theory must be able to explain all aspects of the phenomenon; past, present, future and it cannot be said that we perceive the reality as it is in order to explain the correspondence). In other words, when we talk about Newton's laws of motion, does nature follow the laws or is it in our understanding nature obeys these laws? So, laws are not for nature, rather that's the prism through which we understand nature. As Albert Einstein said about the relation between science and nature, nature is like a watch dial we can know the time through the dial but we will never know what is happening inside. It is not the case that nature is dictating to us about its phenomenon. It is we, using our sense experience and further logical calculations and imaginations who make up the picture of nature.

1.3 Status of Realism in Science

Science is considered to be the top among the most successful human endeavours. It is considered as the highest pinnacle of rationality. This superiority of science is conceptualised in terms of the very rationality of methods which it possesses and the correspondence to reality. During the time of Galileo, it was considered that science has an intrinsic reality such that the theories and laws in science are in correspondence with the reality. Scientific theories are as much real as the phenomenon (nature). Scientific theories were considered as the mapping of the reality (nature) in terms of correspondence, hence these theories has intrinsically reality. .Moreover, use of mathematics of language and the certainty of the theories resulted from the very reality of nature and the correspondence of the theories to nature. Even today the same view is predominant, though it may not be with the same force as it was before.

The reason for realism to be a more prominent view is that it gives a more unified and ordinary sense data-based representation of the world. To an extent, it avoids relativism which enables for an objective judgement (axiomatic). Science aims to provide explanations for natural phenomena and casting them in terms of the absolute conception would help realize this aim. In fact, science lacks an external standard until we understand and define it. Unlike olden days, the realist conception of science, that nature is given to us and we understand nature in the way which nature actually exists is no longer a tenable position. Right now, it is better to have more of a Kantian position such that, scientific knowledge becomes a collective effort of the observer and nature. Nature is given to us as possibilities and it is through our understanding, we conceptualize the patterns of nature. An exact articulation of this position would be difficult. Consider the two extreme arguments on the nature of realism and constructivism. According to realism, the nature we see, exist as we comprehend it while on the other hand according to constructivism, the theories are basically the constructions of the thinking mind or the observer with no reference to an external reality. But science is an empirical enquiry at first, and the basic reference for the scientific statements (directly observable or inferred) is from nature in the form of phenomenon. With the conceptualisation of the phenomenon, correspondence and related notions like truth and accuracy are built.

The thesis of the existence of nature which is independent of the observer can never be rejected. It is necessary for the correspondence theory of truth which is ultimately the kind of conception of truth which is present in science with modifications as per situation. But, as mentioned earlier, it is not just nature that dictates theories. Nature is the collection of phenomenon which we understand in accordance with our comprehending techniques. There would not be one single conception of nature and the burden of selecting the conception out of many is entitled to the scientific community in a way to suit the purpose. On the other hand, science is never a domain where everything goes, as genuine scientific enquiry has to conform to certain principles which are independent of us.

This being said, when there is a phenomenon in front of us and a handful of theories on the same phenomenon, out of which we have to qualify one theory as the right theory, the notion of rightness is certainly temporal. Certainly, science is embedded with choices and in practice even in case of a simple experiment, the choices are huge. Ultimately, one has to guarantee that what every scientific theory demand is the correlation with the phenomenon.

1.4 Truth and Science

Scientific enquiry talks about a world that is independent of human cognition. Scientific realism holds the belief in the observable and unobservable facts given by science (because at times, science use theoretical entities which are inferred not directly observed. But scientific realism hold the belief in those kind of entities like electron which are not directly given to science even with the artefacts. It is with the microscope they are inferred from other observations and these entities are used to explain the phenomenon and scientific realism holds belief in existence of these entities). There is a human tendency to see the world as how science describes it along with our common sense notions. So now the question is, to what extent the 'truths' given by science are really 'true'. One notion of truth is that if the properties ascribed to the entities is identified with, then it is true or else, it is false.

Statements concerning sciences stretches from ordinary level observations to unobservable entities. So, in this case, where ordinary observations would not suffice and are not self-evident, the claims need an external independent principle which guarantees the truth. Without the principle, the eternal recurrence of reasoning for truth will occur. Because except for a self-evident principle in order to be truth it requires reasoning and this reasoning if it's not based on a self-evident principle is again in need to be reasoned, like a chain of reasoning which can only be ended with a self-evident principle that will occur. In the absence of a self-evident principle the reasoning will recur without end (a similar idea can be perceived in the Cartesian scepticism). Moreover, only with such a principle, can we talk of a certain truth. Conception of an independent world is very much commonsensical such that it is not the 'I' which can only see things. But others can also see the world and describe the world in a similar manner such that it appears acceptable to us and there is a common agreement about the external world. So, this uniformity in perceiving the world can pave the way for considering there exist something independent of us.

The notion of truth in science doesn't curb the possibility of counteracting theories which might come later, as we develop more information about the phenomenon. Keeping that in mind, certainty is never a viable candidate for scientific theories. If at all science is said to be certain, it is based on certain presuppositions like uniformity of nature. As Kant describes, reality cannot be perceived as such. It is only perceived through the conceptual frame work developed by the environment which we belong to. Different groups might radically differ in this depending on what they are surrounded with. So, to find a reality separated out of these alternatives is not possible because reality can only be perceived. Even to infer a reality beyond perception would be granting all these alternatives the same status which would be a contradiction of realism. As we cannot know with certainty what is the reality beyond the perception in that case we cannot say one alternative is right and all others wrong. This would not be a proposition acceptable to realist because if we are comparing the theories with something beyond perception there is no other way but to grant all these conceptions the same status. No necessary correlation can be established between the theories and reality. The absence of necessary correlation between perception and reality is a complete ban of certainty. Such that, science can only deliver contingent truths. But this does not mean that science cannot deliver a legitimate conception about world at all.

During the time of Galilean science, science was expected to have an intrinsic reality to which the scientific theories correspond and become the cornerstone for truthfulness of theories. Truth in terms of correspondence is the ideal which science tries to achieve through its practice. But as this is not an easy task to be attained in the practical field, often, success in terms of prediction or explanation depending on the contexts is taken to be truth. This does not always hold on the strict meaning of truth and so truth in scientific domain is always temporal.

According to realists, there is success and truth correlation:

1. P1- If scientific theories are true then they will typically be empirically successful
2. P2- If the central term in scientific theories genuinely refers then they will be successful
3. P3- Scientific theories are empirically successful

Conclusion- Scientific theories are true and their terms genuinely refers (Laudan, 1981)

However from the history of science, there are a lot of counterexamples of theories being empirically successful and later being found not true (for instance the example of ether) and vice versa. So by itself, this is not a very valid position to hold. Similarly, the pessimistic meta-induction argument by Larry Laudan (1981) talks about the difficulty in the absolute conception of the truth.

The pessimistic meta-inductive argument:

1. P1- Most of the current successful theories are true
2. P2- Many of the past successful theories were false
3. P3- Most of the past successful theories were true

Conclusion- Current successful theory would be false later.

The history of science offers a lot of examples for the above argument. For example, 'ether' which was existent for a long time had its existence denied later. So, equating success with truth cannot be proven. This is very vital in the value discourse because the general definition for epistemic values is given as truth conducive. On the other hand, to believe that there does not exist a world totally independent of us and everything is a construction would be an extreme view. So the best would be to stay in between these two extremes.

The subsequent verification and probabilistic confidence gained through this verification is a better articulation for truth rather than an absolute conception. This is based on the presupposition which might have come from the experience that, success is correlated with accuracy and success in prediction implies that the view about the underlying entity is right. But again, this can be only given as a reason for the partial rightness and truthfulness of the theory and thus, this would be a more convenient and moderate view to hold.

1.5 Concept of Objectivity in Science

Objectivity is one of the important ideals which all systems of knowledge strive to attain. Objectivity is often treated as an important factor in the authority which a knowledge system enjoys. Objectivity can be basically characterised as the non-influence of the subjective interests such that it is universal for every one and there is no personal bias which is exhibited in the knowledge. Similarly in science, objectivity is basically the avoidance of the personal idiosyncrasies at different stages of science. Being a system, which presupposes that personal affiliations and interests are kept out before entering the laboratory the scientific knowledge so produced is objective. The key to objectivity can only be identified at the practical level. It cannot be identified at the theoretical level. Objectivity at the metaphysical level means the correspondence with reality and at the practical level it can be translated to intersubjective agreement which are unbiased (and it must be identified with the consensus of scientific community in practice so what gives objectivity in the scientific practice is the consensus).

In science, objectivity has a history and the very conception of objectivity has changed over time. As we advance, different instantiations of objectivity have happened in order to avoid the personal idiosyncrasies being influenced in science. Like science, objectivity also has two facets which are product objectivity and process objectivity. Product objectivity is identified in terms of science describing about the laws and theories which accurately describe the world out there. Process objectivity is identified in terms of the non-influence of the subjective interest (non-epistemic values). Aperspectival objectivity is one among the different instantiation which objectivity has taken during the course of time. Necessarily speaking, every statement we make regarding the nature must be perspectival. The conception of objectivity presupposes that there are two kinds of qualities: one that vary with the perspective one has or takes, and one that remains constant through changes of perspective. The latter are the objective properties. Thomas Nagel explains that we arrive at the idea of objective properties in three steps (Nagel 1986)[2].

1. Perception occurs as a result of the independent existing objects through their effect on the sense of the observer.
2. The actual nature of the object is not dependent on the observer. It is not necessary that the effect created by the object on the observer's sense will be replicated on other things.
3. Objectivity enables to form an understanding about the "true nature" of the object independent of perspectives. Nagel calls this conception, the "view from nowhere". It basically gives us the picture of nature as it is, free from subjective perspectives and other interest.

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[2] &[3] Scientific Objectivity. Retrieved from https://plato.stanford.edu/entries/scientific-objectivity/ (August 2014).

Francis Bacon, one among the strong proponent of the ideal of objectivity expected science to be the enquiry of above mentioned phenomenon which is same for one and all. Daston and Galison (2007) provide an account of the transition or evolution of objectivity from mechanical to aperspectival. In all the changes that has happened to the conceptualization of objectivity over the time, the spirit of non-encroachments of subjective influences is maintained and idealised. Moreover, objectivity is never actualised to the fullest.

Objectivity is certainly a concept which is very much legitimate and important to hold. But the question is, to what extent can this conception be held? The issues in attaining this, has to do with 'value' discussion in science. In a value discourse, objectivity is considered as the standard which needs to be followed in various decisions which are taken in science. This standard at the ideal level, guarantees knowledge to be objective. So, let us see to what extent this conception of objectivity can explain the decisions made in science in order for science to be value-free. Certainly, not every value impeachment is an issue for the objective ideal. So objectivity basically talks about which all values can influence science and which all values are not allowed in science. One way, objectivity becomes relevant to the value discourse is that even though an exact conception of objectivity is not possible so far, objectivity can be defined within the boundaries of non-epistemic values. Science is objective to the extent it can keep out the non-epistemic values.

The problems in actualising the concept of objectivity and how it gets connected to the value discourse are discussed in the later part of the chapter.

1.6 Different Models of Rationality

"Though there is no dispute on the rationality of science, the methodology of scientific rationality is not unanimous" (Jayard 2012). According to Hempel, there are primarily two schools of thought; the Analytic-empiricist school (Prescriptive/ Methodological rationalism) and Historic-sociological school (Descriptive/ Methodological naturalism). The former, developed by logical positivism necessitated the need of definite or absolute principles as criteria for formulating and testing scientific endeavours. The principles are grounded on logical and philosophical basis and is not bound by any historic or psychological facts. This is in contrast to the later school of thought, as it considers the actual behaviour/ practices of the scientist and the preference/value of the scientific community in question. Hempel and Popper are considered to be methodological rationalist when it comes to the formulation and choice of scientific inquiry and attributes. Kuhn and Feyerabend are considered to be methodological naturalist. Though proponents of different paradigms of scientific rationality, Hempel agrees with Kuhn's view on the need of the socio-historic milieu in scientific inquiry. He agrees that the normative account of science must be in line with its actual practice. However, the lack of a clear understanding of the notion of rationality is perplexing to Hempel. He argues that there must be rigid knowledge of the kinds of understanding involved in analysing the notion of rationality. He questions Kuhn's notion of simplicity. Theory choice cannot just be made on a sequential basis of superiority based on a set of desiderata (epistemic values). Goal of the scientific community then becomes an important fact that should be considered. This goes over the individual behaviour of the scientist that at times act as interferences than as factors that can contribute to scientific inquiry. Accordingly, Kuhn's argument though rational also involves non-rational elements as it does not require well-reasoned and logically sound norms. Kuhn essentially identifies the social aspect of scientific practice. His account of scientific rationality looked in to the behavioural aspect of scientists. His concept, like paradigm shift essentially has social values which does not fit in to the traditional account of rationality. Hempel thus refers to Kuhn's position as being adoptive rather than rational. To him, goal-directed reasoning becomes an important feature of rationality in science. Hempel's notion of rationality is expressed in terms of an action. It is bound by the goal of the action, the context of the action and the conditions/ beliefs entertained in the pursuit of the action.

These factors are stipulated by the rational action of the scientific inquiry. The methodological principles are not given in rigid/ absolute terms but rather, in its ways of proceeding that will fulfil scientific objective. Rationality is thus explainable through what must be the end and the means to the end of the scientific inquiry. The fact that a certain action can be rational in one scenario and not in another makes rationality context-dependent. In the practice of science, this factor needs to be incorporated along with the methodological principles that used to be the only yardstick of the logical positivist. Accordingly, the socio-historical milieu in play as the standards of rationality of the particular inquiry is dependent on how it is explainable and interrupted in the particular context. Similarly, Hempel sets different conditions to ascertain the rationality of science. These are applicable if the goal of the scientific inquiry is to reflect an empirical belief of the world or to obtain relevant information of the world. In this case, factual accuracy is not the only insisting factor as the hypothesis and theories need to be checked against the relevant data of the world. This small account of rationality intends to show that rationality of science gives no consideration for non-epistemic values. Methodological rationalist thinkers envision a unique systematic methodology to science guided with logical principles. This fixed methodology only consists of epistemic principles that needs to be followed in practice and will provide legitimate scientific knowledge. The rationality is identified with the calculated reasonable proceedings in the process of scientific enquiry.

1.7 Values

Science is never a static enterprise; it evolves with time and there is no one set of ways in which science ought to proceed. In such a scenario, the process of selection occurs, which essentially is driven by values. Even if we hold a normative account of selection, value matters because without value judgement, it is not possible to choose. So, values are essentially part of science. No scientific theory is ever conclusively proven. Moreover, no theory possesses all epistemic qualities. “The assessment of a scientific theory rather corresponds to a judgement where different criteria are carefully weighed than to the mechanical application of a rule or algorithm to determine the best theory” (McMullin, 1984).

Science is a domain which involves a lot of choices. Starting from the choice of the research topic till the application of the qualified theory. In terms of the logical proceedings in science, Science can be divided in to three phases:

1. appraisal of topic
2. appraisal of evidence
3. application of evidence

A different set of classification is:

1. pre-epistemic
2. epistemic
3. post-epistemic

Values in science are basically standards which guide choices about the theories, qualification of the observation as evidence, qualification of theories as right or wrong, etc. Every choice presupposes values and there are several choices which has to be made in science.

1.7.1 *Epistemic values*

Epistemic values in general are said to be truth conducive which reliably promote the attainment of truth (Elliot 2014). These values are said to be decisive in defining knowledge to be closer to truth, rational and free from subjective interests. This necessarily makes these values, objective and universal.

The word episteme in epistemic values has its origin from the Greek term ‘episteme’ which means knowledge. The simple straight forward definition for epistemic values would be, values which necessarily help in attaining knowledge or truth (Steel 2010). In general, epistemic values are generally considered to be the companion of scientific paradigms. The choices which are based on these values are the legitimate choices in an objective truth-oriented science. In fact, the choices which are made in science should be confined to these values. At least, that’s how the popular conception of science goes and this is what scientific practices strives to achieve.

By definition, a science which is confined to this truth conducive values are called as value-free science or good science. There are different conceptualization of epistemic values given by different philosophers. “Sometimes epistemic values are regarded as a subset of cognitive values and identified with values such as empirical adequacy and internal consistency that directly bear on the veracity of a scientific theory” (Laudan 2004). Heather Douglas also follows a similar conception considering epistemic values as the subset of cognitive values.

The list of epistemic values is not completely exhaustive. McMullin doesn’t include simplicity in the list of epistemic values. According to McMullin (1984), there is no conclusive argument which guarantees simplicity to be truth conducive, hence it is not a candidate for epistemic values. But in the Kuhnian account of epistemic values, simplicity is included. Kuhn identifies simplicity, consistency, broad scope, accuracy, fruitfulness as epistemic values. For McMullin, predictive accuracy, internal consistency, external consistency, unifying power, fertility make the list of epistemic values.

1.7.2 *Non-epistemic values*

Given the definition of epistemic values in the last section, non-epistemic values are basically subjective values which, scientific domain strives to keep out. These include social values, political values, etc. If we consider the history of science, these sorts of values have influenced science during many instances both in good ways and bad ways. At present, arguments are made, in that, effective use of non-epistemic values are necessary for a socially responsible science. But the question is, is it fundamentally necessary? In the beginning of British royal society craftsmen, traders were kept out of the society by Francis Bacon. This might have been because of the notion that scientists are the sacred practitioners devoted for unravelling the nature. Throughout the history, these sorts of values are considered to be the biggest opponents of objectivity and rationality. These values do not have a uniform conception among the society and these sort of values changes from culture to culture and group to group. But science can never appreciate this sort of spatio-temporal differences. Traditional account of scientific rationality considers these values as constructions of a minority (subjective) group not necessarily out of scientific reasoning. Empirically it is verifiable that these notions do not have a universal acceptance. So, these values are not appreciated in science. Even more, these values are deliberately kept out of the scientific domain. The concept of objectivity in science can thus be understood in the sense that it is free from non-epistemic values.

1.7.3 *Distinction between epistemic values and non-epistemic values*

Different philosophers have tried to give different set of distinctions. For example, Hugh Lacey (1999) gives his account about values by defending the distinction between cognitive values and social values. Cognitive values are criteria for assessing the extent to which a hypothesis provides scientific understanding. Whereas, social values are used to evaluate social systems.

Helen Longino, in her work, draws the distinction between constitutive values and contextual values. Constitutive values are the values which are generated from analysing the goal of science to explain the phenomenon. Moreover, these values are the standards for the acceptable scientific practice. Contextual values are the values which are generated from the social and cultural background in which scientific enquiry is practiced. Heather Douglas, in her approach, draws the distinction between cognitive and non-cognitive values. Epistemic values are considered as the subset of cognitive values. For her, only empirical adequacy and internal consistency are epistemic values. Rest of the values which come under the title of epistemic values by Kuhn is identified as cognitive values (Rooney 2007).

From the different articulations by different philosophers, in general, simplicity, external consistency, internal consistency, predictive accuracy, explanatory power, accuracy, unifying power, fertility, scope, etc., are examples for epistemic values. Social, political, ethical values, etc., are considered to be non-epistemic values.

1.7.4 *Epistemic values, pragmatic values and non-epistemic values*

There are arguments that say, a definite distinction between the values is impossible. However so, a somewhat exact distinction of these values can be drawn. There is a possibility to do so by finding certain characteristics which is specific to each and then differentiating between them.

The following analysis diverts a bit from the usual classification of epistemic and non-epistemic values. Strictly speaking, there can be only one epistemic value which is 'Accuracy' as it is the resemblance of the theory to the phenomenon which constitutes the truth, science is aiming at. Or in other words, accuracy is the only value which can be related to the truth value of the theory. Truth value basically operates in terms of correspondence. Accuracy as defined before gives an account of this correspondence. More accurate means it corresponds more to the phenomenon. The correspondence can be explained in terms of reference of the terms to the phenomenon or in terms of the explanatory or predictive power. So accuracy can contribute to the truth value of the statements. Hence, in the strict sense of epistemic values which is truth conducive, only accuracy qualifies.

Considering the fact that consistency is necessary for a statement to be true, 'Internal Consistency' could be considered as an epistemic value in a weaker sense (this weaker sense shows how it is termed under epistemic values in general classification). In case of internal consistency, it can only demand the formal truth value but cannot guarantee for the truth value of the premises or the fit between the theory and the phenomenon. And sometimes, the internal consistency might not be achieved due to factors unknown. For example, in case of anomalous expansion of water there is a difference in the trend between 4 degree and 0 degree which might have initially been considered as an incorrect observation, but later, different explanation was given for it. In other words, if the mode of inference in science is inductive, then consistency as it is seen in the deductive reasoning cannot be expected. Unlike cases of deduction, internal consistency cannot necessarily guarantee the truth in science because inductive inference does not necessitate a formal truth. So, it fails to be an epistemic value in a strict sense.

In the shortcomings of the different inferential models in science, the presence of auxiliary hypothesis is taken to be an important factor for having more confidence over the theory and to facilitate the inference more smoothly. Also, 'External Consistency' could be considered as an epistemic value in a weaker sense. Because, the auxiliary hypotheses which we use is also in need of justification and if it is proven then it must be considered as truth for the time being. So, in such a scenario if the hypotheses proposed is contradicting the auxiliary hypothesis, it seriously affects the truth value and our confidence over either auxiliary or proposed hypothesis (considering the fact that the auxiliary hypothesis is proven which later can turn out to be false). Auxiliary hypothesis does not guarantee the necessary attainment of truth. Hence, external consistency is not an epistemic value in a strict sense. It is thus better to classify internal consistency and external consistency under the pragmatic values (next session) in terms of lacking of necessary attainment of truth.

One important aspect in the general division of the epistemic and non-epistemic value is that, the concept of objectivity and the priority of evidence must be maintained. It must be in this sense that under the usual classification, the rest of the pragmatic values come under the title of epistemic values. What distinguishes between the epistemic values and non-epistemic values is the preservation of objectivity and priority of evidence. Pragmatic values in general can be said to be a bridge between the agent or the subject and the theory in which the subjective interests are not instantiated through these values. Consider the value, simplicity, it is not necessary for an absolute conception of truth to be simple or complex. Similarly other values like unifying power, there is no necessarily relation between unifying power and truth. In case of pragmatic values it is used for the better comprehension and confidence over the theory for the observer. Pragmatic values add onto the confidence which we have over the theory or hypotheses proposed, but this does not necessitate the truth. And by this feature of necessity, the strong epistemic quality cannot be attributed to pragmatic values. Whereas the fact that, pragmatic values maintain the objectivity and priority of evidence, differentiates it from non-epistemic values. In order to consider the pragmatic values the theories must have objective character and priority of evidence. For instance we cannot talk about a theory which is 'simple' if it is not supported by evidence. Similarly the theories must have a universal acceptance in terms of the support with evidence. Hence, it is appropriate to call values other than accuracy which come under the title of epistemic values in the general classification under the title of pragmatic values. Unlike non-epistemic values, pragmatic values are not problematic in a scientific enquiry so it could be characterized as epistemic values in weaker sense.

As Hempel pointed out, an account of scientific methodology must have descriptive and justificatory aspects. Science must be able to give justification in terms of the choice it makes. The language of coincidence or non-reasonable decision which later turn out to be a fruitful one cannot be a candidate for a good rational science. Most of the rationality models of science insist that the scientific practice should be logical and should conform to a systematic principle. For positivists "the methodology of science, thus understood, is concerned solely with certain logical and systematic aspects of science which form the basis of its soundness" (Jayard 2012).

Considering the three factors such as priority of evidence, objectivity, and attainment of truth.

1. Epistemic value- Priority of evidence, objectivity, necessary attainment of truth
2. Pragmatic value- Priority of evidence, objectivity, possibility of attaining truth
3. Non-epistemic values- Non-objective, no influence in attaining truth, priority of evidence not necessarily a concern

Consider the value 'simplicity', it is more intelligible and easier to proceed with a theory if it is simpler at the conceptual level and if the explanation is simple. The principle of Ockham's razor states that entities need not be multiplied unnecessarily and those with lesser entities are supposed to be right. In a similar line, simplicity also helps in gaining more confidence over the attainment of the truth of the theory. Here in case of simplicity, what makes it different from the non-epistemic values is the non-encroachment of subjective interests. And as it does not necessarily help in attainment of truth, it cannot be considered as an epistemic value in its strict sense. Hence, it is better to classify simplicity under the title of pragmatic values as the value makes sense for practical purpose.

Similarly, consider the value 'explanatory power', a sound explanation need not be highly probable. Hence, it is not necessarily a truth attaining value. Considering the above classification, the value is more suitable under the title of pragmatic values. Similarly, fruitfulness of a theory is related to the understanding of theory. But here, the understanding is considered in a universal and objective sense differentiating it from non-epistemic values and does not necessarily guarantee truth. But a good explanation can always increase our confidence over the theory by making it convincing. Hence, it is appropriate as a pragmatic value.

Unifying science, in general, is a grand plan which past history of science has tried and failed. Unifying power of a theory enables us to reduce the overload of methods and statements by setting a theory or method to explain many other phenomena. Again, unifying power does not necessarily guarantee the attainment of truth. And it does not promote any subjective interest, rather, it tries to achieve a grand explanatory schema. Hence, unifying power can also be categorized under pragmatic values.

The above said classification might enable us to set a hierarchy with attainment of truth as standard. Certainly, accuracy needs to be at the top followed by internal consistency. For the rest of the pragmatic values, it is not easy to set a hierarchy. There is also the possibility that later the list might expand. But the top candidates in the list hold power over the others because those deals with the basic truth conduciveness of theory whereas the rest of the values deals between the subject and the theory. At the ideal level, all the theories must be accurate or should not sacrifice accuracy at any cost.

Had it been the scenario that the legitimacy is given to non-epistemic values then there is high chance of subjective interests benefitting over the fundamentals of science, which is something that is never appreciable in science. The last statement points out the question: if the non-epistemic values (at present) shows the characteristics of objectivity and priority of evidence, would that be permissible? Or in other words, can we have legitimate non-epistemic values?

From the analysis, the value-free ideal essentially relies on the concepts of objectivity, truth conduciveness and priority of evidence. In order for science to be value-free it must satisfy these ideals at the practical level. And is science value-laden or not depends up on the fulfilment of these concepts at the practical level and science will be value-laden to the extent it deviates from these concepts.

1.8 Problem of Inductive Risk and Underdetermination of Theories

There are major arguments given against the concept of value-free science. If we go according to the inductivist model of inference, the acceptance of theory must reasonably address the problem of induction. The problem of inductive risk finds its roots in Hume's claim of the logical gap between observations and predictions. For accepting a theory, the confidence over the theory must be related to this inductive inference. The concern for value discourse in this context would be, can the epistemic values fulfil this logical gap in determining the strength of evidence? This is also related with inductive risk. In the areas where the consequences of theories can be predicted and calculated, this problem of inductive risk is taken into account by calculating the consequences. But in cases of pure research, how can this be calculated? Similarly in disregarding certain observations to be not valid, inductive risk is very important. So, can epistemic values explain the confidence over this risk? The concept of inductive risk also becomes important in defining the observations and qualifying observation to evidence which will be explained in the next chapter. Because, if simple statistical majority cannot be a good explanation for a scientific acceptance then scientific practice would be no more different form a democratic procedure where majority decides.

Scientific practice at the ideal level rely only on the evidence for belief over a theory. But simple evidential basis cannot give us the expected belief over theory. In such a case, scientific practice relies on epistemic reasons (values) and proceed to what extent the deficiency created by the inductive risk can be rectified by epistemic values and give confidence over a theory. The problem of inductive risk can open a lot of difficulties such as difference in opinion regarding evidence, strength of evidence, accuracy of a theory, etc. Moreover, how this confidence over a theory is lost by inductive risk can be regained by epistemic values. In other words, how are objectivity, truthfulness and priority of evidence fulfilled by taking account of the inductive risk?

Scientific theories are not just limited to the observational domain. It sometimes uses unobservable theoretical entities or inferential entities in order to explain the phenomenon. So in the Hypothetico-Deduct model, first the problem is formulated then the theory is proposed which is later confirmed by experimentation. This mode of inference is also caught up with the problem of under-determination of theory with evidence. Multiple theories are confirmed with same evidence that is which theory must be chosen over the other. For example, in quantum theory, there has been three proposed theories namely the Bohmian quantum mechanics, the many-worlds interpretation and the spontaneous-collapse approach. These were confirmed by same set of evidence and there were no observational basis to keep one over the other. Another example is given by Duhem, during 200 B.C an astronomer named Apollonius was able to come up with two different theories confirming to the same set of astronomical data namely the 'eccentric theory' and 'epicyclic theory' (Psillos 2005).

So different theories give different epistemic benefits: one may be good in prediction while another might be good in explanation. So the question is, how this choice is made and can epistemic values alone explain this choice? Along with this, under-determination is a major threat to objectivity. Also, the intersubjective agreement in practice may not be fulfilled as the scientist can have different viewpoints. The example of difference between Niels Bohr and Einstein shows the different commitments which scientists can have in accepting quantum theory. This disagreement resulted from the difference in the metaphysical conception about reality. For Einstein, nature was ordered and coherent whereas for Bohr it was not the case (McMullin 1984). Einstein famously said "he (God) does not play dice with the universe". This shows that scientists can have different perspectives and in context of under-determination, this can violate the intersubjective agreement. In case of under-determined theories, prioritizing of epistemic value over the other is detrimental to the concept of objectivity. In such a scenario how can objectivity and truthfulness be attained in the selection of the theory (here evidence is same for both the theories)[3]? So, these two are the biggest questions which a value-free science tries to solve and to what extent they succeed, science will be value-free.

The value-free ideal which operates at the ideal level which identifies science in the first place is defined earlier. This is often used for the authority of scientific knowledge. The concept of value-laden in science is that if these choices in science are made in confirmation with the ideals of objectivity, truthfulness and priority to evidence in confirmation of a theory, then that practice can be said to be value-free and not value-laden. As we have seen from different models of rationality, these concepts will not really be able to explain the practical aspect of science completely. This intensifies the question of whether science is fundamentally value-laden keeping the value-free ideal and epistemic commitments as primitive.

The next chapter will in detail examine the priority of evidence and the difficulties in actualising the priority of evidence with the epistemic concern. Along with explaining the notion of value-ladenness, the chapter has tried to show the difficulties in attaining the other two ideals.

[3]Underdetermination of theory by evidence is of two types 'transient underdetermination' and 'permanent underdetermination'. Transient underdetermination holds the view that it is possible that in future evidence might be available to break the tie between theories. Whereas, permanent underdetermination holds the view that alternative theories are confirmed by all the possible evidence. Sticking to the argument given by Philip Kitcher that every underdetermination is a case of transient or local underdetermination. Because in principle there is always possibility of evidence occurring in later period of time. So, underdetermination identified here is transient underdetermination (Kitcher 2003).

CHAPTER 2

Evidence and Values

Introduction

This chapter will discuss in detail about how the priority of evidence is achieved. The concept of priority of evidence includes the concept of observation and concept of evidence. Also discussed is the practical aspect of interpretation and qualification of observation to evidence. The chapter tries to analyse the process of appraising of evidence and how independently priority of evidence is achieved in justifying a theory. As discussed in the first chapter, priority of evidence is a necessary condition for value-free science. The process of generating theory constitutes the concept of observation, the concept of evidence, interpretation of observation and qualification of observation to evidence. The first part of the chapter defines the concept of observation and identifies its essential features as given by philosopher Dudley Shapere. Following the discussion of observation, the next section analyses the concept of evidence and various theories given about evidence by philosophers like Hempel, Popper, Glymour and logical positivists. These theories expect evidence to have a formal relation between theory and evidence. Analysis of these theories enables us to see that these theories do not identify the practical side of generating evidence. The problem of inductive risk and under-determination of theory shows us that there cannot be a necessary relation between theory and evidence. Logical positivist defined evidence to be independent of the theory. But the analysis of three experiments given in the chapter along with the absence of necessary relation between theory and evidence shows that evidence is necessarily theory-laden.

The three experiments discussed in the chapter are cathode ray experiments by Henrich Hertz and J. J. Thompson, Eddington expedition to prove the theory of relativity and gravitational wave detection experiment. Analysis of these experiments shows us the theory-ladenness of evidence and how theory-ladenness hinders the priority of evidence (in situations where the theoretical value and experimental value does not match). The analysis also enables us to show the influence of the theory over experimental design and choice of methods for the analysis of experimental data and interpretation of evidence. These three experiments instantiate the situations where theory is given priority of the experimental result (evidence). Through this analysis in the chapter I have tried to explicate the role of consensus of scientific community in attaining the ideals of objectivity and priority of evidence. I would thus like to propose that at the practical level, objectivity is identified with 'common acceptance'. The final section of the chapter illustrates how theory-ladenness causes value-ladenness in light of the analysis of experiments and the basic nature of evidence. I try to show that the priority of evidence cannot be attained in an independent manner without any reference to theory. This essentially make science viable for value-ladenness. Accordingly, in cases where theory is given priority over evidence, it makes the evidence value-laden and when the evidence is value-laden, it makes science value-laden.

2.1 Observation

Observations are the set of events which can be represented directly or indirectly. The term 'observation' can have different meaning in various domains. The way in which a philosopher understands the term observation might be different from the way in which a scientist looks at the term. Observations can be qualitative and quantitative, for example, the patch is red is a qualitative observation. Similarly, the given square is 10 cm in width is a quantitative observation. Observation can be direct or indirect. Any statement referring to the events which are presented directly to our senses are also observations, there exist a cat out there is a direct observation. Sometimes observations are mediated by artificial aids which enable things to be recognized by senses. For example, telescopes help to see far things and microscopes enables us to see tiny particles or cells etc. Similarly, there are indirect observations, like the existence of electrons are not made with our normal senses or using any artificial aids which enable us to see it. These are inferred from the observations obtained from sophisticated experiments. In other words these experimental methods allow us to observe and measure these kind of entities which are not given direct to senses. So, observations cover a huge lot of areas which are sensible directly or indirectly, quantitative or qualitative etc. In science also, we deal with a lot of observations.

In general, there can be two conceptions of observation just as the two accounts on the traditional view of rationality in science (discussed in the earlier chapter). One is, observations are pure and has no connection with the theory. The logical positivist considers theories to be made from the inductive enumeration of observation and the validity of scientific theory essentially lies in the observable part of the phenomenon. Second is, the Hypothetico-Deduct model which considers observation to be theory-laden.

Dudley Shapere in his paper, "The concept of observation in science and philosophy' (1982) reflects on the usage of the term 'observation' by the astrophysicist (scientist) and the philosopher. With the help of the solar neutrino experiment, he questions how and why the philosopher's use of the word is different from that of the astrophysicist. For the philosopher, the term "observation" is primarily linked with the perceptual aspect implying a special kind of perception or focused attention and secondarily, the epistemic aspect, where "observation" provides evidence for knowledge or supports existent beliefs. On the other hand, in the astrophysicist's use of the term, there is a suppression of the perceptual aspect of the word. Yet, the astrophysicist uses other words such as 'see', 'looking' that are directly linked with sense perception. The use of these words like 'see' is more of a generalization emphasizing on the epistemic aspect of the word.

Among the astrophysicist's use of the term "observation", there is a contrast presented with the use of the adjective 'direct', 'direct observation'. Shapere argues that, this distinction between the astrophysicist use of the term 'direct' and the common usage of the term 'direct' is in the context of the solar neutrino experiment by providing two contrasting ways of observing the center of the sun (direct and indirect). Information about the center of the sun obtained through light photons is referred to as the indirect method, while information obtained through neutrinos is regarded as the direct method. In the former, information is relayed by the reception of electromagnetic energy (light photons). As photons are highly susceptible to undergo interference on account of its small mean free path, the electromagnetic information would be altered by the time it reaches the surface. Accordingly, the light photons that were initially produced as high frequency, short-wave gamma rays would be received as low frequency, long wave visible light. The alteration and interference in the light photons occur en-route the journey from the core to the sun surface which takes 100000 to 1000000 years. Once the light photons reach the surface, they only take minutes to reach earth's surface with very few or no interference. However, the circuitous and long journey en-route the sun surface would have already drastically altered the information about the center of the sun. On the other hand, the neutrinos have a low probability of being interfered or altered (on account of its weak interaction theory) and thereby the information obtained is more reliable. The contrast between the two is thus in their manner of transmission. In the solar neutrino experiment, Shapere identifies three different aspects, the release of the neutrino, and the transmission of the neutrino and the reception of neutrinos. He calls this, the theory of the source, the theory of transmission and the theory of receptor.

Furthermore, Shapere emphasizes the role and importance of "background information". The background knowledge is the already reassumed set of facts, beliefs and theories that guide the respective research. In this case, Einstein's equation $E{=}mc^2$, the theory of stellar evolution, the

Russell-Vogt theorem, the theory of general relativity are some of the laws and theories taken for granted, in that these act as the background information that guided and paved way for the research. In the above-mentioned experiment, the theory of the source (energy production in the core of the sun and neutron transmission) necessitates the theory of general relativity, Einstein's equation, theory of stellar evolution. For the theory of transmission, background information such as information about the surface received through photons and the weak interaction theory is crucial. In the theory of receptor, the construction of the detector, its location, interpretation of information require background knowledge of the chemical composition and the theory of general relativity.

This throws light on Shapere's Principle of Scientific Internalization that presently governs scientific activity. The principle outlines the process that should govern the expansion of ideas within science. It entails; "The sorts of considerations that have led us [and that should always lead us] to alter our beliefs about nature, at least when those considerations are ones we call 'rational' or 'based on evidence', have themselves been scientific ones". (Abímbólá, 2006).

Thus, what is counted as observations or interpretation of observations are dependent on scientific claims that can be substantiated. This explanation ties into the epistemic aspect of the word 'observation'. But this does not imply that there is no connection between the astrophysicist's use of 'observation' and its perceptual aspect. The role of observation in modern science can be said to be expanded and generalized on the basis of well-founded beliefs of science.

With respect to the role of background information, Shapere outlays that for philosophers, the employment of background knowledge is defined as "theory-ladenness" of observation. However, he discusses that though background information is employed, the scientist uses it with the caution, in that it is uncertain and doubtful. However, the uncertainty does not deter the use of theory as it is at times the best information available to extract and attain further information. This is evident through the example of the solar neutrino experiment which necessitates the knowledge of background information. Thus, “observation” in science doesn’t imply ladenness with background information, nor is it without doubt and question. More observation and increased learning are possible only with increased background information. Simultaneously, an error in background information would lead to a decrease in learning. Background information is thus not a barrier to the acquisition of knowledge of nature. All of knowledge rest on, which helps in adding knowledge, increasing ability to learn about nature and extending that ability to observe more.

Along with the above discussion by Shapere, Stephen Jayard (2012) in his book ‘Towards a theory of rationality in science’, offers the following aspects of observation.

2.1.1 *Causality in observation*

The principle of causality which is very much relevant in the design of observation, especially when we are looking for specific observations. Observations are often created in science using various experimental techniques or in other cases, the phenomenon is natural and cannot be replicated in a laboratory. In this latter case, the observations are created depending on the way which we want to use them for. Certainly so, in order for a representable observation we need techniques to characterise the observation either qualitatively or quantitatively. This requires certain techniques depending on the context. The knowledge of causation is also very crucial in representing the phenomenon in the observational language needed. Because in the experimental setup there must be clear idea about what would be the effect of an event. Similarly, what is causing the event? The knowledge of causation refers to the knowledge of repercussions of an event and the reasons of an event. This is very essential for the control over the experiment and in theorising the experiment and experimental result. Consider a simple pendulum experiment, in which the knowledge about what causes the pendulum to swing, the effect of gravity, knowledge of the effects of damping forces, etc., is necessary for a proper interpretation of the observation and control. In experiments which include high risks like thermo nuclear reactions the causal knowledge is very crucial in concern to the safety of the experiment.

There is also the selection of certain dimensions as not every aspect of a phenomenon can be expected to be covered under one observation. For example, the least count of an apparatus like Vernier Calliper or a ruling scale makes the observations limited to that particular scale.

2.1.2 *Reliability of background information*

Every observation assumes a lot of background theories and procedural theories for its understanding and interpretation. In doing so, the acceptability of the theories has to be ensured as it is practically impossible to go on reasoning the validity of the methods employed in an experiment. This is especially crucial in the quantitative analysis of the experiment as the quantification of observation has to assume accepted methods. It is on these accepted theories or standards the further measurements of observation are made.

Different scientist employing different methods and standards is susceptible to intersubjective validity of the observation. There are instances when measurements have an accepted standard or definition. For example, what is a 'meter' has to be same for all. It is not the case that a German scientist will have a different definition for the term 'meter' from another fellow scientist. But this claim doesn't mean that all background information deployed will be certain and accepted forever. The very definition of 'meter' was later subjected to change when the velocity of light got fixed (with the consensus of the scientific community even though fluctuations exist). The definition was changed to the distance travelled by light in a 1/299794548 of a second. Earlier, from 1889 to 1960 it was defined as the distance between two lines on a platinum-iridium bar (the “International prototype Meter”) preserved at the International Bureau of Weights and Measures near Paris. From the 1960 to 1983, it was defined as 1,650,763.73 wavelengths of the orange-red radiation of Krypton 86 under specified conditions[4].

2.1.3 *Interpretation of observation*

Just as nature does not dictate itself to us, the interpretation of observation to be meaningful is entitled to us. The meaning of observation is created by proper interpretation which is based on our purpose of understanding while conferring to the standards imposed by nature. As it cannot be the scenario where we have observations of any sought just because we expect them to be so. Hypothetically, in a scenario where observable entities are not able to explain the phenomenon, it is common to go for unobservable theoretical entities to explain the phenomenon.

Similarly, the existing current background knowledge which the scientific domain possesses is crucial in interpreting an observation. This is evident through the experiments on cathode rays conducted by Hertz in 1880s and Thomson in 1890s. Hertz had concluded that cathode rays was charge less which was later amended by Thomson who proved the cathode rays are negatively charged particles. Till date, this is accepted. The difference in the result was due to the fact during the time of Hertz, there was no adequate idea or technique to create vacuum which was developed by the time of Thomson. So, the theoretical context in which the observation is made plays an important role in accessing the observation as well as evidence and qualification of observation.

[4] Retrieved from https://whatis.techtarget.com/definition/meter

2.1.4 *The interaction between the object and the receptor*

Observation occurs only with the participation of an active observer. Even if the observation is direct or indirect or made using some artificial means, at the end, the observation has to be observed by the observer in a metaphorical sense. For example, when measuring the length of the block, the scale only shows that the edges of the block coincides with the two points of the scale. The rest of the part of the observation is made by the active observer.

It is clear that observations cannot be just limited to sense perception as the empiricist expected observations to be. For instance, the very electromagnetic spectrum covers a large area of light that is not detectable by our normal senses. Similarly, in sound, some frequencies that are generated can be perceived by dogs while it is undiscernible to the human naked ear. Other innovations like telescope, microscope, etc., necessarily show that observations are not limited to the sense experiencer.

Just as subjective intuition cannot be termed as an observation or an interpretation of observation in science, vagueness cannot be part of an observation. It requires an intersubjective agreement even though it is impossible to claim that everyone has the same sort of observation. This is why science is looking for a technical universal language and apparatus that is not fallible. But experimenters regress discussed in objectivity (first chapter) raises serious objections towards this. Either these apparatus or means are in need of justification which will in turn result in an infinite regress of reasoning.

Nature has enabled us with various ways in which observations can be made at different levels or at the same levels. As it is practically implausible to take all these observations (each and every one) into consideration even with presently available super computers, filtering needs to be done in the justificatory part of the theory. The very choice of this filter has to be made before getting in to the core justificatory part of science. This choices constitutes the justification for theory. This is the appraisal of evidence or setting the priority of evidence.

2.2 Evidence

Evidence in general can be defined as the accessible collection of facts which can establish the 'truth' or falsity of the statement which the evidence intends to support. Always in case of evidence, the necessary relation between the evidence and the hypothesis is expected. So, in analysing the concept of evidence, how this necessary relation is established is very important. The traditional rationalist account of science envisioned a unique way in arriving and accepting scientific theories. Their concept of evidence was also more or less the same such that, they expected certainty in evidence which will enable to have confidence over the certainty of the theory.

Like observation, evidence also presupposes the epistemic background which the theory possesses at a particular interval of time which makes the evidence conclusive for that time being. As we see in the history of science the theories get outdated or proven to be false later because of the new information gained during the course of time. But at the time of confirmation of that particular theory the evidence was found reasonable and there was no counter-acting observations. So, essentially the epistemic situation is crucial in the making the evidence conclusive for the theory for the time being. Even if the evidence is based on the pragmatic success, epistemic situation enables for the success and epistemic privilege of evidence for the time being.

So far, in history of science, no theory can be said to be proven conclusively such that theory is certain and the theory is successful eternally. As mentioned in the last paragraph at the practical level, one important aspect which decides the temporal success of the theory and truth is the epistemic situation in which the evidence is proposed. At times evidence is created out of the raw data using auxiliary theories. On other instances in which the observation is interpreted is about qualifying observation to evidence. But validity of evidence is limited to the epistemic situation in which the evidence is proposed. As the information increases in the epistemic situation, the way in which evidence is seen also varies. Evidence can only be evaluated with respect to the theory within the limit of its epistemic situation and the limit of the consensus of the scientific community. As the epistemic situation gets better and informative, it will give more perspective on evidence.

An ideal evidence must be able to support the theory independently. But at the practical field, the concept of subjective evidence becomes very crucial as it depends on the confidence of the person supporting the particular theory and is not always necessarily valid. Validity is ensured only if there is consensus among the scientific community which transforms the subjective evidence into objective evidence. So, in establishing the priority of evidence it is necessary to see how subjective evidential confidence is conveyed to others at the practical level while keeping in mind the unattainability of objectivity and truth (discussed in the earlier chapter).

There are two ways in which we can conceptualise evidence. If E is the evidence for H such that E provides a good reason to believe in H. It does not necessitate that H is true or not. Other is E helps in asserting H as most probable or true. In principle this is what science looks for, E asserting H as most probable or true which in turn acts as a good reason to believe in H.

2.2.1 *Theories of evidence*

Most of the theories of evidence expect necessary (formal) relation between the evidence and the theory. These theories tried to establish a formal deductive relation between theory and evidence without reference to the content of the hypothesis. The following discussion in the next session will enable us to see how the notion of necessary relation between the evidence and the theory is established independently.

In philosophy of science and epistemology the concept of evidence is inherently crucial. In the former, evidence is primal in confirming or refuting scientific theory. Accordingly, it formulates our justifiable decision between competing scientific theories. In epistemology, evidence links knowledge and justified belief where the latter is a requirement of knowledge.

There are different theories on account of the relationship of observational evidence on a scientific theory where the relationship can be probabilistic, semi-probabilistic or non-probabilistic or qualitative theories. The first two types of theory incorporate probabilities to some account in its theories whereas the last type deters any reference to probabilities. Also referred to as qualitative theories of evidential relationship, they deal with deductive reasoning between evidence and hypothesis. The three theories are Hypothetico-Deductivism, Hempel's evidence as positive instance and Glymour's bootstrap theory.

In simple terms in the Hypothetico-Deductive theory, a hypothesis is formulated (hypothetico) and observational consequences are drawn from it that can be tested (deductive). If these (observations consequences drawn from the hypothesis) turn out to be true when tested via experiment, the hypothesis is accepted as evidence has been obtained in favour of the hypothesis. On the other hand, if the consequences turn out to be false, the hypothesis is refuted and the theory is said to be falsified. However, there have been several objections to the Hypothetico-Deductivism. One of which points outs that just because the evidence turns out to be true, it does not verify the hypothesis rather it just supports or confirms it and there is a degree of support associated with the evidence. Carl Hempel postulated an alternative to this objection with this account of evidence as a positive instance of a hypothesis.

According to Hempel, "E is evidence for a universal hypothesis H, when E describes a positive instance of H- or when E says of the items mentioned within it what H says of all items. Intuitively, in such a case E would "instantiate" H, thus would be evidence for it. While this is hardly ground breaking, what is novel about Hempel's approach is that he marshalled the resources of basic predicate logic to give his account of a positive instance, thereby construing the evidential relation, like deduction, as being a syntactical relation obtaining between sentences. That is, on this approach E is evidence for H not by virtue of the specific sorts of objects E and H describe, but by virtue of the formal features of the manner in which they describe them."[5]

Another adequate alternative is provided by Clark Glymour. His theory is based on the notion of instance that is additionally derived from Hempel's notion of evidence is positive instance. In Glymour's theory of bootstrapping, hypothesis of theories and its evidence can be used to obtain evidence for other hypothesis in the same theory. Simply put, let e1 be evidence for hypothesis h1 in a theory. Then, according to Glymour, this can be used to provide evidence for another hypothesis h2 in that theory. One of Glymour's examples is Newton's law of gravitation for which Newton used Kepler's law of planetary motion and other additional observational evidence and hypothesis from Newton's second law. These theories of evidence give no consideration to the content of theories and the aspects like background knowledge and confidence over the theories which is presupposed in the theory. However these theories are not successful in explaining the evidential relation in the practical aspect of science.

In the practice of science, a formal definition between theory and evidence is not enough. As it is described in the 'epistemic situation' (mentioned before in the chapter), the beliefs over the theories used in arriving at knowledge, etc., is very crucial. A formal relation between theory and evidence will not capture the aspects mentioned above.

[5] Retrieved from https://www.iep.utm.edu/evidence/#SH2cii

2.2.2 *Distinction between the demonstrative and non-demonstrative inference*

The relationship between the evidence and theory must be found on some rational inference procedure which can justify the necessary relation between evidence and theory. It was Hume who put this justification under severe scrutiny (the concept of causality and inductive inference). But so far, we are only able to provide an empirically adequate reply to the logical problem raised by Hume. Moreover, inference and its feature are very crucial in making the claims about the unobservable from the observables

Demonstrative inference is the one in which the conclusion is not false if the premises are true. Non-demonstrative inference does not possess this kind of a necessary condition. One main feature which ensures the necessity of truth preservation of the conclusion from the premises is that it is not extensive rather, it cannot say anything more than what is there in the premises (non-ampliative).

However, the main problem with induction is that:

Consider an inductive argument where

P1- Some crows in the nature has been observed

P2- All the observed crows are black in colour

Conclusion: All crows are black in colour

This argument is not truth preserving and there is no necessity which is existing between the premise and conclusion. But one premise more to this can make the argument truth preserving which is about the uniformity of nature.

Let's consider the third premise to be

P3- If the qualities of two or more entities of the same species are same, then it is same for all of the species.

In general, science assumes to have this principle granted until something opposing comes up. In fact, the term 'everything remaining the same' is another way of articulating the above principle of uniformity. But as from the experience it is clear that there is no evidence to conclusively prove that nature possesses uniformity nor is it possible to hold uniformity in nature to be a necessary principle.

But even if we hold the Hypothetico-Deduct model it would not help in establishing a necessary relation between evidence and the theory. The fact is that if it has to be deduction then the inference cannot be ampliative. But in case of Hypothetico-Deductive model, the prediction is ampliative such that it predicts the future occurrences. However, the theory can only be made corresponding to the occurred phenomenon which essentially consists of past observations not the future ones. So, to conclude, to hold a necessary relation between the theory and evidence such that particular set of evidence only supports one particular theory in an absolute sense is not possible. The evidence can only be based on the past experience. It is not necessary that the future is also same as the past. So, every evidence is viable to the problem of induction.

The problem of underdetermination of theory also shows the contingent nature between the theory and evidence. Underdetermination of the theory by evidence shows the possibility of having more than one theory confirming to the same set of evidence (within the epistemic situation). The concept of underdetermination of the theory (which might or might not get settled as we progress with more and more information) also shows the inability to hold a necessary relation between theory and evidence.

2.3 Theory-ladenness

Theory-ladenness of evidence and observations is considered as threat to objectivity, hence a value-free science. Theory-ladenness of evidence can hinder the priority given for evidence in justifying a theory. Theory-ladenness can lead to theory getting importance over the evidence and evidence manipulated according to theory (especially in cases where there is no perfect match between experimental result and theory). Setting out the priority of evidence in confirming a theory or making a theory choice is a very crucial step that needs to be upheld throughout scientific procedures. Logically, every evidence presupposes an observation. Or in other words, potentially every observation can be evidence even if it may not be for the same theory. Thus, observation has the potential to support a theory in accordance with the context. In order to understand how priority of evidence in justifying a theory works, it is essential to analyse how the qualification of observation to evidence happens and on what basis and to what extent the qualification is objective (value-free) and independent of the theory. As there cannot be a necessary relation between evidence and theory, in that how evidence can establish confidence over the theory to be true. Answering these will help in understanding the value-ladenness or value-freeness of evidence. The analysis consists of examining the theory-ladenness of evidence and its effect in interpretation of observation and qualification of evidence to observation. The later part of the chapter will examine how theory-ladenness of evidence can lead to value-ladenness

Here we consider the following experiments.

2.4 *Experiment on Cathode Rays*

The history of cathode rays starts from 1859 with Julius Plucker's discovery. The experiment was designed with an air filled glass tube containing positive and negative electrodes. When the pressure inside the tube is reduced to a sufficiently low level (0.001 nm of mercury), cathode rays was produced. Later Johann Hittorf showed that these rays travel in straight lines perpendicular to the surface of the cathode.

2.4.1 *Heinrich Hertz's experiment*

Background of the experiment

Post the discovery of the cathode rays, two theories about the basic nature of the cathode rays was proposed. One of the theory was, cathode rays are negatively charged particles and the other was that cathode rays are waves in ether.

It is interesting to note that the proponents of the two theories could be categorized on nationalistic lines. Most of the French and British physicists were in support of the particle theory, the Germans including Hertz were in support of the wave theory.

Purpose of the experiment

The experiment was designed to verify whether cathode rays are negatively charged or not.

Theory of the experiment

Pure cathode rays were made to pass through a medium of gas between two electrified plates. If the cathode rays show deflection then the rays are charged particles.

Design of the experiment

The apparatus designed by Hertz consisted of the following components;

- A glass cylindrical container containing the cathode and anode. In this design the anode is a brass tube that surrounds the cathode with a circular opening through which cathode rays can pass through.

- A wire gauze or wire mesh through which the cathode ray pass. The mesh separates the ordinary electric current from the cathode rays. Accordingly, the cathode rays that pass through are regarded as pure.
- A metal case that completely covers the portion of the cylindrical tube beyond the wire gauze such that it does not contain the electrodes. This metallic case shields off any additional electrostatic forces the cathode might produce.
- A metal mantle with a hole in one end for the cylindrical tube to be inserted. It is also connected to a pole of the induction coil.
- The cathode tube is fitted between strongly and oppositely electrified plates. This tested whether the cathode rays would be affected by external electrostatic force.

Both the metallic case and metallic mantle are then connected to an electrometer that measures the deflection caused.

In the experiment, if the cathode rays were electrically charged, it would be defected by the presence of these plates.

Result of the experiment

The cathode rays didn't show any deflection. By which Hertz concluded that cathode rays are charge-less.

2.4.2 *J. J. Thomson's experiment*

Background of the experiment

Unlike Hertz, J. J. Thompson interpreted the result in a different manner. He had a better idea about ionization of the gas at high potentials. He was more equipped with the technology to create deeper vacuum. Before Thompson, Perrin manipulated Hertz's experiment and inferred that cathode rays are charged. This experiment was then modified by Thompson.

Purpose of the experiment

To verify whether cathode rays are charged or not.

Theory of the experiment

Pure cathode rays were made to pass through vacuum between two electrified plates. If the cathode rays show deflection then the rays are charged particles.

Design of the experiment

The underlying theory behind this experiment was also similar to that of Hertz. But it differed in the design of the experiment. One substantial difference was the deeper vacuum created between the plates. Secondly, instead of induction coil as in Hertz experiment, he used a battery.

Result of the Experiment

The cathode rays showed deflection hence the cathode rays are negatively charged particles.

2.4.3 *Discussion on the two experiments*

A comparison of these two experiments helps us to understand about the theory-ladenness of the experiment and how it affects the qualification of observation to evidence.

It is not just necessary that the experiment is done on a complete unbiased basis such that the prior conception of the theory does not influence the experiment and analysis that follows. Though this would enable us to say that the decisions are done based on an objective value free manner. Rather, it is the authority of the scientist and the epistemic situation that determines the success of the experiment and the success of the theory until contradictory facts arises. J. J. Thomson did not dispute the observational results of Hertz that there was no deflection. Rather his interpretation was completely opposite to how Hertz had interpreted. Thomson's modification of the design of the experiment resulted in the intended result. The main difference between the two experiments was the idea of vacuum.

Thomson emphasized the need of deeper vacuum as he was more equipped with the theories of ionization (by the time, Rutherford and he had published results of ionization of gas and the conduction of X ray). Thomson thus managed to produce a deeper vacuum compared to the experimental design made by Hertz. Hertz was not oblivious about the factor of vacuum, rather he took it in a different sense. According to Hertz, deeper vacuum might impede the electrostatic effects of the ray. So, vacuum was not given much importance in the experimental design.

Subsequent is the explanation given for the Hertz experiment results by treating cathode rays as negatively charged particles. Under high potential the gas between the anode and cathode plates ionizes. The positive ions accumulate towards the cathode and negative ions towards the anode neutralizing charge of the cathode and anode. This ionization and neutralization of cathode and anode makes the medium between the plates to be charge less or zero potential. Since the anode and cathode is not charged, the cathode ray passing through would not get deflected. Hertz interpreted this non-deflection as the charge-lessness of cathode rays (but the epistemic situation was comparatively limited to him as he didn't have much idea about the idea of ionization of gases).

Another point which is unexplained in the experimental design of Hertz was the usage of induction coil instead of 2000v battery which he had used in prior experiments. Hertz himself admits that the use of the coil would not result in a stable result when compared to the battery and still why it was used needs explanation. Even though before the Hertz experiment, Goldstein (one of the members of the wave theory camp[6]) had demonstrated the negative

[6] But the explanation was given in the wave theory perspective didn't treated cathode rays as particles.

charge of cathode ray, Hertz stuck to his proposed theory. It would not be wrong to suggest that Hertz was sure about what he wanted as the result of the experiment and this in turn influenced the design of his experiment. This particular case shows that observation itself can be theory-laden.

Arguably, though Hertz's awareness of the idea of vacuum might not have been as good as Thomson, he did not try to experiment with deeper vacuum. This allows us to infer the influence of preconception that affects the generation of observation and evidence. But history of science reasons out the failure of Hertz's experiment on account of the inadequate knowledge about vacuum.

These two experiments which resulted from different interpretation of the same observation suggest the theory-ladenness of the evidence in its strongest form and theory-ladenness of the observation in its weakest form. Weakest in the sense that the theoretical presumptions was necessary for this observation to be created. The manipulation of observation presupposed the causal knowledge of repulsion of like charges, construction of pure cathode rays, etc. Ideally the experiment was open to both chances of having deflection or not. So, observation was not theory-laden in the way evidence is. The interpretation of the observation happened in correspondence with the evidence expected from the result by the scientist. In other words, this experiment doesn't have already interpreted observation. Here observation acted as a raw data which needs interpretation (theory-laden in the weak sense).

There are other instances in which evidence and observation is already interpreted and theory-laden in which establishing the priority of evidence is more about qualifying certain observations as evidence and discarding others.

2.5 Eddington Expedition

Purpose of the experiment

To check the validity of Einstein's theory of relativity over Newtonian theory of gravitation

Theory of the experiment

Both Newton and Einstein predicted the bending of light near massive objects due to gravitational attraction. Till 1915, both their calculations matched and the predicted value was 0.86 seconds of arc. Later Einstein realized an error in his calculation and that his magnitude of deviation was incorrect by a factor of 2. He then proposed the new magnitude as 1.74 seconds of arc. The Eddington expedition was set to check which of these values are correct.

Design of the experiment

The main equipment used for the experiment consisted of two "astrographic" object glasses about 10 inches in diameter, one to Sobral (Brazilian town) and the other to Principe (West African island). The experiment data included photographs to show the relative proximity of the stars with respect to the sun. Since, the brightness of the sun would obscure the presence of the stars during daytime, photographs to know the proximity position are possible only during night time. The comparison photographs are then taken during an eclipse which will show both the presence of the sun and the stars. This helps to measure the relative position of the star (Hyades, the star cluster) around the sun during an eclipse. Since the experiment required the occurrence of an eclipse (29th May 1919), it was conducted over a long period of time and was found to be tedious.

The expedition involved two teams, one to Sobral (from Greenwich observatory) and the other team to Principe (from Oxford observatory). In addition to the astrographic object glass, a smaller objective lens of 4 inches in diameter was taken to Sobral as backup. Along with both expeditions carried two large coelostats (mirrors used for solar observation). A detailed description is provided by Peter Coles (2001), "The reason for the mirrors was that no mechanical devices were available to drive the steel tubes containing the object glasses to compensate for the rotation of the Earth. The tubes had to be as long as the focal length of the lens, which in this case was about 3.5 metres, so they were difficult to move once set up. If a telescope is not moved by such a driver during the taking of a photograph, the stars move on the sky during the exposure and the images turn into streaks. In the eclipse experiment, the trick used was to keep the telescope, still but to have it pointing downwards towards the coelostat which reflects the light into the telescope lens. The mirror is much small (about 16 inches across) and a relatively small clockwork device can be used to move it to correct for the Earth's rotation instead of moving the whole telescope."[7]

Practical difficulties of the experiment

On account of bad weather condition in Principe, Eddington team managed to return with two useable photographic plates. On the other hand, Sobral had a better weather condition that gave hope for clear photographic plates. However, Crommelian (who led the Sobral team) made a blunder while setting up the main telescope. As they set the focus of the telescope overnight, they didn't account for the effect the increasing morning temperature would have on the mirror. Subsequently, the tube and coelostat mirror expanded due to the heat resulting in the plates being blurred. The only consolation were the plates from the 4inch telescope which performed well and were usable photographic plates for analysis.

There were also several other problems since the expected light deflection result was very small. There were thus additional aspects that could cause a shift in the position of the stars on the photographic plate such as the non-uniformity of the emulsion applied on the plate and the expansion of plates due to rise in temperature. The eclipse plates were thus subjected to varying weather conditions when compared to reference plates. Also, the change in the refractive properties of the atmosphere during the eclipse would have resulted in the distortion of the

[7] From Peter Coles 2001 paper, 'Einstein, Eddington and the eclipse'.

images. An additional situation that affected the Eddington expedition was the unexpected strike of the steam engine workers that forced him to leave before taking reference photographs after the eclipse. As a result, Eddington relied on the reference plates taken before the eclipse at Principe and at Oxford.

Result of the experiment

Amidst all the technical difficulties, the Sobral and Principe plates came up with photographic plates that could be analysed. Further calculation revealed that the Principe plates were poor in quality while the 4inch Sobral plates were of better quality. The result of the calculations of the plates are:

Sobral

Poor plates	0.86 (mean) secs of arc
Good plates (4inch)	1.98 (mean) secs of arc

Principe

Poor plates	1.62 (mean) secs of arc

When calculating the deviation in the Principe plates, the method deployed was ambiguous and a clear strong influence of Einstein's calculations was visible. Particularly, Eddington's method used Einstein's derivations in calculating the initial displacement of the star.

2.5.1 *Discussion on the experiment*

This expedition result clearly shows theory-ladenness of observation and evidence. Eddington faced no confusion in the way in which the observations should be interpreted. The priority of evidence for the acceptance of the hypothesis was modified such that it was preconditioned to give results in favour of the theory of relativity. One significant reason was the already dominant influence and acceptance of the theory of relativity by the entire scientific community. Similarly, the reference values were values of Einstein and Newton though the actual observational values could lead to be entirely different.

In the meeting following the expedition for the analysis of the result, no common consensus was generated among the scientist gathered in support of a particular theory. Some of the scientists even questioned the statistical reliability of the data. The use of Einstein's equations by Eddington in his early stage of calculations on the Principe plates was not made very clear and some scientists felt the omissions of certain data disputable. As some of the plates yielded a value that was close to the Newtonian value, few of the scientists were not ready to support the relativity theory over the Newtonian theory. But, amidst all these discrepancies and ambivalences in the obtained observations and calculations, Eddington and the chair of the British Royal Society, J. J. Thomson approved the result and qualified the observation as evidence in favour of the theory of relativity.

It is interesting to note J. J. Thomson's remark "it is difficult for the audience to weigh fully the meaning of the figures that has been put before us. Astronomer royal and Prof Eddington have studied the material carefully and they regard the evidence as decisive in favour of the larger value (Einstein)"[8]. In this particular case, objectivity is merely reduced to the consent of the scientific community or the authority and their sanctioning. Even though in the meeting the opinions were ambivalent and the readings done were clearly in light of the theories already present. This clearly shows how the positivist notion of scientific development constituting theory independent observations is violated. Observation and evidence are theory-laden in the sense that the interpretation of the observation is made in such a way that it should match with

[8] Taken from Collins Harry (1993)

the Einstein value. This went to the extent that the observational value retrieved form the Principe plates used Einsteinian theory in a bizarre manner.

In the Hypothetico-Deductive model, a high degree of equivalence is expected between the prediction and theory. In this case, the values were made to match deliberately and taken up as evidence. So, the confidence of evidence and objectivity with respect to the theory of relativity was decided by the consensus of the authority of scientific community (decision making at this juncture). In the process of this analysis how the weightage was not given to the other Sobral plates. It was in 1952, a better result of the same was obtained. Yet, in 1919 the theory was confirmed and labelled as one of the most important developments in Newton's law of gravitation. In J. J. Thomson's words "this is the most important result obtained in connection with the theory of gravitation since Newton's day"[9] In what sense this became a valid statement remains dubious on account of its non-reasonable inconclusive evidence. At this point, it can be clearly seen as an instance of clear violation of the value-free ideal which is expected in science. It might be the case that the popularity of Einstein's theory of relativity and its various aspects in other problems of physics led to the result. But, none of this can be seen as an adequate reason for the decision taken in 1919 which at the end was not objective in any manner or guided by evidence in any way. So, it could be inferred that at that moment science behaved in a way which is value-laden.

With concern to the setting out of priority of evidence in scientific domain it is clear that both observation and evidence are theory-laden as it is clear that only two values were considered 0.8 by Newtonian and 1.7 by Einstein). Even though, it was possible to think of other values. This point was also raised during the meeting. Unlike the previous mentioned experiment, this experiment did not involve interpretation of observation. Rather what matters is the

[9] Quoted from Cowen, Ron. 2019, "Gravity's Century: From Einstein's Eclipse to Images of Black Holes" (p: 64)

qualification of observation as evidence. Here, only the values which favoured Einstein's values were considered while the other values were discarded though not in an unambiguous way. This is thus certainly an instance of theory-ladenness of the evidence and the dominant theory controlling the entire qualification procedure of observations to evidence in favour of the particular theory. The possibility of this kind of a scenario arises from the practical difficulty in independent formulation of evidence. In many instances like this, the dominant theory could make the observations and qualification evidence in favour of the theory which is not epistemically driven choice in its strict sense. This is because the theory gets the priority over evidence and the evidence is manipulated according to the theory by ignoring the counter acting observations from the evidential status. Moreover interpretation of the unclear data was interpreted in accordance with the theoretical value and this observation was later qualified as evidence.

The repercussion of this decision was that it enabled many others to have confidence over the theory ignoring the discrepancies in various other fields. In a holistic view, the theory-ladenness of evidence did not end with that particular theory. It gets propagated in instances which has reference to that theory (so is value-laden). In an account given by Glymour soon after this confirmation of the general theory of relativity by Eddington, the uncertainty in explaining the phenomenon of redshift became certain. Earman and Glymour (1980) put it as "The eclipse results gave solar spectroscopists the will. Before 1919 no one claimed to have obtained spectral shifts of the required size; but within a year of the announcement of the eclipse results several researchers reported finding the Einstein effect. The red-shift was confirmed because reputable people agreed to throw out a good part of the observations. They did so in part because they believed the theory; and they believed the theory again at least in part, because they believed that the British eclipse expeditions had confirmed it. Now the eclipse expeditions confirmed the theory only if part of the observations were thrown out and the discrepancies in the remainder ignored."[10]

In other words, the subjective evidence of the scientist became an objective evidence with the sanction of the authority (The decision of Astronomer Royal was most decisive and this could be translated as the consensus of the scientific community). Another important factor is the academic status of Eddington. It was said that by 1920, Einstein and Eddington were two persons who fully understood the meaning of the theory of relativity. Probably, had it been the case that any other scientist would have made the same expedition and the same kind of ambiguous calculations, they wouldn't have got this much acceptance. So certainly, professional status could be an important factor in making the subjective evidence to be objective evidence.

2.6 The Controversies over Detection of Gravitational Waves

History of Gravitational wave

In 1916, Albert Einstein predicted the existence of the gravitational waves in his general theory of relativity. The gravitational wave was first proposed by Henri Poincare in 1905. Gravitational waves generated by massive accelerating bodies manifest through fluctuations (disturbances) in the space-time curvature. The following decades witnessed a plethora of theoretical work (for and sceptical) by various physicists and mathematicians namely; Nathan Rosen, Howard P. Robertson, Hermann Bondi, Felix Pirani, Ivor Robinson, Andrzej Trautman and others. But it was only in 1959, the first experimental attempt to detect gravitational waves was made by Joseph Weber. Though his findings were controversial as it couldn't be duplicated, he is regarded as the founder of the field of gravitational wave detection[11]. Later

[1010] Quoted from "The Golem: What everyone should know about science" p:53, by Harry Collins and Trevor Pinch (1993)

[11] Gravitational Waves Explained by Praveen P. A. (2017).

on, in 1974, definitive proof of the existence of gravitational waves was put forward by two astronomers, Joseph Taylor and Russell Hulse. They were awarded the Nobel Prize in Physics for this discovery in 1993. The world's first direct detection of gravitational waves occurred on 14th September 2015. The researchers at the Laser Interferometer Gravitational-Wave Observatory (LIGO) confirmed the results conclusively and announced it on February 2016, exactly hundred years later from its prediction. The discovery awarded three physicists Rainer Weiss, Kip Thorne and Barry Barish the Nobel Prize in Physics in 2017.

Timeline

LIGO was funded by the US National Science Foundation in 1979. It was however only in 1994, the construction of LIGO began in two facilities, Hanford in Washington state and Livingston in Louisiana. In 2002, LIGO, operated by Caltech and MIT began its search for evidence of gravitational waves. The first phase of LIGO ended in 2005 after five searches with no detection of gravitational waves. With the upgrade to Enhanced LIGO, the new hunt for evidence began, along with observations from Virgo (in Pisa, Italy). A second update, Advanced LIGO began in 2010 which was completed in 2014. In the joint collaboration of LIGO and Virgo, gravitational wave signal was detected in 2011. The discovery, titled as the evidence of direct detection of gravitational waves was subsequently found to be a hoax before its announcement. It was said to be a 'blind injection' challenge, a fake signal that was injected into the data to test the detector and analysis[12]. Though this was disappointing, it showed that gravitational waves could indeed be detected. The detectors then underwent another upgrade. The subsequent upgraded LIGO with four times the sensitivity of the original LIGO began its search and for the very first time, the universe's gravitational waves were observed on 14th

[12] "Blind injections" stress tests LIGO and Virgo's search for gravitational waves https://www.ligo.org/news/blind-injection.php

September, 2015. On 11th February, 2016, the successful detection of gravitational waves was announced.

Design of LIGO

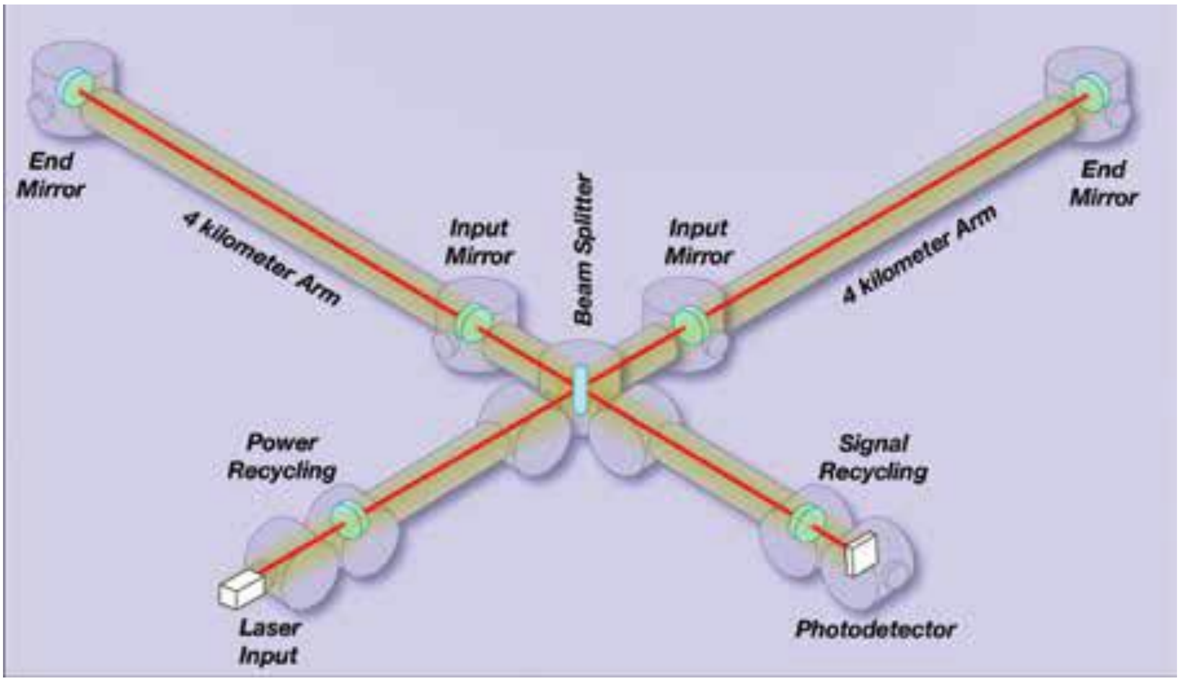

Figure 1: Design of LIGO

LIGO consists of two interferometers, each with two 4 km (2.5 mile) long arms arranged in the shape of an 'L'. These instruments act as 'antennae' to detect gravitational waves this detector claim to have the power to detect signals which are up to 1/10000 the width of a proton.

The heart of LIGO is its 200W laser beam. Four intermediary steps are done to amplify the power of the beam from 4W to 200 W and to refine its wavelength to a level of precision that is typically not seen in a laser of this kind (1064 nm). This is the beam that ultimately enters LIGO's interferometer.

In the working of the interferometer, the gravitational waves are ripples that occurs in the time space curvature. From the set-up as shown in the figure, the laser beam splits into two perpendicular arms and are made to travel to each of these arms that are equipped with mirrors at the end. This will reflect the laser to the splitter and the waves with different phases and same wavelength will cancel each other. So, when a gravitational wave occurs, the length of one of the arms become shorter when compared to the other and moments later it switches to the other arm. This process of expansion and compression of the arms continues until the wave is passed. This creates variations in the phases and the wavelength of the laser coming from the two arms will not cancel each other. The interference pattern is later amplified and converted into electric signals for further analysis.

Without going much in to the technical aspects of how LIGO functions, let us look in to the issues in the detection of gravitational wave. This includes the idea used behind the observatory and the responses of the scientist towards the detection of the gravitational wave. Also, of interest is how authorities has responded to the doubts or criticisms and how the detection was made to be a conclusive detection.

Practical difficulties in detection

The following are the practical difficulties in detecting the Gravitational wave:

- The magnitude of change (length of the arm) produced by the gravitational wave in the apparatus is very minute, to the order of almost 1/1000 the diameter of proton which is the smallest reliable measurement made so far. So, the apparatus design must be able to detect variations with in this minute limit.
- The use of highly advance computer programs and algorithms which is needed to interpret the data in order to trace the nature of the gravitational wave from the noisy data.
- The presence of noise. The detector cannot be made to detect signals which are only generated due to gravitational waves. Other sources can also create detection in the apparatus such as the seismic activity of the earth. The Brownian motion of the particles

in the detector can alter the results, even the pressure of the laser used in the apparatus can create phase shifts.

- The stability of the laser beam. Since laser beams are inevitable part of the apparatus the stability of the laser beam is very crucial in the detection of the waves.

The most important part of the gravitational wave detection is the clearing of noise from the data. So, conceptually what the scientist has done is set up different detectors at different corners of world. For our current purpose what is important is the two detectors, one situated at Louisiana and one situated near Washington. The idea behind this is that these detectors will have different set of noise and by comparing the data from the different detectors we might be able to get the real pattern of gravitational waves. The method which is presently used in the analysis of data is the numerical relativity. And the stability of the laser is assumed to be sufficient

Now let us get in to the objections raised by various scientist against results in various aspects. Prof. Rana Adhikari from CALTECH points out some fundamental limitations in the detection of the gravitational wave.[13] One of which is regarding the laser used by LIGO. For the detection of gravitational wave, it is necessary to have one stable wavelength of laser which is sufficient to measure a variation of 10^{-18} m of variation. The variations created in the arms is to be of this order in case the gravitational wave is from a powerful source. He raises this practical issue of the stability of the laser which is not achieved to the sufficient theoretical level it needs for detecting gravitational wave. LIGO expects to measure the wavelength at 1064nm, which is measuring to the order of 10^-20. However, the practical measuring ability of LIGO is only of the order 10^-19. Even with this practical constraint LIGO announced that it detected the gravitational wave in 2015.

[13] Interview of Prof. Rana Adhikari, https://www.youtube.com/watch?v=1D2j8nTjOZ4

2.6.1 ***Controversies in data analysis and Discussion***

One main point is regarding the noise. In a normal expectation, the noise signal at the two interferometry should be different. But what was actually shown in the 2015 detection was an almost ditto reproduce of the same pattern. So, the noise and the amplitudes remained the same. In such a scenario, there arises the question of how the data and its analysis enables us to point out that we have actually detected the gravitational wave. This objection was very recently raised by a group of Danish scientists. After two years of careful analysis, the Danish group of scientist's claim puts reasonable doubt on the analysis of the data generated by LIGO. LIGO immediately responded by saying that the three techniques used in the data analysis were extremely complicated. Thereby, the problems raised by the Danish group was a result of the fact that they weren't able to fully comprehend the techniques involved.

The following are further discussion on the objections raised by the Danish team without mentioning the technicalities. When the gravitational wave was detected at the two detectors after sufficient interval of time, technically only the gravitational wave can be correlated while the noises should not correlate. But in case of this particular instance, the noises were correlated. This defeats the whole concept of having two distant detectors as its idea was to get rid of the noise which will technically not appear as the same in both data. It is on this crucial point that the Danish Team raised their objections which seems to be commonsensically reasonable. Rather than providing a responsible public response to the question raised, LIGO harped on the complexity of the analysis and so far, has not given a responsible response. The Danish team of scientist concluded that since the noises correlated, the data is essentially not apt. Thereby, the detection of gravitational wave from this data questions the validity of the detection. In short there is no dispute about the signals being generated. The problem is in identifying one particular signal is of gravitational wave out of many similar signals.

According to Andrew Jackson, a spokesperson of the Danish group, “We believe that LIGO has failed to make a convincing case for the detection of any gravitational wave event”. According to the group, the breakthrough was “noting of the sort: it was all an illusion”.[14]

According to LIGO, the first step to resolve the gravitation dispute is to know what the researchers should look for. The way they excavate signal from noise is to calculate what a signal should look like and then subtract it from the detected data. If the result then looks like pure, residual noise, it is marked as detection. Reitze, a LIGO spokesperson expressed that the analysis done by Jackson et al. looks for residuals after subtracting the best fit waveform from the data. “Because the subtracted theoretical waveforms are not a perfect reconstruction of the true signal-they never are, since we have a discrete set of waveforms that we use to search the data-[they] find residuals at a very low level and claim that we have instrumental artifacts that we don’t understand. So therefore, he believes that we haven’t detected a gravitational wave”.[15]

Another spokesperson Shoemaker says that while Jackson has considerable expertise in signal analysis of large data sets like the CMB, he does not work directly on gravitational waves. “They are coming to [LIGO’s data] with a tool set they’ve developed for this other field, the cosmic microwave background radiation. They are determined to use their concepts and not try to learn from our sometimes bitter, long, and frustrating experience.”[16]

This very response points to the fundamental nature in decisions regarding the appraisal of evidence. The very decision of the choice of which method to use for analysis and which method to produce is many times preconditioned by the theory. The statement made by Cornish, LIGO’s data analyst also points to the same thing. If you want to get the intended

[14] https://www.newscientist.com/article/mg24032022-600-exclusive-grave-doubts-over-ligos-discovery-of-gravitational-waves/

[15], [12] Quoted from https://arstechnica.com/science/2018/10/danish-physicists-claim-to-cast-doubt-on-detection-of-gravitational-waves/

result, it must follow the particular method which they [LIGO] have followed even if they have access to other methods. This is a perfect example of the theory-ladenness of the experiment, observation and evidence. In this scenario, rather than evidence leading to theory confirmation, we are looking for evidence led by the theory. The disparity in the result obtained from the different analysis shows that evidence is necessarily theory-laden and the qualification of observation to evidence is also theory-laden. In an extended report given by Cornish, he talks about the numerical relativity method which pre-calculates the expected result. Even though he himself admits that "we are unable to solve Einstein's equations exactly for the case of two black holes merging,"[17] instead the analysts use several methods to approximate the signals they expect to see. This throws light on the manner of choice of one method out of several methods. Even this preference is theory-laden. To be more reasonable the LIGO officials should be able to show why the methods deployed by them is superior over the Danish team and what the criterion for that supremacy is. The response which can be interpreted from their releases is that the authority of method chosen is entitled to the LIGO officials. The method deployed by Danish team were thus not apt as they were not able to see what the LIGO officials managed to show as result.

The episode of gravitational wave detection also shows that there are no independent standards (in this case) which can guide the decision-making procedures in science. Rather, it is the consensus within the scientific community which characterizes the theory and methods deployed as appropriate over other methods and theory. This like the earlier cases relates to the concept of objectivity to the consensus of the scientific community.

Another point that can be drawn from this specific instance is that they haven't made the data public yet which restricts further analysis by others. For instance, *New Scientist* learned that

[17] Neil Cornish quote from https://www.newscientist.com/article/mg24032022-600-exclusive-grave-doubts-over-ligos-discovery-of-gravitational-waves/

the LIGO collaboration decided to publish data plots that were not derived from actual analysis. The paper on the first detection in *Physical Review Letters* used a data plot that was more "illustrative" than 'precise' (says Cornish). Some of the results presented in that paper were not found using analysis algorithm, but were done "by eye". Such a presentation of "hand-tuned" data in a peer-reviewed scientific journal was certainly unusual. "*New Scientist* asked the editor who handled the paper, Robert Garisto, whether he was aware that the published data plots weren't derived directly from LIGO's data, but were "pedagogical" and done "by eye", and whether the journal generally accepts illustrative figures. Garisto declined to comment. There were also questionable shortcuts in the data LIGO released for public use."[18] For instance, in the data after the subtraction of the Louisiana signal from the Hanford one, there were correlations, the very same correlations that Jackson had noticed in the approximated data. Presently, the data release webpage of LIGO contains a note that states that "the publicly available waveform was not tuned to precisely remove the signal". Cornish comments that whatever might be the shortcomings in the reporting and publication of data, the actual analysis of the data "was done with processing tools that took years to develop and significant computing power to implement"[19] and that it worked perfectly. However, LIGO's attempt to "open data and reproducible science" is questionable. Jackson says, "it's problematic: there's not enough data to do the analysis independently."[20] So, anybody outside the collaboration should just take LIGO's analysis by its words.

"The Danish group's independent checks, published in three peer-reviewed papers, found there was little evidence for the presence of gravitational waves in the September 2015 signal. On a

[18] Reported from *NewScientist* https://www.newscientist.com/article/mg24032022-600-exclusive-grave-doubts-over-ligos-discovery-of-gravitational-waves/. Also, discussed in https://physicsphilosophy.science.blog/2018/11/03/do-you-denounce-the-practice-of-hand-tuning-ligo-data-in-peer-reviewed-scientific-journals/

[19], [20] Referred from https://www.newscientist.com/article/mg24032022-600-exclusive-grave-doubts-over-ligos-discovery-of-gravitational-waves/

scale from certain at 1 to definitely not there at 0, Jackson says the analysis puts the probability of the first detection being from an event involving black holes with the properties claimed by LIGO at 0.000004. That is roughly the same as the odds that your eventual cause of death will be a comet or asteroid strike – or, as Jackson puts it, “consistent with zero”. The probability of the signal being due to a merger of any sort of black holes is not huge either. Jackson and his colleagues calculate it as 0.008.”[21]

This essentially shows the authoritarian nature of science. It just adds to show how science is essentially social in its proceedings (not necessarily always). This particular instance and statement make science no less than a dogma. We are supposed to believe what is given to us in the way it is reasoned out.

Further detections of gravitational waves were made in 2017 but this doesn’t validate the scientist conclusive announcement of detection in 2015. Weber claimed the first experimental attempt of gravitation wave in 1959. For a short period of time, this was convincing but the possibility of reproducibility of results made Weber discard his findings. It was later assumed that there was a deliberate manipulation of data. With such a legacy in detection of gravitation, it is not unrealistic to cast serious doubts on the results which they claim only they can understand it completely.

2.7 Theory-ladenness of evidence

So far, in this chapter the practical aspects of setting out the priority of evidence is illustrated. Just as truth does not stand independent of theory as imagined by positivists (discussed in the earlier chapter), evidence too is not independent of theory. At one level or another the observational language and evidential language are necessarily theory-laden. In cases where

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[21] https://www.newscientist.com/article/mg24032022-600-exclusive-grave-doubts-over-ligos-discovery-of-gravitational-waves/

evidence does not match with the theory, the consensus of the scientific community sets out the priority of evidence. Similarly, the consensus of the society can make a theory to be objective. This consensus of scientific community makes the scientific domain a social one. In other words, it is not the independent principles of evidence and truth that result in an objective decision process as envisioned by value-free science rather it is the consensus of the scientific community. This reflects on the humane aspects of scientific endeavour wherein the only things that can be said is that scientist qua scientist is free from all non-epistemic influence. But as we have already seen, at the practical level the epistemic values alone cannot guide the decision making in science especially in the epistemic phase. This is fundamentally because at the practical level, the concept of objectivity, truth and priority of evidence cannot be obtained independently. So, the scientist has to essentially look onto non-epistemic aspects as well. The reputation of theory and prior influence of the theory can play a crucial part in the confirmation of the theory as evidence is theory-laden.

In other words, the subjective evidence needs to be converted to objective evidence. Initially every theory is the product of the observation and experimentation of a scientist. At this particular stage the evidence of the particular theory and the confidence over the theory is subjective to that particular scientist. However, once it is convinced to others (scientific community) the evidence and confidence over theory becomes objective. Ideally it should be the case that the relation between evidence and theory is established reasonably. Moreover everyone (scientific community) should assent to the same judgement because it is reasonable. But here, objectivity does not imply that each and every person assents to the same judgement regarding the evidence. It is often not the case that everyone assents to the same judgement. However if there is a common acceptance which implies that there will not be objections and if there is, it must get nullified. Ideally (in practice) if the objections is due to any personal biases it will get nullified very easily because the objective statement is very reasonable and every one must be able to accept that. Being reasonable essentially implies it should be acceptable for all (ideally). But here instead of having common consensus, amidst the difference in opinions, objectivity in terms of common consensus is fulfilled by the authority of the scientific community. This enables the dominant theory to overpower the objections against the theory (which might or might not get nullified later). This overpowering of the theory ignores every objection raised against the evidence of the theory. This is enabled through the sanctioning of the theory with the disputable evidence by the authority of scientific community (Astronomer Royal in case of the expeditions and the LIGO team in case of gravitational wave detection). Especially in scientific experiments which are really expensive and hard to replicate the persons in charge of the experiments becomes the authority. This chapter so far have tried to illustrate the practical difficulties in setting priority of evidence suitable for a value-free science.

As discussed, theory-ladenness and consensus of scientific community become very crucial in the appraisal of evidence. This is one aspect of science which makes evidence value-laden. In speculative sciences, the experiments are especially very sophisticated and costly. Not everyone will get a chance to conduct the experiment (accessibility of techniques, funding, etc., become problematic). So, politics inside the scientific community becomes partly responsible for the dominance of a particular theory. As seen from the last two experiments this 'theory dominance' affects the appraisal of evidence. Theory-ladenness is also viable for personal inclinations (could be out of epistemic or non-epistemic interest). For instance, the debate between Bohr and Einstein on quantum mechanism is basically about the differences in their world view (metaphysical), which in the strict definition of value-free science is often considered as non-epistemic values.

In Glymour's (1980) paper, he points out "Great changes in scientific opinion do not occur without the advocacy of influencial person"[22], he was referring to Eddington who was pivotal in getting approval for Einstein (German scientist) in the British scientific community. Moreover, we have seen this theory-ladenness had pervaded in the design of the experiment, interpretation of the experiment and qualification of experiment. We have seen in case of Gravitational wave detection the selection of methods for data analysis is chosen in such a way that it can validate the theory to be proven. The statistical methods used by the LIGO team and the Danish group were different and resulted in opposing conclusions. However, the LIGO team hasn't been able to show why their method is appropriate than the others. Even though we separate epistemic and pre-epistemic phase, the dominant theory (due to many factors like the reputation of the scientist, the success of the theory in past) essentially influence the appraisal of evidence. But that is not what is expected in a strict value-free science.

In a value-free science the appraisal of evidence must be confined to the particular experiment and its evidence. We have seen fundamentally it is not possible to do this within the limits of that particular experiment, without considering the other factors outside the experiment. To quote Collins (1993), "we have no reasons to think relativity anything but the truth. But it is a truth which came in to being as a result of how we should live our scientific life and how we should license our scientific observation. It was a truth brought about by agreement to agree about new things. It was not a truth forced on us by the inexorable logic of a set of crucial experiments (p: 54)."

[22] Glymour (Earman and Glymour, 1980) discusses how nationalistic tendencies affects science. Einstein being a German citizen, in the early stages didn't get much attention from the British scientific community. Prof Eddington and Frank Watson Dyson was instrumental in getting the attention of British scientific community.

2.8 Theory-ladenness and Value-ladenness

As is discussed in the first chapter, epistemic values are identified by the features of priority of evidence, objectivity and truth conduciveness. So, in order for science to be value-free attainment of these features is necessary. The first chapter discussed the unattainability of absolute conception of truth and the practical difficulties in objectivity. The second chapter discusses in detail, the process of setting priority of evidence in justification of theory and influence of values in the process.

The notion of priority is not a temporal one. The priority of evidence is used in the sense that evidence must be the justification of the theory to the extent the evidence can support the theory independently. It should not be the case that the theory determines the result which should be achieved in the experiment and evidence is manipulated accordingly (as seen in the Eddington expedition. The experimental result must be made without the influence of the theoretical value, and comparison of the independent experimental result with the theoretical value should decide the theory is justified or not .We have seen, there cannot be a necessary relation which can be established between evidence and theory. One of the main obstacles in the independent support of evidence for the theory is theory-ladenness. Evidence is theory-laden which in turn affects the design of the experiment, interpretation of the experiment, and the qualification of the observation to the evidential status.

So, in cases where the evidence is theory-laden and experimental values do not match perfectly, what would be the case of the theory? If it is a dominant theory (which might have been validated by many other experiments), it determines the evidence and the observations are manipulated accordingly. In other words, in such a case the experiments and the justification of the theory influence the evidence so that the experimental result will match the theoretical value. In case of Eddington expedition we have seen, the experimental data pointed to other alternatives other than Einstein' theory. But those observations were discarded and only the observations which was in match with Einstenian value was given the evidential status. Also, the theory-ladenness can influence the interpretation of observation in such a way that the methods used for analysis enables the observational value to come in accordance with the theoretical value. This essentially stems out from the lack of necessary relation between evidence and theory. Ideally speaking, in science, the justification of the theory must arise from the independent experiment and their result. But many times, this is not possible and the evidence and the entire experiment is influenced by the theory.

In theory-ladenness what makes it value-laden, is that not every theory gets the privilege of justification even if the evidence does not match perfectly. Let's call these theories to be dominant theory. Since this dominance of the theory can only be explained in terms of the subjective preference of scientist, this preference can have non-epistemic interests. As we have seen in the Eddington expedition and the gravitational wave detection experiment, in setting out the priority of evidence, the concept of objectivity (in terms of universal assent) is not fulfilled. Though within the scientific community, the decisions are not unequivocal, the consensus of the authority of scientific community stands for fulfilling the objectivity. Just as we have seen in the case of Eddington experiment, the experiment does not give a reasonable conclusive evidence for theory independently. In this case, the theory-ladenness enables to give the evidence by choosing and interpreting the observations in accordance with the theory. Which means that the subjective preference of the scientist which makes the theory dominant is also playing important role in the appraisal of evidence. So the non-epistemic, epistemic value associated with the subjective preference of the scientist influence the evidence. Hence the evidence is value-laden.

Not every belief is said to be knowledge in science, as knowledge must be the justified true belief. But in many cases, the belief of some peoples over the theory (which may or may not be true) essentially gets justified by the consensus in the scientific community even if the experimental observations are open to different possibilities. So, the dominance of the theory is essentially not epistemically acceptable. Another point, is the status of the scientist as seen in the Eddington expedition, the Astronomer Royal says Prof. Eddington has fully understood the theory and it is difficult for others to understand it. This essentially shows the reputation of the scientist can be influential. Thus, in experiments which are not reproducible easily like the Eddington experiment or the gravitational wave detection experiment the peoples who do the experiment become the authority of the experiment and there is not much room in questioning the methods and the data (as seen in gravitational wave detection experiment). This again is a violation of the concept of the objectivity and points towards the authoritarian nature in science which is not a feature of value-free science.

In the above-mentioned cases, the evidence is determined by the theory which also determines the methods and experiments so that it will suit the result. This is because of the confidence of a group of people who essentially becomes the justification of the theory (which may or may not be true later). These sorts of procedures put science in a position no better than dogmatism. This does not intend to say that any of theories is right or wrong. Rather in the process of setting out the priority of evidence for the justification of theory where we lack a necessary connection between the theory and evidence, the dominance of the theory, the consensus of the scientific community (authority), the reputation of the scientist, etc., become important and these can have non-epistemic aspects. In other words, the decisions regarding the appraisal of evidence cannot be made solely focusing on the aspects of truth and objectivity (these two are practically unattainable). The logical methodological steps envisioned in the value-free science is not enough to explain the decisions taken in this regard (in case of Eddington expedition, the theory-ladenness of evidence determined a conclusive result, similarly so in case of gravitational wave detection experiment). So, in proclaiming these theories to be valid (it's better to use successful), the non-epistemic element is present which enables to overcome the uncertainty associated with the justification of the theory by evidence. What makes this non-epistemic element to be sanctioned in the practice of science is the discretion of scientist and the consensus of the scientific community which sanctions the discretion of the scientist. So at least in cases like the ones we have discussed (which are practically difficult experiments), the appraisal of evidence and the justification of theory cannot be explained in terms of truth and objectivity, hence those decisions must be value-laden. This makes the evidence value-laden

The priority of evidence cannot be set out in a manner envisioned by the positivist nor by the Hypothetico-Deducto method. Popper was right in one aspect; the number of positive instances cannot guarantee the validity of the future instances. As Kuhn discusses 'in the structure of scientific revolutions', when a paradigm shift occurs, the social consensus determines which theories need to be retained and which needs to be discarded. As seen, the Eddington and gravitational wave detection experiment are not valid because it is justified in a reasonably transparent manner. To be gentle, science is no more than a democratic procedure as we lack a necessary connection between evidence, theory, observation and the priority of evidence is set according to the decisions of the majority and the authority. Similarly, the concept of objectivity cannot be said to be the case, where all the members of scientific community find something to be reasonable and assent to the same opinion (practically). In such a scenario there is no guarantee that personal preferences will not come into play because at the end of the day, what matters is the success of the theory. In the Eddington experiment, prior success of theory of relativity that influenced the experiment and the out-dation of theory (Newtonian theory in the Eddington expedition) all essentially depend on the discretion of the scientist to choose which theory needs to give importance in the experiment. This preference can influence the other aspects of the experiment. In the meeting following the expedition, there were people who were ardent admires of the Newtonian theory who vouched against the results for the

Newtonian theory. In similar epistemic situations, different opinions point out how the personal differences of the scientist matter. The cathode rays experiment and Eddington's experiment allows us to see the personal preference of the scientist and its influence on the appraisal of evidence.

So, there is no guarantee that can be given that science is objective in the practical field such that personal idiosyncrasies do not infiltrate. But crossing all these, once the theory is established to be true (as per the results of the experiment or in way in which is theory-laden as discussed in the second chapter), the theory becomes objective and the validity of theory is given on the basis of priority of evidence. From thereafter the concern of how the evidence matched the theory is no more a concern. The value-freeness of evidence lies in making the generation of evidence to be reasonable for the scientific community. Moreover in cases where there is no common opinion yet, there is a sanctioned result, which is only possible by the presence of non-epistemic values.

CONCLUSION

In this thesis, I have tried to analyse the notion of value-ladenness in science and to explicate the practical limitations in attaining the value-free ideal. These limitations essentially give scope for science to be value-laden. The thesis has mainly focused on the value-ladenness of evidence which is an essential aspect of the acceptance of a theory. None of the scientific theories so far can be said to be absolutely true and certain. There are no necessary relations between theory and evidence, between theory and truth. Every theory tries to correspond to the phenomenon (in terms of explanation or in terms of prediction). It would be quite unlikely to think that science can incorporate deduction as a means of inference. The problem of inductive risk and under-determination of the theory are always going to be the limitation of certainty of theories in science. In spite of having these limitations at the fundamental level, Science proceeds. Over the years science has made tremendous progress.

In this thesis, science is identified as practice. Value-free science is identified with features of objectivity and priority of evidence in appraisal of evidence (justification of theory). What essentially matters in science is the success. By all means every scientist tries to show their proposed theory is successful. The concept of success might be that the theory will be able to explain some unexplainable phenomenon or it might just be the experimental success. This means to succeed involves a lot of choices which are taken according to the preference of scientist and the epistemic situation. Further the scientist must be able to explain why these choices are reasonable and if it is convincing to others (scientific community). Then in the practical sense it is an objective epistemic value judgement. In practice, I would like to argue that this is how 'objectivity' in science can be identified. The last statement presupposes that if a judgement is reasonable then it will have a universal acceptance. But as we have seen the opinions of the scientific community are not equivocal even though reasonable objections are raised against the justification of choice (theory). Yet many times they are overlooked and the theory gets accepted. Probing to why there is no common opinion; it is because the choice which is made does not appear to be reasonable to all (scientific community). Especially in setting out the priority of evidence, when the scientific community does not have a common opinion, reasonable objections have been made. This is happening because there is no perfect match which has been established between the experimental result and theoretical values. This mismatch allows at least some members of the scientific community to think of other alternative theories (which might be already existing but outdated or new ones). But despite these mismatches, the evidence is manipulated to suit the theoretical value such that the experiment is made to produce the results matching with the theoretical value. Which is essentially giving importance to theory over experimental result. It is not necessarily the case that every observation is not in support of the theory. In that case those observations which are in accordance with theoretical value becomes evidence. Rest of the observations will be ignored. What is the basis of this discarding (which the scientist must be able to convince others)? If it is not convincing to others then it is no better than that particular scientist.

Similarly in case of the experiment which theory needs to be the dominant theory is at the discretion of the scientist and if it is not made convincing to others in terms of independent experimental results and analysis it is simply the personal preference of the scientist. But even though, it is not possible to convince every members of the scientific community, at times the reasonable objections against the justification of the theory is overlooked and the theory is sanctioned to be justified by the scientific community. From then the theory is considered to be objective and reasonable (based on the evidence) until it is disproved by other results. But this clearly is not an epistemically driven choice. In that case the choice is governed by non-epistemic value. Because it is the subjective preference (this could be due to many factors but not epistemic, the values which are playing at the pre-epistemic level can be considered as the reason for this theory preference) of the scientist which influence and overpower the epistemic feature (priority of evidence) through the theory-ladenness which gets justified (sanctioned) by the scientific community authority amidst the objections. This effectively allows the values influenced in the pre-epistemic state to influence the evidence. Which essentially makes the evidence value-laden, hence science also. These statements are discussed in light of particular experiments (the three experiments discussed in the thesis).

Science is a domain which needs to have a lot of choices. In concern with the generation of evidence also there are a lot of choices which needs to be made in the design of the experiment, methods for analysis of experimental result, in qualifying or discarding the observations as evidence, etc. Science does not possess a single methodology in all these stages. So it is open for the discretion of the scientist to choose and these different methods end up in different results (as we have seen in cathode ray experiment and detection of gravitational wave detection experiment). The problem of induction and under-determination of theory shows that there cannot be a necessary connection between the theory and evidence. So there is a limit which the epistemic features can lead us to, because by default an experiment cannot suggest which methods we should choose. Also, in interpreting evidence we cannot say that it essentially points to one single theory and there is no self -evident principle which can be shown to prove the appropriateness of the choice made. It is essentially the scientific community which decides the appropriateness or in-appropriateness. Success of every theory is temporal and not eternal. As we have seen in case of Gravitational wave detection, the LIGO team essentially becomes the authority which decides the appropriateness of the decisions (methods and the result) they made and their experimental data is not transparent (which essentially shows the authoritarian nature of science). There is uncertainty which is associated with every theory. No evidence can prove a theory conclusive and certain. So in light of all the above mentioned statements I would like to argue that 'priority of evidence' which is a necessary feature of value-free science cannot be set out independent of the theory in the practical domain. There is a leap of faith which every scientist necessarily has to take over the uncertainty, this leap of faith cannot be explained by the epistemic values and hence it must be non-epistemic. By keeping that leap of faith open for criticism and transparent, one can make it more reasonable.

There are a lot of other values which influence the practice of science which are not given importance in this thesis. For example: especially in experiments which are hard to replicate and when not everyone can afford to have experiments (like gravitational wave detection), the privileged group (who are in possession of that experiment) becomes the authority of the experiment. Then the transparency of the results and experiment essentially operates on 'trust', in that the results are transparent and not manipulated. So in getting the consensus of the scientific community and for other people to have confidence on the evidence of the theory 'trust' which is a non-epistemic factor is also a part. Similarly deeper analysis of the methods used for experiment, data analysis can answer more questions in the science and value discourse.

BIBLIOGRAPHY

Achinstein, Peter. 2001. The Book of Evidence. Oxford: Oxford University Press.

Basu, Prajit K. 2003. "Theory-ladenness of Evidence: a Case Study from History of Chemistry." Studies in History and Philosophy of Science Part A 34, no. 2: 351-368.

Betz, Gregor. 2013. "In Defence of the Value Free Ideal." European Journal for Philosophy of Science 3, no. 2: 207-220.

Brooks, Michael. 2018. “Exclusive: Grave Doubts Over LIGO’s Discovery of Gravitational Waves.” New Scientist: Physics, October 31, 2018. https://www.newscientist.com/article/mg24032022-600-exclusive-grave-doubts-over-ligos-discovery-of-gravitational-waves/

Brown, Matthew J. 2013. "Values in Science Beyond Underdetermination and Inductive risk." Philosophy of Science 80, no. 5: 829-839.

Carrier, Martin. 2011. "Underdetermination as an Epistemological Test Tube: Expounding Hidden Values of the Scientific Community". Synthese 180, no. 2: 189-204.

Coles, Peter. 2001. "Einstein, Eddington and the 1919 Eclipse." https://cds.cern.ch/record/489163/files/0102462.pdf

Collins, Harry M. and Trevor Pinch. 1993. The Golem: What you Should Know About Science. Cambridge: Cambridge University Press.

Cowen, Ron. 2019. Gravity’s Century: From Einstein’s Eclipse to Images of Black Holes, pp: 60-66. Harvard: Harvard University Press.

Daston, Lorraine and Peter Galison. 2007. Objectivity. Massachusetts: The MIT Press.

Earman, John, and Clark Glymour. 1980. "Relativity and Eclipses: The British Eclipse Expeditions of 1919 and their Predecessors." Historical Studies in the Physical Sciences 11, no. 1: 49-85.

Elliott, Kevin C. and Daniel J. McKaughan. 2014. "Non-Epistemic Values and the Multiple Goals of Science." Philosophy of Science 81, no. 1: 1-21.

Elliott, Kevin Christopher. 2017. A Tapestry of Values: An Introduction to Values in Science, pp. 1-19. Oxford: Oxford University Press.

Galison, Peter. 1987. How Experiments End. Chicago: University of Chicago Press.

Jayard, S. Stephen. 2012. Towards a Theory of Rationality in Science: A Plea for Reasonableness. New Delhi: Global Vision Publishing House.

Kincaid, Harold, John Dupré, and Alison Wylie, eds. 2007. Value-Free Science: Ideals and Illusions? Oxford University Press.

Kitcher, Philip. 2003. Science, truth, and democracy. Oxford: Oxford University Press.

Kordig, Carl R. 1971. "The Theory-ladenness of Observation." In The Justification of Scientific Change, pp. 1-33. Springer, Dordrecht.

Kragh, Helge. 2001. Quantum Generations: A History of Physics in the Twentieth Century. Universities Press.

Lacey, Hugh. 1999. Is Science Value Free?: Values and Scientific Understanding. New York: Routledge.

Lacey, Hugh. 2017. "Distinguishing Between Cognitive and Social Values." In Current Controversies in Values and Science, pp. 15-30. New York: Routledge.

Laudan, Larry. 1981. "A Confutation of Convergent Realism." Philosophy of science 48, no. 1:19-49.

Laudan, Larry. 2004. "The Epistemic, the Cognitive, and the Social." In Science, Values, and Objectivity, pp. 14-23. Pittsburg: Pittsburg University Press.

LIGO Scientific Collaboration. "Blind Injection" Stress-Tests LIGO and Virgo's Search for Gravitational Waves." https://www.ligo.org/news/blind-injection.php

Longino, Helen E. 1979. "Evidence and Hypothesis: An Analysis of Evidential Relations." Philosophy of Science 46, no. 1: 35-56.

Malik, Saira. 2017. "Observation Versus Experiment: An Adequate Framework for Analysing Scientific Experimentation?" Journal for General Philosophy of Science 48, no. 1: 71-95.

Mattingly, James. 2001. "The Replication of Hertz's Cathode Ray Experiments." Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics 32, no. 1: 53-75.

McMullin, Ernan. 1970. "The History and Philosophy of Science: A Taxonomy." Historical and Philosophical Perspectives of Science, Volume (5), pp. 12-67. Minneapolis: University of Minnesota Press.

McMullin, Ernan. 1984. "A Case for Scientific Realism." In Scientific Realism, pp. 8-40. California: University of California Press.

Narlikar, Jayant V. 2015. "The Early Days of General Relativity." Current Science: 2214-2219.

Nola, Robert. 1990. "Some Observations on a Popperian Experiment Concerning Observation." Journal for General Philosophy of Science 21, no. 2: 329-346.

Ouellette, Jennifer. 2018. “Danish Physicists Claim to Cast Doubt on Detection of Gravitational Waves.” Ars Technica: Science, November 1, 2018. https://arstechnica.com/science/2018/10/danish-physicists-claim-to-cast-doubt-on-detection-of-gravitational-waves/

Perovic, Slobodan. 2001. "Theory-ladenness of Observation in the Experimental Context." http://philsci-archive.pitt.edu/id/eprint/8914

physicsphilosophymath. 2018. “Do you Denounce the Practice of “hand-tuning” LIGO data in Peer-reviewed, Scientific Journals?” Physics Philosophy Science (blog). https://physicsphilosophy.science.blog/2018/11/03/do-you-denounce-the-practice-of-hand-tuning-ligo-data-in-peer-reviewed-scientific-journals/

Praveen, P. A. 2017. Gravitational Waves Explained. eInk Solutions.

Psillos, Stathis. 2005. “Underdetermination Thesis, Duhem- Quine Thesis.” Encyclopedia of Philosophy. http://users.uoa.gr/~psillos/PapersI/55-Encyclopedia%20of%20Philosophy-Vol9%20Underdetetmination.pdf

Rooney, Phyllis. 2017. “The Boderlands Between Epistemic and Non-Epistemic Values.” In Current Controversies in Values and Science, pp. 31-45. New York: Routledge.

Rudner, Richard. 1953. "The Scientist qua Scientist Makes Value Judgments." Philosophy of science 20, no. 1: 1-6.

Salmon, Wesley C. 1967. The Foundations of Scientific Inference. Pittsburg: University of Pittsburgh Press.

Schindler, Samuel. 2011. "Bogen and Woodward’s Data-phenomena Distinction, forms of Theory-ladenness, and the Reliability of Data." Synthese 182, no. 1: 39-55.

Shapere, Dudley. 1982. "The Concept of Observation in Science and Philosophy." Philosophy of Science 49, no. 4: 485-525.

Solomon, Miriam. 2012. "Socially Responsible Science and the Unity of Values." Perspectives on Science 20, no. 3: 331-338.

Steel, Daniel. 2010. "Epistemic Values and the Argument From Inductive Risk." Philosophy of Science 77, no. 1: 14-34.

Thomson, George Paget. 1970. "An Unfortunate Experiment, Hertz and the Nature of Cathode Rays." Notes and Records of the Royal Society of London 25, no. 2: 237-242.

Winsberg, Eric. 2012. "Values and Uncertainties in the Predictions of Global Climate Models." Kennedy Institute of Ethics Journal 22, no. 2: 111-137.

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Value-ladenness of Evidence in Science

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