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An Analysis of Thomas Kuhn's Concept of Scientific Revolution

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Abstract
This article focuses on an analysis of Thomas Kuhn's concept of scientific revolution. Kuhn argues that science develops through revolution. The fundamental questions are: What does Kuhn mean by scientific revolution? What are the activities of scientists during scientific revolution? What are the essential features or characters of revolutionary change? What is the relationship between scientific revolution and scientific development? What are the strengths and weaknesses of Kuhn's account of scientific revolution? These and other related issues are the central focus of this article. The researcher examines critically Kuhn's idea of scientific revolution and exposes both the strengths and weaknesses of his idea. Despite the fact that Kuhn made remarkable contributions towards the growth of knowledge both in philosophy of science and other disciplines through his unique idea of scientific revolution, some of his claims are very controversial, and thus are subjected to severe criticisms. Obviously, the researcher agrees with Kuhn that science basically develops through revolution which brings about non-linear or discontinuous fashion of scientific development. However, the researcher argues that though scientific revolution may involve reconstruction or even total destruction of earlier views, Kuhn seems to over-emphasize the issue of discontinuity in the conception of scientific revolution, and undermines the impact or contribution of earlier theories on new ones. Despite the shortcomings of Kuhn's idea, his unique account of scientific revolution gives a good insight towards understanding the nature of scientific development, and as such, his account of scientific revolution deserves commendations.

Key Words: *Science, Revolution, Development, Non-Cumulative*

INTRODUCTION

Thomas Kuhn, a great historian and philosopher of science, articulated his idea of scientific revolution in his famous book *The Structure of Scientific Revolutions*. His concept of scientific revolution is quite very unique, and it is revolutionary in nature. Such revolutionary idea distinguishes Kuhn as an outstanding contemporary philosopher of science. He presents a new way of conceiving scientific development through his unique idea of scientific revolution. This differs remarkably from the claims of logical positivists on scientific development. His novel idea of scientific revolution became the center of attraction for philosophers of science in the contemporary era. Logical positivists conceive scientific development as a linear as well as continuous activity such that a new scientific theory is nothing but an extension of the older one. This was the dominant perspective in the contemporary philosophy of science before the emergence of Thomas Kuhn who completely rejected this perspective. Kuhn's novel idea of scientific revolution presents a discontinuous version of scientific development such that the new scientific theory that emerges in the course of scientific revolution is totally different from the old one. Being a historian of science, he places serious emphasis on the historical context of scientific discoveries. Kuhn's scientific revolution is opposed to what Kuhn describes as 'normal science' which has to do with the daily as well as dogmatic activities of scientists characterized by complete acceptance as well as fidelity to the prevailing paradigm. However, the analysis of Kuhn's normal science is outside the scope of this article. The focus of this article is the analysis of Thomas Kuhn's concept of scientific revolution. The fundamental questions that are very necessary in this discourse include: What does Kuhn mean by scientific revolution? What are the activities of scientists during scientific revolution? What are the essential features or characters of revolutionary change? Has scientific revolution any relationship with scientific development? What are the strengths and weaknesses of Kuhn's account of scientific revolution? These questions and other related issues are scholarly very pertinent in the discourse on Kuhn's concept of scientific revolution, and as such they are to be given required attention in this article.

This article is divided into four major parts. The first part focuses on the clarification of the key terminologies. The second part examines the meaning of Kuhn's scientific revolution. The third part focuses on the character or nature of revolutionary change. The fourth part is the evaluation and conclusion of the article.

Conceptual Clarifications:

Concept of Revolution

The term 'Revolution' is one of the key terminologies in this article. Hence, it is scholarly necessary to clarify the concept of revolution in general before examining what scientific revolution is all about. Etymologically, the term 'revolution' was derived from the Latin word 'revolutio' meaning 'a turn around'. It is a total or radical change. It is a basic change that takes place in the organizational structure of things in a relatively short period of time. Whenever the term 'revolution' is mentioned, what readily comes to mind is political revolution. According to Gallin (1967):

> The concept of revolution, although subject to ever-widening application in popular usage and in the social sciences, refers properly to a sudden or abrupt departure from a main line of political development. Most changes in the social, economic, intellectual, or religious orders are actually "evolutions", since they represent transitions that are typically gradual and more permanent. In the political order, revolution connotes the use of force in effecting the desired change... (p.450)

Obviously, Gallin (1967) is specifically referring to political revolution, and he conceives revolution fundamentally from political perspective. It ought to be noted that the term 'revolution' has varied meanings and varied applications, and as such cannot be limited to the political dimension of life. It can mean change in political organization or the overthrow of a government. It can mean the motion of a body such as a planet in a curved line or orbit. It can mean the act of revolving or turning round on an axis. Also, it can mean the overthrow or replacement of one scientific theory by another scientific theory etc. Revolution can take place in different dimensions of life. Thus, there are many types of revolution such as political revolution, proletarian or communist revolution, industrial revolution, earth's revolution, scientific revolution etc.

Generally, revolution involves rapid change from one system or structure to another. Nickles (2011) examines the major conceptions of revolution, and observes that all involve rapid change from one phase or structured system to another. Identifying and examining the major conceptions of revolution, Nickles (2011) states:

> (1) revolution as simply turning, e.g. revolving; (2) revolution as overturning; and (3) revolution as a great leap forward into new, previously uncharted territory....(1) The turning may be either revolution as in a turning wheel or a turning away from one path or direction to another....(2)The overturning can be either with or

> without replacement. In the former case, the replacement can be either a turn away from the past toward an imagined future or a return to a (supposed) past, overlapping trope.... (3) The leap forward can be either a rapid but continuous, 'evolutionary' development or so momentous as to constitute a sharp break with the past but nevertheless progressive, that is, a kind of extension of an existing enterprise into new intellectual or practical terrain.

From the foregoing, it is obvious that revolution fundamentally has to do with sudden change, and it initiates something which is different from the present condition of things. As already demonstrated above, revolution can occur in different dimensions of human endeavor. However, our concern in this article is scientific revolution.

Concept of Scientific Revolution

The previous section examines the concept of revolution in general. In this section, attention is focused on scientific revolution. It is obvious that scientific revolution is the type of revolution that takes place in the scientific world. It has to do with the replacement or the overthrow of the existing scientific theory or what Kuhn calls 'paradigm' with a new one. The history of science is replete with the replacement of one scientific theory with another one. Thus, there have been many scientific revolutions in the scientific world such as Copernican revolution, Darwinian revolution, Newtonian revolution, Einsteinian revolution etc. I. B. Cohen as cited by Nickles (2011) identified four necessary conditions for the correct attribution of a scientific revolution. In the first place, the scientists concerned must see themselves as revolutionaries. Secondly, it must be recognized by histories as a revolution. Thirdly, subsequent philosophers as well as historians must recognize it as such. Fourthly, subsequent scientists in that area must recognize it as a revolution. With the above conditions, he excludes as revolutionaries those who had insufficient impact on the field to sustain the judgment of history. He seems to have laid too much emphasis on the intentions of the generators of scientific revolution.

Philosophers of science have different conceptions of scientific revolution. Karl Popper sees scientific revolution as a radical activity, but which must preserve the success of the previous scientific theories. In the words of Popper (1987) "...scientific revolution, however radical, cannot really break with tradition, since it must preserve the success of its predecessors. This is why scientific revolutions are rational. By this I do not mean, of course, that the great scientists who make the revolutions are, or ought to be, wholly rational beings." (p.106) Thus, Popper insists that progress in science, though revolutionary must be able to explain the success of its predecessors. Thomas Kuhn's concept of scientific revolution is different from that of Popper. Kuhn (1970c) describes scientific revolution as "non-cumulative developmental episodes in which an older paradigm is replaced in whole or in part by an incompatible new one." (p.92) Kuhn's idea of scientific revolution is quite very unique, and it is the central focus of this article.

THOMAS KUHN'S CONCEPT OF SCIENTIFIC REVOLUTION

Thomas Kuhn's concept of scientific revolution is very remarkable in the history of philosophy of science. It brought about a version of scientific development that differs completely from logical positivists' cumulative fashion of scientific development. Analysing the logical positivists' linear conception of scientific progress, Shapere (1987) states that logical positivists' view of scientific development is "a process of development-by-accumulation (and systematization), characterized by meaning-invariance..." (p.56) This entails that science progresses by continuous addition of new ideas to the already existing one. Logical positivists did not pay attention to the history of science in their conception of scientific development, and as such their approach to science is ahistorical. Hence, Bird (2018) notes that "In *The Structure of Scientific Revolutions* Kuhn paints a picture of the development of science quite unlike any that had gone before." (para. 8) Kuhn's idea of scientific development is enshrined in his concept of scientific revolution. His account of scientific revolution is historically oriented. Thus, Kuhn (1970c) states: "History, if viewed as a repository for more than anecdote or chronology, could produce a decisive transformation in the image of science by which we are now possessed." (p.1) His concept of scientific revolution emerged from the historical record of research activity. He insists that science develops through revolution which comes up after a long period of normal science. The question that is very pertinent at this juncture is this: What actually does Kuhn mean by scientific revolution?

Kuhn (1970c) describes scientific revolutions as "non-cumulative developmental episodes in which an older paradigm is replaced in whole or in part by an incompatible new one." (. p.92.) For a better appreciation of Kuhn's description of scientific revolution, there is need to briefly analyse the prominent terms in the above description. Such prominent terms include: 'non-cumulative', 'developmental' and 'incompatible'. The term 'non-cumulative', implies that the new scientific tradition that emerges after scientific revolution is not an extension of the old one. By the term, 'developmental', Kuhn emphasizes that science develops through revolution. Hence, the transition from paradigm in crisis to a new one through revolution is the actual developmental pattern of science. The term, 'incompatible' entails that the new scientific tradition that emerges after scientific revolution is different from the old one.

Kuhn observes that revolutions exist both in political development and scientific development. Articulating the similarity between what inaugurates political revolution and that which initiates scientific revolution, Kuhn (1970c) states:

> Political revolutions are inaugurated by a growing sense, often restricted to a segment of the political community, that existing institutions have ceased adequately to meet the problems posed by an environment that they have in part created. In much the same way, scientific revolutions are inaugurated by a growing sense, again often restricted to a narrow subdivision of the scientific community that an existing paradigm has ceased to function adequately in the exploration of an aspect of nature to which that paradigm itself had previously led the way. In both political and scientific development, the sense of malfunction that can lead to crisis is prerequisite to revolution. (p.92)

Thus, in both political revolution and scientific revolution, there are always cases of malfunctioning of the current system or theory which has failed to meet adequately the problems posed by the environment. This malfunctional system triggers crisis which may end up with revolution. He argues that such parallelism holds for major paradigm changes like those attributable to Copernicus and Lavoisier. Political revolutions change political institutions, and necessitate the partial relinquishment of one set of institutions in favour of another. In a similar way, scientific revolution changes the scientific conceptual worldview. It is crisis that attenuates the role of political institutions as it attenuates the role of scientific paradigms. In the case of political revolution, as the crisis deepens, many individuals embark on the reconstruction of society in a new institutional framework. At this point, the society is divided into opposing camps, one camp defending the old institutional constellation, the other camp seeking for a new one. The same thing is applicable to scientific revolution. Revolutions play important role in the evolution of political institutions as well as scientific paradigms. Kuhn claims that both in political revolution and scientific revolution, the assent of the relevant community as well as the technique of persuasive argumentation play vital role in the choice of a new system or theory.

From the foregoing, it is obvious that Kuhn describes the transition from the scientific theory in crisis to a new and different one as scientific revolution. Instances of major scientific revolutions are the major turning points in scientific development associated with Copernicus, Newton, Darwin, Lavoisier, Einstein etc. Thus, one can talk of Copernican revolution, Newtonian revolution, Einsteinian revolution etc. Commenting on these revolutions, Kuhn (1970c) states:

> Each of them necessitated the community's rejection of one time-honoured scientific theory in favour of another incompatible with it. Each produced a consequent shift in the problems available for scientific scrutiny and in the standards by which the profession determined what should count as an admissible problem or as a legitimate problem-solution. And each transformed the scientific imagination in ways that we shall ultimately need to describe as a transformation of the world within which scientific work was done. Such changes, together with the controversies that almost always accompany them, are defining characteristics of scientific revolution. (p.6.)

It is scholarly necessary at this juncture to substantiate Kuhn's idea of scientific revolution with his description of Copernican revolution. He notes that Nicholas Copernicus transferred to the sun many astronomical functions attributed to the earth in Ptolemaic astronomy. Ptolemaic astronomy was geocentric, while Copernican astronomy was heliocentric. Thus, Kuhn (1970a) observes that Copernican revolution "was a revolution in ideas, a transformation in man's conception of the universe and of his own relation to it." (p.1) It transformed the way scientists conceive the universe, and ushered in a new approach to astronomy, which is very different from Ptolemaic astronomy. In the words of Kuhn (1970a): "Copernicus' innovation first destroyed the traditional explanation of planetary motion and then, as modified by Kepler, suggested a radically new approach to celestial physics." (p.245.) It is a landmark in the history of astronomy and scientific development. Thus, Copernican revolution is "an epochal turning point in the intellectual development of western man." (Kuhn, 1970a, p.1) This is as a result of the fact that it involves a reconstruction of Ptolemaic astronomy. The above illustration portrays that the new theory that emerges after scientific revolution is not just an increment to what is already known. It involves a revolutionary process that requires the reconstruction and the re-evaluation of the prior theory. Revolution "always involves the rejection and replacement of a framework or some of its integral parts." (Kuhn 1970b, p.242) This sort of change characterizes scientific development.

During Scientific revolution, the prevailing scientific theory is under attack, and thus subject to change. It is more often than not preceded by an anomaly in the prevailing paradigm, which on its accumulation, leads to crisis. Kuhn argues that the transition from one paradigm to another one via scientific revolution is not a cumulative process. Rather, scientific revolution reconstructs the commitments of scientists. According to Kuhn (1970c):

> A revolution is for me a special sort of change involving a certain sort of reconstruction of group commitments. But it need not be a large change, nor need it seem revolutionary to those outside a single community, consisting perhaps of fewer than twenty-five people. It is just because this type of change, little recognized or discussed in the literature of the philosophy of science, occurs so

> regularly on this smaller scale that revolutionary, as against cumulative, change so badly needs to be understood. (pp. 180-181)

Kuhn often uses the terms 'scientific revolution' and 'extraordinary science' interchangeably, and both entail 'non-normal science'. Scientific revolution brings about rearrangement of objects in different scientific theories, which inevitably leads to communication failure between the proponents of different scientific theories. Elaborating on this, Kuhn (1970c) states:

> One central aspect of any revolution is, then, that some of the similarity relations change. Objects that were grouped in the same set before are grouped in different ones afterward and vice versa. Think of the sun, moon, mars and earth before and after Copernicus; of free fall, pendular, and planetary motion before and after Galileo; or of salts, alloys, and sulphur – iron filing mix before and after Dalton. Since most objects within even the altered sets continue to be grouped together, the names of the sets are usually preserved. Nevertheless, the transfer of a subset is ordinarily part of a critical change in the network of interrelations among them.... Not surprisingly, therefore, when such redistributions occur, two men whose discourse had previously proceeded in apparently full understanding may suddenly find themselves responding to the same stimulus in incompatible descriptions and generalization. (pp. 200-201)

Also, Kuhn argues that the new paradigm that emerges after scientific revolution must conflict with the old one. Thus, the paradigm that discloses anomaly and the one that later renders such anomaly law-like must conflict with each other. The new paradigm that emerges after scientific revolution should in a way permit predictors that are different from those derived from its predecessor. This is as a result of the fact that the new scientific theory emerges with some destructive changes in the old one. Kuhn (1970c) argues: "It is hard to see how new theories could arise without these destructive changes in beliefs about nature. Though logical inclusiveness remains a permissible view of the relation between successive scientific theories, it is a historical implausibility." (p.98) scientific revolution changes the meaning of certain established and familiar concepts in a theory, and thus brings about conceptual transformation. Kuhn illustrates this with the transition from Newtonian to Einsteinian mechanics, and argues that the transition from Newtonian to Einsteinian mechanics portrays scientific revolution as a displacement of the conceptual network through which scientists conceive the world. Successive theories say different things about the universe. They differ substantially. As a result of these differences, Kuhn argues that the reception of a new paradigm after scientific revolution involves a redefinition of the corresponding science. Thus, "all revolution involve, among other things, the abandonment of generalizations the force of which had previously been in some part that of tautologies." (Kuhn, 1970c, pp.183-184.)

Kuhn further claims that the scientific paradigm that emerges after scientific revolution is both incompatible and incommensurable with the old one. Obviously, the issues of incompatibility and incommensurability of successive scientific paradigms are controversial issues in philosophy of science. Thus, when paradigm changes as a result of scientific revolution, there are always significant shifts in the criteria that determine the legitimacy both of problems and of proposed solutions. This is because paradigm incorporates theory, methods and standards in an inextricable mixture. Thus, scientific revolution brings about changes in the practice of scientists. This led Kuhn to liken the scientist who embraces a new paradigm to someone putting on inverting lenses. In his words:

> What occurs during a scientific revolution is not fully reducible to a reinterpretation of individual and stable data...Rather than being an interpreter, the scientist who embraces a new paradigm is like the man wearing inverting lenses. Confronting the same constellation of objects as before and knowing that he does so, he nevertheless finds them transformed through and through in many of their details. (Kuhn, 1965, p.86)

It becomes obvious from the foregoing that scientific revolution changes completely the conceptual world-view of scientists within a scientific community.

Scientific Revolution as Change of Scientific World View

Scientific revolution has serious effect on the conceptual worldview of scientists. It ought to be noted that scientific revolution and its consequent paradigm shift brings about changes in the conceptual worldviews of scientists. Thus, after revolution, scientists see the world differently. According to Kuhn (1970c):

> Led by a new paradigm, scientists adopt new instruments and look in new places. Even more importantly, during revolutions scientists see new and different things when looking with familiar instruments in places they have looked before. It is rather as if the professional community had been suddenly transported to another planet where familiar objects are seen in a different light and are joined by unfamiliar ones as well. Of course, nothing of quite that sort does occur: there is no geographical transplantation; outside the laboratory, everyday affairs usually continue as before. Nevertheless, paradigm changes do cause scientists to see the world of their research- engagement differently. In so far as their only recourse to that world is through what they see and do, we may want to say that after a revolution scientists are responding to a different world. (p.111.)

Kuhn claims that scientific revolution brings about alterations in scientists' worldview such that what were 'ducks' in the scientists' world prior to revolution are 'rabbits' afterwards. At the time of revolution, the normal scientific tradition changes as well as the scientist's perception of his environment. Kuhn likens the perceptual transformation as well as the conversion experience of scientists after scientific revolution to 'gestalt switch'. In his words,

> In their most usual form, of course, gestalt experiments illustrate only the nature of perceptual transformation ... An experimental subject who puts on goggles fitted with inverting lenses initially sees the entire world upside down. At the start his perceptual apparatus functions as it had been trained to function in the absence of the goggles, and the result is extreme disorientation, an acute personal crisis. But after the subject has begun to learn to deal with his new world, his entire visual field flips over, usually after an intervening period in which vision is simply confused. Thereafter, objects are again seen as they had been before the goggles were put on. The assimilation of a previously anomalous visual field has reacted upon and changes the field itself. Literally as well as metaphorically, the man accustomed to inverting lenses has undergone a revolutionary transformation of vision. (Kuhn, 1970c, p.112)

Thus, the term 'gestalt switch', for Kuhn, characterizes the conceptual transformation during revolution because the interval in which the conceptual vocabulary shifts is usually short, and some scientists do experience gestalt switches during that interval. Hence, shift of vision occurs after scientific revolution such that scientists perceive things or phenomena differently. However, Kuhn claims that changes that occur during scientific revolution are not total, because the actual world has not changed and some of the laboratory instruments are still the same. In his words:

> After a scientific revolution many old measurements and manipulations become irrelevant and are replaced by others instead. One does not apply all the same tests to oxygen as to dephlogisticated air. But changes of this sort are never total. Whatever he may then see, the scientist after a revolution is still looking at the same world. Furthermore, though he may previously have employed them differently, much of his language and most of his laboratory instruments are still the same as they were before. As a result, post-revolutionary science invariably includes many of the same manipulations, performed with the same instruments and described in the same terms, as its prerevolutionary predecessor. If these enduring manipulations have been changed at all, the change must lie either in their relation to the paradigm or in their concrete results. (Kuhn, 1970c, pp.129-130)

Nevertheless, as a result of criticisms from other scholars, Kuhn later limited the change that occurs during scientific revolution to some part of the network of similarity relations that gives structure to the class of intended applications. He further argues that scientific revolution brings about theory change, which is accompanied by a change in the ways in which terms attach to nature. Thus, Kuhn (2000) maintains:

> Theory change, in particular, is accompanied by a change in some of the relevant metaphors and in the corresponding parts of the network of similarities through which terms attach to nature. The earth was like Mars (and was thus a planet) after Copernicus, but the two were in different families before. Salt-in-water belonged to the family of chemical compounds before Dalton, to that of physical mixtures afterwards. (pp.203-204)

It thus becomes obvious that after a revolution, scientists work in a different scientific worldview, and communication across the revolutionary divide is unavoidably partial.

THE CHARACTER OR NATURE OF REVOLUTIONARY CHANGE

Kuhn's idea of scientific revolution articulated in his book *The Structure of Scientific Revolution*, underwent significant shifts. This is as a result of his attempt to rethink and extend his concept of revolutionary change. In his later book, *The Road since Structure,* Kuhn examines the character of revolutionary change, and gives a philosophical analysis of the historical scientific changes concerning the theories of motion, the voltaic cell, and black-body radiation. These scientific changes share certain characteristics which are the essential characteristics of revolutionary change. Firstly, Kuhn describes revolutionary change as that which is different from normal change. According to him:

> Revolutionary change is defined in part by its difference from normal change, and normal change is, as already indicated, the sort that results in growth, accretion, and cumulative addition to what was known before. Scientific laws, for example, are usually products of

> this normal process.... Revolutionary changes are different and far more problematic. They involve discoveries that cannot be accommodated within the concept in use before they were made. In order to make or to assimilate such a discovery one must alter the way one thinks about and describes some range of natural phenomena. (Kuhn, 2000, pp.14-15)

At this juncture, Kuhn examines the historical scientific changes in order to bring out very clearly the essential characteristics of revolutionary change. He argues that the concepts of force and mass as used in Newton's law of motion differed from those in use before Newton's law of motion and "the law itself was essential to their definition." (Kuhn, 2000, p.15) Thus, it becomes obvious that change in the meaning of scientific concepts is one of the essential characteristics of revolutionary change. Kuhn gives a second example with the transition from Ptolemaic to Copernican astronomy. According to him,

> Before it occurred, the sun and moon were planets, the earth was not. After it, the earth was a planet, like mars and Jupiter; the sun was a star; and the moon was a new sort of body, a satellite. Changes of that sort were not simply corrections of individual mistakes embedded in the Ptolemaic system. (Kuhn, 2000, p.15)

This transition involves changes in laws of nature, and also changes in the criteria by which some terms in those laws attach to nature. Hence, it becomes obvious from Kuhn's specification that changes in the laws of nature as well as changes in the criteria by which certain terms in the laws attach to nature are also the essential characteristics of revolutionary change.

Thus, as a result of these changes, Kuhn insists that scientific development cannot be cumulative. One cannot describe the new theory in the vocabulary of the old one or vice versa. For instance, the term 'planet' was used in Ptolemaic astronomy and Copernican astronomy, but the two mean different things in the theories. The planets revolve around the earth in Ptolemaic astronomy, but in Copernican astronomy, they revolve around the sun.

Kuhn gives another example of revolutionary change with the transition from Aristotelian to Newtonian physics. He initially approached Aristotle's physics through Newtonian mechanics which he read previously. In such approach, Aristotle appeared to Kuhn as a bad physical scientist that is ignorant of mechanics. His views on motion seemed erroneous. Later Kuhn realized that his perception of Aristotle was completely wrong, and discovered that Aristotelian mechanics should not be approached through Newtonian perspective. He notes that historians reading old scientific texts encounter passages that seem to make no sense, and observes that the apparent textual anomalies are products of misreading. This is due to the fact that the "historian has been understanding words and phrases in the text as he or she would if they had occurred in contemporary discourse." (Kuhn, 2000, p. 59) Some interrelated terms are used differently. Kuhn discovered that the major problem in reading Aristotle's physics is that the term translated as 'motion' in his text "refers not simply to change of position but to all changes characterized by two end points." (Kuhn, 2000, p.60) This involves more than mere changes in the use of terms, thus illustrating what Kuhn calls 'incommensurability' of scientific theories. This was illustrated with the lexicon of Newtonian mechanics, especially the interrelated terms 'force', 'mass' and 'weight'; and argues that the terms, 'force', 'mass' and 'weight' in their Newtonian senses can only be acquired together with the theory itself. Hence, "as Newtonians use 'force', not all motions signify the presence of its referent, and examples which display the distinction between forced and force-free motions are therefore required." (Kuhn, 2000, p.68) Kuhn observes that the Newtonian use of the three terms is quantitative and this alters their individual uses.

Hence, the transition from Aristotelian to Newtonian mechanics alters the meaning of certain terms, and they attach to nature differently. This sort of difference between Aristotelian and Newtonian mechanics characterizes revolutionary change. Thus, Kuhn (2000) states:

> Though scientific revolutions leave much piecemeal mopping up to do, the central change cannot be experienced piecemeal, one step at a time. Instead, it involves some relatively sudden and unstructured transformation in which some part of the flux of experience sorts itself out differently and displays patterns that were not visible before. (p.17)

Kuhn gives another instance of revolutionary change with Max Planck's work on the black-body problem. The black-body problem is "the problem of black radiation." (Kuhn, 1978, p.1) Planck solved the black-body radiation problem firstly in 1900 using the classical method developed by Ludwig Boltzmann. The problem was "to explain the way in which the color of a heated body changes in temperature." (Kuhn, 2000, p.26) However, 6 years later, crucial error was discovered in Planck's derivation, and other physicists argued against Planck's work. This made Kuhn to insist that revolution is always accompanied by changes in the meaning of certain terms like 'motion' or 'cell'.

Furthermore, revolutionary change is associated with 'meaning change', that is variation in the meaning of certain concepts, and change in the way their referents are determined. Kuhn argues that normal science may also alter the way in which concepts attach to nature; but what characterizes revolutions is not simple change in the way referents are determined, but change of a still more restricted sort. However, Kuhn did not offer full solution on how best to characterize that restricted sort of change, but only attempted it. In his words:

> But roughly speaking, the distinctive character of revolutionary change in language is that it alters not only the criteria by which terms attach to nature but also, massively, the set of objects or situation to which those terms attach. What had been paradigmatic examples of motion for Aristotle-acorn to oak or sickness to health – were not motions at all for Newton. In the transition, a natural family ceased to be natural; its members were redistributed among pre-existing sets; and only one of them continued to bear the old name. (Kuhn, 2000, p.31)

Thus, what characterizes revolutions is change in the taxonomic categories of scientific theory. Such change entails an adjustment of the way in which given objects and situations are distributed among pre-existing categories. Revolution alters the nature of scientific language. Elaborating further on the nature of revolutionary change, Kuhn (2000) states:

> If I am right, the central characteristic of scientific revolutions is that they alter the knowledge of nature that is intrinsic to the language itself and that is thus prior to anything quite describable as description or generalization, scientific or everyday...Violation or distortion of a previously unproblematic scientific language is the touchstone for revolutionary change. (p.32)

Hence, revolutionary change entails change in meaning and language, and thus becomes the issue of semantics. Revolution, for Kuhn, displaces some of the basic concepts in the existing scientific theory.

EVALUATION

Scholarly attention has been given to Kuhn's concept of scientific revolution in this article. As it is obvious from the discourse, Kuhn claims that revolution is the actual developmental pattern of mature science. This section centers on a critical assessment of Kuhn's idea in order to ascertain its strengths and weaknesses.

Obviously, Kuhn revolutionized philosophy of science through his unique idea of scientific revolution. Thus, Okasha (2002) observes that Kuhn's idea of scientific revolution is the "most influential work of philosophy of science in the last 50 yrs." (p.77) Precisely, he made notable contributions towards the understanding of scientific development through his unique and systematic account of scientific revolution. He challenged the traditional assumption in philosophy of science that science develops cumulatively and linearly towards a particular scientific ideal, and insists that science develops through revolution which is discontinuous. It seems to the researcher that Kuhn's idea of scientific revolution is in a sense correct. Hence, the researcher agrees with Kuhn that science basically develops through revolution which brings about non-linear or discontinuous fashion of scientific development. The researcher also agrees with Kuhn that scientific development is not gradual approximation to the ideal truth as logical empiricists claim. If scientific development is towards such an ideal truth out there, science would have attained such truth considering the long history of science, or would one day attain it; and thus would stop developing. The fact of scientific development just like that of knowledge in general is very obvious, because science is never static. No one could be said to have attained the final truth in science. Each scientific achievement serves specific purposes, and responds to specific problems at the moment, but cannot be said to be the ideal. This claim can be substantiated with the account of brief historical development of philosophy in general. In the ancient period of philosophy, the Ionian philosophers like Thales, Anaximander, Anaximenes etc. were searching for the basic stuff of reality. Thus, their philosophy was cosmocentric. Later, the sophists, Socrates and Plato centered philosophy on man and the quest for knowledge. In the medieval period, Aquinas, Augustine and other Christian thinkers placed philosophy at the service of theology. Thus, philosophy became the handmaid of theology. In the modern period of philosophy, the quest for rational justification of human knowledge was given a more serious attention. Rationalists like Descartes, Spinoza, Leibniz etc defended the view that there are innate ideas, and that reason is the major source and justification of human knowledge. On the contrary, empiricists like John Locke, George Berkeley, David Hume etc claimed that knowledge comes basically through experience, and denies the existence of innate ideas. These conflicting positions enkindled the criticisms of the extreme positions of rationalism and empiricism by Immanuel Kant and his attempt to critically mediate between the dogmatic rationalists and sceptical empiricists. In the contemporary period, many schools of thought or philosophical movements emerged such as existentialism, phenomenology, hermeneutics, pragmatism etc. Each school or movement tries to respond to some philosophical or human problems. It is obvious from the historical development of philosophy that philosophy is not progressing towards a specified ideal truth. Rather, each philosophical school of thought responds to a particular and prevalent problem at the moment. In the same way, science is not progressing towards an ideal truth which the idea of its cumulativeness suggests. Rather, each scientific paradigm tries to solve specific puzzle. Hence, the researcher subscribes to the idea that scientific development is non-linear. No one philosopher of science could be said to have a final word, but each contributes to the growth of knowledge in that field.

Furthermore, Kuhn's concept of scientific revolution could be justified because scientific development is not like the growth of a tree. This is as a result of the fact that science does not develop just by the addition of new facts. The development of scientific knowledge can involve reconstruction, abandonment or even total destruction of earlier ideas and views. For instance, the development of astronomical knowledge during the period of Copernican revolution involved the abandonment of Ptolemaic astronomy, which necessitated a fundamental shift from geocentric astronomy to heliocentric astronomy. However, it ought to be noted that though scientific revolution can involve abandonment, reconstruction and even total destruction of earlier views, Kuhn seems to over-emphasize the issue of discontinuities in the conception of scientific revolution, and undermines the impact or contribution of earlier ideas or theories on new ones.

Despite the fact that Kuhn made remarkable contributions to the growth of knowledge in philosophy of science and in other disciplines through his ideas on scientific revolution, some of his claims are very controversial, and thus have been subjected to criticisms by scholars. Some of the criticisms were as a result of the weaknesses or loopholes in Kuhn's arguments, and some still were as a result of misinterpretations of his idea. Obviously, the researcher is not satisfied with some of the claims Thomas Kuhn made in his idea of scientific revolution. Before examining such dissatisfactions as well as the researcher's criticisms of Kuhn's idea, it is worthwhile to firstly examine the criticisms levelled against Kuhn by some philosophers and scholars. Bird (2018) is not satisfied with Kuhn's idea. Thus, he notes that "…it has been argued that Kuhn's account of the development of science is not entirely accurate." (para. 43). It ought to be noted that Kuhn's idea of scientific development is a direct offshoot of his concept of scientific revolution which necessitates non-cumulative as well as discontinuous fashion of scientific development. Adams (2017) is another scholar that felt dissatisfied with Kuhn's concept of scientific revolution. In an attempt to criticize Kuhn's view, Adams (2017) states: "In reality, all of science does not operate this way. Scientific revolutions that completely shift the paradigm like Einstein's theory of relativity from Newtonian physics are built on years and years of assertions made before them. Today, both "paradigms are taught in schools at a young age." (para. 9) Criticizing further Kuhn's idea of scientific revolution, Adams (2017) further argues:

> In addition, the model of scientific theory-change that Kuhn puts forth does not apply to the progress in all of science, as it seems to with physics paradigms. For example, the progress observed in biology is more accumulate in nature than "paradigm-like". Biology has progressed from gross anatomy to histology to biochemistry, and the academic approach to this reduction of biology has retained the same goal of connecting structure and function through empirical observations. Despite these areas sharing similarities, they operate independently as fields with their own terminology and techniques, and so cannot necessarily be considered the same paradigm. (para. 10)

From the foregoing, it follows that Kuhn's idea of scientific revolution applies basically to the domain of physical science. The question now is this: 'what of other branches of science?' Also, Adams (2017) brings out very clearly the limitations of Kuhn's idea of scientific revolutions thus:

> …despite having a compelling premise, the scientific progress theories of Thomas Kuhn contain limitations. These limitations include: a failure to account for historical scientific advancements that occur outside of their supposed "paradigm"; a failure to explain additional factors that affect scientific progression such as irrational operation of science by non-scientific powers; and an inability to be applied universally to every field, outside of Kuhn's favored physics examples. (para.12)

Hence, it becomes obvious that there are loopholes in Kuhn's idea of scientific revolution.

Furthermore, Mitra (2003) argues that Kuhn caricatured the history of science. This stems from the fact that his idea of scientific revolution engendered a non-linear fashion of scientific progress. In his words:

> This is a caricature. Progress has linear and non-linear elements- it is the linear version that is the whipping boy of critics who hate all constructive endeavours. Further, we must distinguish numerical progress from progress as a value: here, progress is a priori numerical and may be, according to some a posteriori valuational. However, such valuation is external and not at all intrinsic. New paradigms are breaks and incorporate elements of the old. (para.2)

The above criticisms demonstrate the fact that some scholars are not comfortable with Kuhn's idea of scientific revolution.

At this juncture, the researcher wishes to examine critically the weakness or loophole he observes in Kuhn's ideas. It seems to the researcher that Kuhn is not a stable thinker. This is very visible in the way he modifies, reformulates and even changes some of his original ideas. This does not imply that one cannot refine or modify his original ideas as a result of criticisms. Obviously, it is a mark of a good thinker and scholar to be open to criticisms, and avoid dogmatism as much as possible. Though Kuhn retained most of the key issues in his ideas, the way he reformulated and modified some of his ideas calls for serious attention. For instance, it is obvious to everyone who is in serious scholarship of philosophy of science that Kuhn made a sharp distinction between normal science and revolutionary science in his book, *The Structure of Scientific Revolution*. Such distinction is one of the major innovations Kuhn made in contemporary philosophy of science. But in his later book, *Road Since Structure*, Kuhn laid less emphasis on such distinction and emphasized more on language change as a result of scientific revolution. In his words, "If I were now rewriting 'The Structure of Scientific revolution', I would emphasize language change more and the normal/revolutionary distinction less." (Kuhn, 2000, p.57)

However, despite the problems associated with Kuhn's idea of scientific revolution, Kuhn remains very outstanding in the history of philosophy of science because of his revolutionary ideas.

CONCLUSION

This article actually examines Kuhn's idea of scientific revolution. It is obvious from the discussion that Kuhn claims that science develops through revolution which comes after a long period of normal science. Despite the innovations Kuhn made in the conception of scientific development through his unique idea of scientific revolution, his ideas were subjected to criticisms. Obviously, it is not out of place that Kuhn's account of scientific revolution has been subjected to severe criticisms for it is very difficult to see a philosophical and scholarly work that has not been criticized in one way or the other. The researcher argues that despite the observed shortcomings and loopholes in Kuhn's idea, he made remarkable contributions towards the understanding of the nature of scientific development through his concept of scientific revolution. His idea of scientific revolution is very outstanding in the history of philosophy of science. Kuhn is one of the great scholars that occupy a central position in the history of contemporary philosophy of science. His idea of scientific revolution is a sharp opposite of logical positivists' concept of scientific development. Thus, Bird (2018) states: "Unquestionably, he was one of the most influential philosophers and historians of science of the twentieth century. His most obvious achievement was to have been a major force in bringing about the final demise of logical positivism." (para. 57) It ought to be noted that bearing in mind the fact of the non-stagnant nature of scientific enterprise, Thomas Kuhn cannot be said to have the last word on the nature of scientific development. However, his unique idea of scientific revolution gives a good insight towards understanding the nature of scientific development, and as such, his account of scientific revolution deserves commendations.

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