AN " INSTRUMENTALISM TO REALISM " HYPOTHESIS

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ABSTRACT

It is proposed here that all successful and complete theories always proceed through an intermediate stage of instrumentalism to the final stage of realism. Examples from history of science (both classical and modern) in support of this hypothesis are presented.

Let us take instrumentalism as a representative antirealistic theory of science. It asserts that the scientific theories are merely instruments whose value consists in their ability to successfully explain and predict the experimental outcomes rather than in their fundamental structure of reality (Ladyman (2002)). Realism on the other hand posits fundamental structure and reality to objects and concepts including mathematical ones.

Here I wish to propose the hypothesis that all successful theories necessarily go through an intermediate "instrumental" stage to the final "realistic" stage. So to say all good theories have to pass through an antirealistic stage to the ultimate realistic stage.

The heliocentric theory of the planetary motions of Nicholaus Copernicus was published posthumously in 1543. The book included a preface by Andreas Oslander who was a friend of Copernicus and who was instrumental in getting the book published. The preface was written by Oslander. In trying to explain the motivation, fundamental basis and philosophical ideology of the heliocentric theory of Copernicus, he said that the motion of earth need not be taken literally. He said it was a convenient assumption to explain the motion of planets. According to him it was just a mathematical fiction which was apparently serving the useful purpose of consistently explaining the physical reality of planetary motion. In general, the historians of science have interpreted this to mean that it was done so as not to offend the church too much. Hence as per this view, it was a conscious attempt on the part of Oslander to appease the church and the contemporary prejudice so as to make it more acceptable to them.

In the light of the facts which will emerge as we study some other example of theories below, I would like to suggest that the reason that Oslander wrote the above preface was perhaps because he (and perhaps even Copernicus) actually believed in the "mathematical fiction" idea. There are reasons why this point of view may be taken seriously. In fact Bertrand Russell (Russell (1946), p. 512) says, " It is uncertain how far Copernicus sanctioned this statement, but the question is not very important, as he himself made similar statements in the body of the book. The book is dedicated to the Pope, and escaped official Catholic condemnation until the time of Galileo." He pointed out that Copernicus was an ecclesiastic of unimpeachable orthodoxy and that, " .. Copernicus .. protested .. against the view that his theory contradicted the Bible." As an honest Catholic and an upright mathematician/scientist the only way that he could have held on to the above view was by sincerely believing that his theory was actually a convenient "mathematical fiction" say, to provide a better calender.

This point of view is further consolidated by the following facts. Rupert and Mary Boas Hall (Hall and Hall (1964) p. 140, 144) point out that it was common knowledge among Renaissance astronomers that the Ptolemy's system was actually quite complicated mathematically and that it did not entirely agree with the Aristotelean universe either. Its tables contained errors and sometimes its predictions were off by weeks. It also failed to teach as to how to make corrections in its calender. "This last problem, of so great concern to church, caused the papacy itself to bless the search for new system". Others besides Copernicus, though not as successfully, also tried to formulate new systems to improve upon Ptolemy's system. In fact, "Copernicanism was not suppressed (one of the friends who urged Copernicus to publish was a cardinal, the other a catholic bishop)" (Hall and Hall (1964)).

Ever since the dawn of human civilization mathematics has always been placed at the highest intellectual level of human thought. Mathematics existing as absolute entity in some putative Platonic world ascribes to this point of view. As to how this Platonic world "dirties" its hands by explaining the "mundane" physical reality has been a puzzle for scientists. Even the mathematical physicist Eugene Wigner (Wigner (1960)) was compelled to state, "The miracle of the appropriateness of the language of mathematics for the foundation of the laws of physics is a wonderful gift which we neither understand nor deserve".

Thus "miracle" is nothing more than "the mathematical fiction" which Oslander talks about. Such a way of treating a theory as a "mathematical fiction" in trying to make a connection between the Platonic world of 'real' mathematics with the fuzzy world of physical reality in which some of the beautiful mathematics finds application in. This is how they reconciled the dichotomy of pure and applied mathematics. This problem has persisted until now and no wonder at the early stages (or even to very late stages) application of a mathematical language which seems to map and explain a physical reality could be considered a "mathematical fiction". Hanging on to this concept of "mathematical fiction" was perhaps one of the fundamental reason why idealism/antirealism of Berkeley and others could sustain itself.

Later Newton developed a more consistent theory of gravity which was found to have a wide and accurate range of applicability and as further observations were made, the "mathematical fiction" of Copernicus started losing appeal. It started looking less of a fiction to others and appeared to become more "realistic". And today, the Copernican theory is considered to be as exact and as real as that any scientific theory can be.

Another example of how a good scientific and successful theory would go from an instrumental stage to the stage of realism is provided by Dalton's atomic theory (Shapere (1964)). Dalton's theory was never fully accepted by his fellow scientists. For example Oswald and Davy and others regarded Dalton's atomic theory with positive dislike and were always looking for an appropriate substitute. At best they were willing to accept "atom" as a convenient fiction which served the purpose of explaining some physical reality. Often they would skip the word "atom" altogether and use other contrived terms like "proportions" or "equivalents". In fact when a Royal Medal was presented to Dalton (Shapere (1964)) the citation stated that it was for his development of the theory of Definite Proportions usually called the Atomic Theory of Chemistry. This clearly shows that in the initial stages the Atomic Theory was instrumentalistic in as much as that was the way it was actually perceived by all the scientists. Today, clearly when scientists have actually "seen" atoms of the size of a few Angstrom, the atoms are as real as the pen in my hand.

Another example of a physical theory undergoing instrumental to realistic "transition" is that of Kekule's visualization of the model for Benzene (C6 H6). He claims to have seen it in his dream. He visualized it as a closed chain of six carbon atoms with six hydrogen atoms hanging from 'strings' from the corresponding carbon atoms. He or his contemporaries did not associate with this picture any actual reality of existence in the three dimensional space. For them it was just a convenient model - an instrument to mock up the existence of Benzene and its properties. Later this structure became real when Van Laue demonstrated its actual physical structure in three dimensional space.

The next example is from modern particle physics / High Energy Physics. Until 1930's scientists were aware of the existence of electron, proton and perhaps photon as the only "elementary particles" of which all the other entities in nature were made up of. Thereafter neutron, mesons and several other objects as elementary entities started manifesting themselves in laboratories. So much so that by late 1950's and early 1960's there were close to about one hundred such entities which could be labelled as "elementary". There was tremendous confusion in physics and new ideas were cooked up to explain this proliferation of particles. One such model was named "nuclear democracy" which in a way provided elementarity and equality to all these multitude of particles. However, the physicists were forced to abandon this model as further empirical information seemed to contradict the predictions of this model.

Protons and neutrons are massive particles whose electric charges are one and zero respectively (in units of negative of electronic charge). To account for the existence of the large number of so called "elementary particles", in the early 1960's, M. Gell-Mann and G. Zweig independently proposed that these were actually built up of more elementary entities (now) called quarks. Quarks were of three different kind and named as: u (up- quark) d (down-quark) and s (strange-quark). These had electric charges 2/3, -1/3 and -1/3 respectively. Proton was made up of 3 quarks : u+u+d whereas neutron was made up of 3 quarks : u+d+d. This description was provided in the mathematical framework of the group SU(3). These quarks were proposed to be the "elementary particles" of which all the other strongly interacting particles known then were made up of. However both Gell-Mann and Zweig did not posit any physical reality onto these quarks. As per them - these quarks were just "mathematical entities" and SU(3) was a convenient mathematical "trick" cooked up to do the job. And indeed, it did a good job of providing a comprehensive and consistent description of reality which hitherto had appeared to be quite bizarre. When Gell-Mann was later awarded Nobel prize in physics in 1969 for this work it was cited as "for his contributions and discoveries concerning the classification of elementary particles and their interaction".

During the Nobel Prize Ceremony Gell-Mann did present a lecture entitled, " Symmetry and currents in particle physics". On Dec 11, 1969 at Stockholm. All Nobel Laureates are supposed to present a written version of these lectures to be published. But for some inexplicable reason Gell-Mann Nobel Lecture was not written up for publication in the collection of lectures (Nobel Lecture (1963 - 1970)). However it is reputed that he had actually referred to quarks as mere "mathematical entities" in his lecture. Also a Presentation Talk is given by a Nobel Committee Member before the award of the Nobel Prize. This was done by Ivar Walter whose talk is present in the Nobel Lecture Physics 1970, p 297. I quote Walter , "The quarks are peculiar in particular because their charges are fraction of the proton charge which according to all experience up to now is the indivisible elementary charge. It has not yet been possible to find individual quarks although they have been eagerly looked for. Gell-Mann's idea is none the less of great heuristic value".

This conveys the idea of a "mathematical fiction" as clearly as possible. For Gell-Mann and Zweig these quarks were mathematical entities/fiction just to get the mathematical symmetries/group theory right. Zweig has said (Zweig (1965), p192), "In fact, it is likely that the fundamental objects do not correspond to physical particles; rather, the units may form a convenient set of symbols that are helpful in expressing certain symmetries of the strong interaction".

Hence it is clear that the quarks in this model were for a long time believed to be mere "mathematical entities" whose role was basically to provide convenient representations of the SU(3) group to describe the empirical facts in a consistent manner. This was the "instrumental" stage of the development of this theory. Today the same quark model is on a very solid footing. In fact, the 1990 Nobel Prize in physics was awarded to J. I. Freedman, H. W. Kendall and R. E. Taylor for basically experimentally demonstrating the physical reality of these quarks. So today quarks are as real to a physicist as any particle can be.

If one studies any particular mature scientific theory carefully, I am sure, one will discover the same pattern as above. The theory would finally become realistic only after going through the initial or intermediate stage of being instrumentalistic. Hence I propose that this "Instrumentalism to Realism Hypothesis" may actually be a "law". However, sometimes this transition may be achieved after decades or even centuries.

One should be warned though that there may be popular scientific theories today which are still in the instrumental stage. For such a theory the final realistic theory is yet to see light of the day. As such that particular theory should be considered tentative at best - as per the prediction of the "Instrumentalism to Realism" hypothesis presented here.

One important example of such a theory is quantum mechanics. Quantum mechanics, in spite of unequivocal successes has fundamental interpretational problems: non-locality, collapse of wave function and quantum jumps to name a few. As such many scientists, working in the field today, have come around to endorse the view that quantum theory at present is only an "instrumental" theory. Let me quote Roger Penrose (Penrose (2004)), "In this chapter, I shall put the case to the reader that there are positive powerful reasons, over and above the negative ones put forward in the preceding chapter, to believe that the laws of present day quantum mechanics are in need of a fundamental (though presumably subtle) change. These reasons come from within accepted physical principles and from observed facts about the universe".

And indeed, as per my hypothesis presented here, this is inevitable. Note that the hypothesis presented here does not only have an explanatory value, but it also has a predictive value as well. And that can help in giving direction to science. This is in spite of the fact that most of the working scientists feel that the discipline of philosophy of science is completely irrelevant to their work. The present hypothesis tells scientists not to become too pessimistic. Many a working scientist in quantum mechanics appear to have done exactly this! This is due to a common feeling among scientists that the Copenhagen interpretation of quantum mechanics (the most popular one) leaves them with hardly any other choice. As per the hypothesis presented here, they should keep looking as the final stage of any good theory is the realistic stage and that is yet to be achieved in quantum mechanics.

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