THE PHILOSOPHY OF
SHEWHART'S THEORY OF PREDICTION

Dr Mark Wilcox
Centre for Business Performance; Cranfield School of Management, Cranfield University, Cranfield, United Kingdom. MK430AL
email:mark.wilcox@cranfield.ac.uk

(Note : This paper is a modified version of the author's presentation to the Proceedings of the 9th Research Seminar: Deming Scholar's Program, Fordham University, New York, February, 2003.)

Abstract

Shewhart's control charts are a feature of statistical process control and linked to systems thinking. A system is a set of interconnected parts (processes) with a common purpose. A systemic view of the universe suggests that nothing ever 'is' (e.g. substance or static), but always in a state of 'becoming' (e.g. in flux). In this paper I show how control charts are a semiotic device illustrating 'being,' 'becoming' and 'prediction'. Articulating his work, Shewhart developed a *discourse of flux* as a means of describing the universe in motion.

Introduction

Shewhart's invention of the control chart in 1924 has been hailed as one of the greatest contributions to the philosophy of science (Deming:1986). For many it is a technique for plotting data derived from a process, service or product. Perhaps through complacency, we accept its shape and form without question, choosing the various types of charts to suit our purpose. Because the majority of users of the charts, over the last 70 years or so, have been engineers, statisticians and mathematicians, it comes as no surprise that they have seen it as a statistician's technique.

However, we also know that Shewhart read widely, and was greatly influenced by more than one philosopher. Now, well etched in the minds of the students of Shewhart's and Deming's work is that they were both greatly influenced by the pragmatist philosopher and Harvard Professor; C.I. Lewis. It is equally well documented how Shewhart read Lewis' theory of knowledge 14 times, while Deming only read it 7 times (c.f. Blankenship and Petersen:1999; Mauléon and Bergman:2002; Wilcox:2002). This empirical data is open to interpretation! Nevertheless, the intriguing conundrum is that apparently, Shewhart did not read Lewis (1929) until after his major work was published in 1931 (or at least, it was not referenced in his 1931 book). So, we are left with a search for the root of Shewhart's ideas in order to understand how he developed the control chart and his theory of prediction.

It would appear that Shewhart used Lewis' work as post-hoc rationalisation, because he is frequently referenced in the 1939 book of edited lectures (Wilcox:2002). While, we can see certain influences from Lewis' work in the 1939 book, we have still to ascertain how he got where he did in 1931. Fortunately, Shewhart was an excellent scholar and documented his sources in great detail. The extended (1931) bibliography is testimony to the research undertaken in developing his ideas. From this we can reliably trace the source of some of his ideas.

The aim of this paper is to try to uncover some of the theories, ideas and sources of information that helped Shewhart develop his theory of prediction and the control chart. While not wishing to shun the influence of statistical theory, this paper will focus mainly on the philosophy of science and theory of knowledge. I will argue, that to fully understand Shewhart's work we have to have more than a grasp of the philosophies that underpin his theories of prediction. I will try to show how Shewhart's work makes a unique contribution to the metaphysics of flux and substance (being and becoming).

Tracing the debates on flux and substance back to the pre-Socratic philosophers, I will describe how this concept was developed over the last 2500 years. An important feature of this debate is the distinction between 'being' and 'becoming'. Being is the static state of what 'is' (e.g. substance), and becoming is the state of 'flux' (e.g. process). Beginning with the now, well hackneyed problem, that Heracleitus had in crossing the same river twice, I will try to show the relevance of these philosophical concepts to Shewhart's work. Time and space will not allow a full coverage of the history of this debate, so I will move quickly on to the work referenced by Shewhart in his 1931 and 1939 books.
I will show how the shape and structure of the control chart is an attempt to capture the 'being and becoming' of a process within a system. The two sides of a control chart, are the scalar and the vector, which, when juxtaposed, provide a means to capture the here and now, while simultaneously representing times' arrow (Eddington:1929). Here, some of the well known, and less well known scholars who influenced Shewhart, will be uncovered. While most people are aware of Fisher's statistical theory, and Keynes' treatise on probability, one rarely finds reference to the more peripheral authors in Shewhart's work. For instance, the data point (the actual dot) on the control chart is underpinned by the theory of signs (semiotics) (Morris:1938) and "location of events" and being and becoming, past, present and future in (Eddington:1929). The design layout of the chart was also subject to detailed consideration using the leading writer on this topic (Dwiggins:1928/48). These quite interesting facts, may come as a surprise, till one considers the task that Shewhart had undertaken, which was to try to make statistical theory and practice accessible to engineers and scientists. In the light of this, we can see how effective the control chart was, both, as a statistical technique, and means of communication.

In conclusion, I will show how Shewhart's invention of the control chart is a multi-faceted concept and a major feat of social construction, aiming to tackle the age-old problem of understanding the universe when it is in a state of flux. To help articulate his ideas, Shewhart (1939) distinguished scientific and emotive language (pp,84,85). I have called his style of writing a *discourse of flux,* weaving a thesis out of engineering, physics, mathematical and philosophical texts. Shewhart was painfully aware of the consequences of using emotive language in the company of engineers and scientists, warning his readers to tread carefully.

The Roots of Shewhart's Ideas

Here, I define and deconstruct the ideas behind Shewhart's theories while using the debate on being and becoming as a focal theory. Whitehead (1929) states that there are two main metaphysical debates, one on substance, the other, on flux. This debate is often referred to as "being and becoming". My aim is to show that Shewhart's work addressed this debate in a unique fashion, with his invention of the control chart, and unknown chance and assignable cause systems of variation.

We do not have to search far in Shewhart's work before we get to the heart of the problem. Opening up his 1931 book, he quotes Pope saying " 'All chance is but action thou canst not see', and we looked forward to the time when we would not see that direction. In other words, emphasis was placed on the *exactness* of physical laws. Today however the emphasis is placed elsewhere… 'Today the mathematical physicist seems more and more inclined to the opinion that each of the so-called laws of nature is essentially statistical, and that all our equations and theories can do, is to provide us with a series of orbits of varying probabilities' " (Shewhart,1931:4-5).

At the time of writing, statistical methods were in their infancy, having been developed in the natural sciences. At the beginning of the 1939 book he made the distinction more clear: "..whereas the concept of mass production of 1787 was born out of an exact science, the concept underlying the control chart technique of 1924 was born out of a probable science" (p4). Engineers were focusing on making "exact" interchangeable parts, which were a feature of the early stages of mass-production which relied on inspection and detection to manage quality.

Shewhart accepts the logical principle that: "It is conceivable that some time man will have a knowledge of all the laws of nature so that he can predict the future quality of product with absolute certainty" (Shewhart, 1931:353). However, he was very good at teasing his readers, and we have to read on, to find that this **"is not merely a long way off but impossible" (op-cit).** Indeed, we should also note that natural laws are subject to variation, and knowledge of *all things* in the past, is a logical impossibility.

My interpretation of this argument is that the engineers and scientists were following a view of the universe based on a Parmedian principle, that the world is one united whole, and knowable. Parmenides was one of the main exponents of the notion of 'being'. His argument was, that there was 'One Real Being'.
"He had declared that the whole of reality is a One Being or Existent Unity, having only such attributes as can be rigidly deduced from the conceptions of Being and Unity. Each conception is taken with the utmost strictness. 'Being' implies complete reality; 'Unity' excludes any plurality. There is nothing but this One Real Thing" (Cornford's editorial commentary in Plato,1935:220).

Lewis referred to Parmenides while criticising the dogmatism of contemporary metaphysicians "…I am reluctant to lay hands on that idealism which has played the role of Father Parmenides to all the present generation of philosophers" (Lewis,1929:9). Lewis had no time for dogma and loathed the sophistry of some of the metaphysical doctrines, that belittled common sense and experience. We shall see the relevance of this point in due course, but first we must return to Shewhart's work.

Shewhart's research project was to develop a more economic control of quality. He had to define the problem to his audience of engineers and scientists, which he did partly in the passage above. The nature of that part of the problem was that the engineers and scientists of the 18^{th} and 19^{th} century had adopted a flawed and unachievable strategy, in believing that they could know all the laws of nature.

With the advent of statistical theory in the natural sciences, a new epoch dawned. Shewhart, and others in the 1920s, started to apply statistical and probability theories to mass production. But with this approach, came a new set of problems. The epoch represented a relatively new way of thinking and was a paradigm shift in the extreme. To fully understand this shift, Shewhart read widely, including many of the great philosophers of his time. He had to understand the consequences of viewing the universe as non-static and in a state of flux. Hence, he was drawn to the philosophers of science for help and guidance.

Shewhart and Becoming

Shewhart tried to explain how there was variation in everything, which was a fundamentally different way of viewing the universe than the exact sciences had been doing. If there is variation in everything, then …
"It follows, therefore, since we are thus willing to accept as axiomatic that we cannot do what we want to do and cannot hope to understand why we cannot, that we must also accept as axiomatic that a controlled quality will not be a constant quality. Instead, a controlled quality must be a *variable* quality. This is the first characteristic" (Shewhart, 1931:6).

This passage is an example of what I have called *a discourse of flux* which Shewhart developed in his work. A discourse of flux, is, as the name suggests, a way of communicating, consistent with the view of the world where everything is in motion. This requires a special skill, for it is easy to lay a philosophical trap or paradox with the careless use of words. I am suggesting that Shewhart was particularly effective at this style of writing, and we shall see more examples of the *discourse of flux* in this paper.

We should not underestimate the profound nature of content of the passage above, particularly when we consider that he was writing for an engineering audience, steeped in the practice of mass-production. While statistical theory was relatively new, the ideas of variation, flux and becoming had been around for 2500 years or more. These debates are at the root of metaphysical and epistemological arguments going back to the pre-Socratic philosophers.

Perhaps, one of the more enduring claims about the Universe was made by Heracleitus 5^{th} Century BC, who suggested everything was in a state of flux or motion, as opposed to being static. This debate has often been referred to as "being and becoming", with the proponents of flux in adopting the "becoming" argument. Heracleitus was probably the founder of the thesis of flux, in which he famously argued that, you cannot stand in the same river twice. One of his followers, Cratylus, took an extreme perspective and argued that you cannot stand in the same river once, because both you and the river are constantly changing. Taking Heracleitus' work to the extreme, can result in 'scepticism', where knowledge of any kind becomes unlikely, and one is driven into a solipsist argument. So, for instance, the meaning of words and concepts would be constantly changing, and a statement cannot remain true, or even the same statement (Plato, 1935:95-106).

Shewhart's Control and Prediction Theory

While the theory of flux is quite seductive, with its emphasis on motion, it clearly brings its own problems, which Shewhart had to address if he was going to use this concept to control quality. Quite adept at making a solid case, Shewhart argued that there was variation in everything, *even the exact sciences*. Here, he demonstrated the semantic skills of a philosopher, while carefully constructing his thesis.

" *a phenomenon will be said to be in control when, through the use of past experience, we can predict, at least within limits, how the phenomenon may be expected to vary in the future. Here it is understood that the prediction within limits means that we can state, at least approximately, the probability that the observed phenomenon will fall within given limits…"* (Shewhart, 1931:6) (emphasis in original).

From this we can see how being able to predict is inextricably linked to control. Control reflects the present, or here and now, while prediction is what may happen in the future. It is surprising how the emphasis on prediction in Shewhart's work appeared to get lost in the passage of time. Only quite recently, has it reappeared in the literature (c.f. Mauléon and Bergman: 2002; Wilcox:2002). Here, we see Shewhart outlining a unique thesis, whereby engineers and scientists would be able to predict, product quality. His theory has many components which space will not allow a full exposition. However, he lays down some rules, as in the following example.

"In fact a prediction of the type illustrated by forecasting the time of the eclipse of the sun is almost the exception rather than the rule in scientific and industrial work.
In all forms of prediction an element of chance enters. The specific problem which concerns us at the present moment is the formulation of a scientific basis for prediction, taking into account the element of chance, where for the purpose of our discussion, *any unknown cause of a phenomenon will be termed a chance cause"*(Shewhart,1931:7) (emphasis in original).

Shewhart's Unknown Causes

The notion of an unknown cause is intriguing and we have to treat this cautiously. We can perhaps see the influence of Professor A.S. Eddington on this concept. In his Gifford Lectures, Eddington (1928) talked about:

"*Something unknown is doing something we don't know what-* that is the what our theory amounts to. It does not sound a a particularly illuminating theory. I have read something like it elsewhere- The Slithy toves. Did gyre and gimble in the wade (taken from Jabberwocky). There is some suggestion of activity. There is the same indefiniteness as to the nature of the activity and of what it is that is acting. And yet from so unpromising a beginning we really do get somewhere. We bring into order a host of apparently unrelated phenomena; we make predictions, and our predictions come off. The reason - the sole reason- for this progress is that our description is not limited to unknown agents executing unknown activities, but *numbers* are scattered freely in the description. … By admitting a few numbers even 'Jabberwocky' may become scientific. We can now venture on a prediction; if one of its toves escapes, oxygen will be masquerading in a garb properly belonging to nitrogen. In the stars and nebulae we do find such wolves in sheep's clothing which might otherwise have startled us. It would not be a bad reminder to of the essential unknowness of the fundamental entities of physics to translate it into "Jabberwocky"; provide all numbers - all metrical attributes - are unchanged, it does not suffer in the least. Out of the numbers proceeds the that harmony of natural law which is the aim of science to disclose. We can grasp the tune but not the player. Trinculo might have been referring to modern physics in the words, 'This is the tune of our catch, played by the picture of nobody" (p.291-292).

A similarity between Eddington's and Shewhart's ideas appears quite transparent, as he articulated the problems of the unknown, and what may be described as chance and assignable causes. Also explicit are the notions of control and prediction. Clearly implicit, is that although he accepted the theory of flux, he needed to develop a notion of control and prediction over the 'things' in flux. His novel idea of a chance cause, was his first attempt to socially construct a discourse of flux, while avoiding the traps of a static or exact discourse. The idea that the variation in a 'thing' is caused by a chance cause is qualified by the assertion that the cause is 'unknown'. For 2,500 years philosophers have grappled with the concept of being and becoming, producing numerous explanations of how we make sense of the here and now, to avoid charges of solipsism, yet avoiding the equally flawed charge of knowing everything. The notion of variation and chance and assignable causes, was Shewhart's attempt to address this problem.

Shewhart appeared to take some advise from Eddington in his use of the Law of Large Numbers with which he provided four examples to show how the theory worked. From these examples he qualified his theory of unknown systems of chance causes to: *Controlled or constant system of chance causes, which are of course variable in nature* (see Shewhart, 1931:Chapter X). He was then able to formulate his ideas around the task of quality control and prediction with more certainty.

However, we find that prediction is a problematic concept, and one that may get confused with other methodologies from forecasting for example. So, having defined his notion of a chance cause, he had to develop a scientific basis for control and prediction. Here he made a distinction between predicting the future price of stock in 30 years time, and the result of tossing a coin 100 times, in 30 years time. Clearly, we would not bet on stock-market prices in 30 years time, for that type of prediction would be unreliable. However, tossing a coin and predicting the result of a similar process, is quite plausible within the limits of probability. This example shows that not all chance cause systems are the same, which lead him to develop the first of three postulates for his thesis.

"*Postulate 1- All chance systems of causes are not alike in the sense that they enable us to predict the future in terms of the past.* Hence, if we are able to predict the quality of product even within limits, we must find some criterion to apply to observed variability in quality to determine whether or not the cause system producing it is such as to make future predictions possible…
Postulate 2- Constant systems of chance causes do exist in nature. To say that such systems exist in nature is one thing; to say that such systems exist in a production process is quite another thing. Today we have abundant evidence of such systems of causes in the production of telephone equipment.
Postulate 3- Assignable causes of variation may be found and eliminated . Hence to secure control, the manufacturer must seek to find and eliminate assignable causes. In practice however, he has the difficulty of judging from an observed set of data whether or not assignable causes are present… What we need is some yardstick to detect in such variations any evidence of the presence of assignable causes. Can we find such a yardstick? Experience of the kind soon to be considered indicates we can. It leads us to conclude that it is feasible to establish criteria useful in detecting the presence of assignable causes of variation or, in other words, criteria which when applied to a set of observed values will indicate whether or not it is reasonable to believe that the causes of variability should be left to chance." (ibid.:8,12,14)

Control Limits, Assignable Causes and Pragmatism

At this point in his thesis, he developed the concept of control limits to distinguish chance and assignable cause systems. Here we see how a table of data is re-presented on three control charts. Now with the use of control limits, the assignable causes could be found and removed.

"Upon the basis of Postulate 3, it follows that we can find and remove causes of variability until the remaining system of causes is constant or until we reach that state where the probability that the deviations in quality remain constant" And then on the final chart he wrote the title: "Judgement Plus Modern Statistical Machinery Makes Possible The Establishment of Such Limits" (ibid.:17).

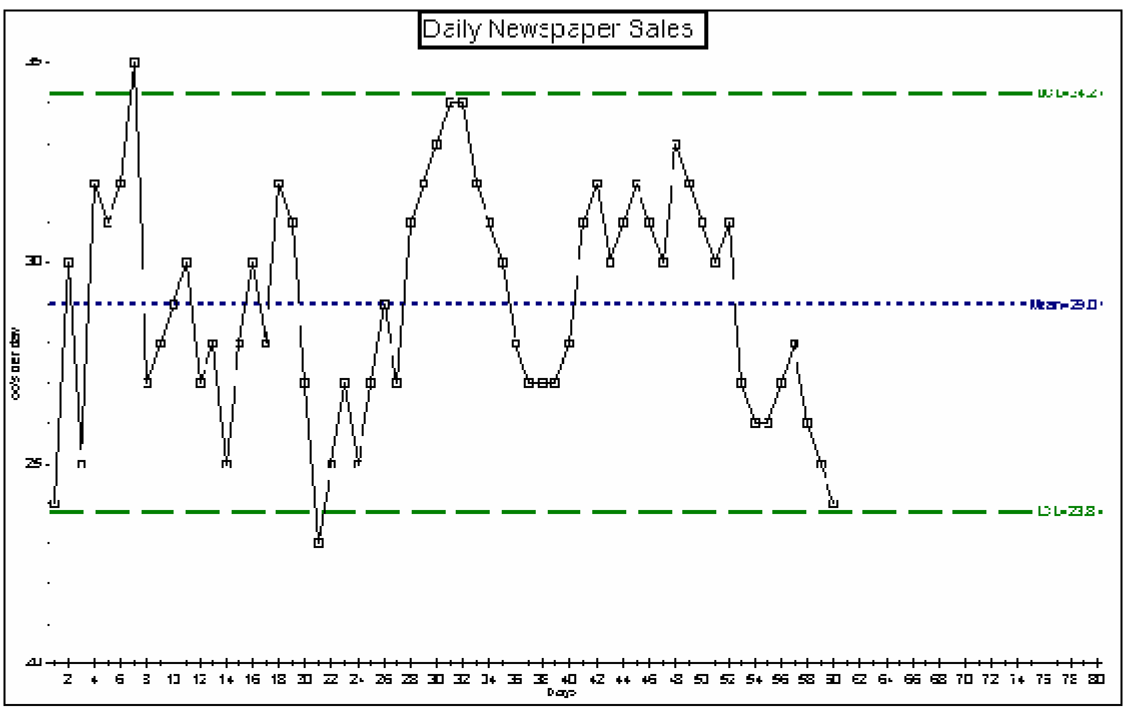
The more observant, will have noticed the word 'judgement' in the passage above. The reason for this soon becomes apparent. For then, he argued that mathematical statistics did not give the desired criterion.

"What does this situation mean in plain English? Simply this: such criteria, if they exist, cannot be shown to exist by any theorizing alone, no matter how well equipped the theorist is in respect to probability or statistical theory. We see in this situation the long recognised dividing line between theory and practice… the fact that the criterion we happen to use has a fine ancestry of highbrow statistical theorems does not justify its use. Such justifications must come from empirical evidence that it works. As the practical engineer might say, the proof of the pudding is in the eating" (ibid.:18)

This pragmatic use of theory and the role of mind in the process was clearly following Lewis' ideas. Shewhart drove home the distinction between pure and applied statistics on several occasions, on the basis that engineers or scientists had to make 'decisions' with 'real' consequences, unlike those confined to the laboratory. Shewhart used trial and error to remove the causes till… "We assumed, therefore, upon the basis of the this test, that it was not feasible for research to go much further in eliminating causes of variability" (ibid.:21).

In 1939 he had included the notion of belief to his work. "The fact that we must depend upon a human individual to choose successfully from his experience those conditions that he believes will lead to valid conclusions through the use of probability theory indicates what appears to be a necessary human act of rational believing and this act is always an attempt to relate past evidence *E* with a prediction *P"* (p.42).

So while statistical theory played a part, it was the role of human judgment that determined the final limits on the chart. The significance of this research in terms of the philosophy of science should not be underestimated. Shewhart attempted to take the theory of flux and construct a discourse and method of illustration that would make it possible to understand and interpret flux in a process. Let us take a closer look at what has now been achieved.



In this case we have the number newspapers sold as the vertical axis, and the time series of daily intervals on the horizontal axis. This simple juxtaposition challenges the critics of the theory of flux by trying to know something, even if it is in flux. The chart illustrates the process flux over time. It tries to illustrate the being and becoming, where the being is in the data point, averaged out on the mean. I will return to this later when we consider the chart as a semiotic device.

Knowing What to Measure

Shewhart's (1931) chapter on defining quality ought to be a standard reference point for anyone defining quality. This chapter sets out the problems of defining quality, and provides an operational definition for his research. It is also a master-piece in the discourse of flux. We have to consider whether the thing we are measuring 'has' an attribute called 'quality' as a form of goodness for example, or 'is' the thing a quality object per se. Shewhart argued that the 'thing' consists of numerous quality criteria, e.g., colour, size, weight, and therefore if we change the criteria, we change the thing. The alternative would be to perceive the thing as having an objective existence (substantive and static) upon which we confer the notion of quality. The fact that he chose this route is quite significant, demonstrating his adherence to the metaphysics of flux.

Precise and Accurate Measurement

A data point on a chart is quite symbolic, trying to represent the here and now. One on its own could be seen as a symbol of being, but when a few are strung together, they illustrate becoming and flux. They are part of a social construction of flux. Lewis (1929) used a notion called an "instant mental reaction to experience" (p.358) constituting an 'island of knowledge'. Lewis, like many others was attempting to avoid the solipsist traps and charges of scepticism. Not surprisingly, we find that Shewhart took the measurement process very seriously. He needed a precise and accurate method of measuring the 'things' in question. Being quite pedantic on this point - he drew on the work of Goodwin (1908). Goodwin defined accurate, as meaning the methods of measuring, and precision, meaning reproducible in similar circumstances. Leaving no stone unturned, Shewhart engaged with the theory of errors, thus demonstrating more variation for the discourse of flux. For the purpose of this paper, we only need to note whether the data was gained by methods in statistical control (e.g. accurate and precise) or not. If the data collection procedures are in control then we may place confidence in the prediction to be made from the data. The converse of this also applies. Shewhart's diagram for a data collection procedure was quite simple, but equally poignant.

$$X^1$$

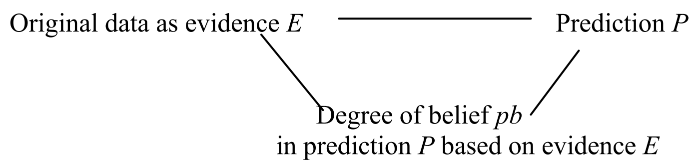
$$H^1 \qquad C^1$$

(Shewhart,1939:89)

Here X = the values of the measurements; $H.$ = the observer; and $C.$= the text describing the initial conditions. In essence, this process occurs at every time data is collected. If either *H. or C.* changes, then this should be noted as it may be cause of the measurement process going out of control. This diagram reappeared later, where it was shown as a series of measurements leading up to the process of prediction. We should therefore think of this as the process behind each data point on a chart.

Prediction

We now have the means to gather data, which leads to Shewhart's theory of knowledge, and the basis for prediction. Lewis' influence on Shewhart's work becomes more transparent and we will soon see the pragmatism appearing in the process of prediction. In essence this process may take place each time data is collected and presented on the chart.



(Shewhart, 1939:86) Figure 11

Using this model, we start at the left hand corner with original data. Shewhart described various methods for predicting, based on best estimates, probability and Student range-type P^1 for example. However, we also have to apply theories to interpret the data. Some of the theories will come from the laws outlined above. The concomitance of data and theory lead to an interpretation using human judgement.

While we acknowledge the influence of statistical and probability theory, we should also be aware of the influence of the philosophy of science on Shewhart's work. Take the following lament:

"In general the problem of estimation presents the universal difficulties involved in all induction. If one reads such a book as *A Treatise on Probability* , J.M.Keynes, … he may feel at first very discouraged, because his attention will have been directed to many of the serious difficulties involved in the application of probability theory. A useful tonic in such a case is to read any one or more of the following books: *The Nature of the Physical World,* Eddington (1928) … *The Logic of Modern Physics* Bridgman (1928),… *The Analysis of Matter* Russell (1927) … At least these three books should provide a tonic, if it is true that misery loves company. Certainly the serious difficulties involved in the interpretation of physical phenomena are common to all fields, and the discussion in these books show how much we must rely upon the application of probability theory even in the 'exact' science (Shewhart, 1931:481) (underlining added).

Historically, induction carries its own problems, and these were inherent in the various doctrines of flux. However, we shall have to leave the detail for another paper, and return to Eddington's work. For instance his notion of 'Location of Events' was developed around the past, present and future, showing how we may locate ourselves in the flow of time, with the here and now. He described how the grand theories of the universe were shaken in the 17^{th} century when the notion of 'Now' was perceived as 'the instantaneous state of the world' at that moment in time. This concept was dismissed by the astronomer Roemer who demonstrated that 'Now', cannot be an instant in the global sense, because of the time, light, took to travel. "That was really a blow to whole system of world wide instants, which were specially invented to accommodate these events" (Eddington, 1928:42,43).

Eddington developed some useful concepts on becoming, entropy and a new epistemology. In concluding the chapter on his epistemology, we find an amusing, but thought provoking paragraph, that may have caught Shewhart's attention.

"It is only through a quantum action that the outside world can interact with ourselves and knowledge of it can reach our minds. A quantum action may be the means of revealing to us some fact about Nature, but simultaneously a fresh unknown is implanted in the womb of Time. An addition to knowledge is won at the expense of an addition to ignorance. It is hard to empty the well of Truth with a leaky bucket" (Eddington,1928:229).

So we may return to Shewhart's work, and how the process of interpretation required knowledge of the present. Equally, every interpretation involved a prediction. So, the sum of knowledge is a 'leaky bucket', varying by the minute.

"Nonstatic character of knowledge….we are forced to consider knowledge as something that changes as new evidence is approved by more data, or as soon as new predictions are made from the same data by new theories. Knowledge in this sense is somewhat of a continuing process, or method, and differs fundamentally in this respect from what it would be if it were possible to attain certainty in the making of predictions" (Shewhart, 1939: 104).

We should also note how theories and laws were judged on their practical value to interpret the present. They were also subject to variation as new data and interpretations either modified, or rendered them false.

Past, Present and Future

To reinforce this argument, we are drawn to a quotation from Lewis (1934) "…knowing begins and ends in experience; but it does not end in the experience in which it begins" (Quoted in Shewhart,1939:80). Shewhart was clearly fascinated with this riddle which he adopted in several ways to help form his ideas. Here we see his attempt to illustrate the riddle in a simple diagram. If we relate this to figure 11 above, we can imagine that this process occurs to the left of the centre, at the present. To see the full benefit of these two figures working together, we should think of the one below as moving with time, with figure 11 acting as a wheel rotating on the present as time's arrow progresses forward. Data-interpretation (knowledge) - prediction - belief in prediction - *ad infinitum*. And so we see Shewhart's epistemological techniques illustrating the notion of flux.

Previously observed Practically verifiable Only theoretically verifiable

$X^{1,} X^2 \ldots X^l, \ldots X^n$ $X^{n+1}, X^{n+2} \ldots X^{n+f}$ $X^{n+f+1}, X^{n+f+2} \ldots$

Past Future

Present →

(Shewhart, 1939:133)

With care we can locate these two diagrams with the origins of the PDSA cycle; Shewhart's wheel. This took the three concepts of specification, production and inspection from the 'exact' methods of mass-production, which he then formed into a circular spiral. "The three steps constitute a dynamic scientific process of acquiring knowledge" (Shewhart, 1939:45). To fully understand how this works, Shewhart explains how scientists and statisticians join forces. The scientists decide on the specification (step1), and then join with the statisticians (step2) to eliminate assignable causes of variation to a point where predictions can be made. The statisticians need the scientists' help to eliminate the causes, because of their knowledge of the process (the physics). When the state of statistical control has been attained the statistician can proceed without the scientist, (step 3) and "set up rules that lead to the most efficient prediction" (Shewhart, 1939: 119).

Now consider Shewhart's discourse of flux describing how he envisaged this working in practice: "In fact an economic standard of quality is not a written finality, but is a *dynamic process*. It is not merely the *imprisonment* of the past in the form of specification (step 1), but rather the *unfolding* of the future as revealed in the process of production (stepII) and inspection (step III), and made available in the *running* quality report " (Shewhart, 1939:119) (emphases added).

This control chart has been specially constructed to represent the future as an unknown, but predictable quantity. Now we can see the past present and future unfolding. It has been said, the control chart is the voice of the process. Metaphorically they 'tell a story'. We can, with experience, learn to read the data points on the chart and detect process shifts (7points above or below the mean) or tampering manifest by zig-zagging for example. The key to understanding this is in the notion of variation. We have to be able to interpret variation, to get the full story from a control chart. However, while understanding variation is important, it must not detract from the real purpose of predicting the future. Indeed, I would suggest that control charts rarely gets used to their full potential as a predictive technique.

A Theory of Signs and the Importance of Display.

Statisticians use symbols to depict many aspects of their work, sometimes providing an index. However, few think of the symbolism of the control chart to portray flux and substance. Shewhart referred to

Morris (1938) to acknowledge the importance of the way we present information with signs and symbols.

"The process in which something functions as a sign may be called *semiosis*. This process, in a tradition which goes back to the Greeks, has commonly been regarded as involving three (or four) factors: that which the sign refers to, and that effect on some interpreter in virtue of which the thing in question is a sign to that interpreter. These three components in semiosis may be called respectively, the *sign vehicle,* the *designatum,* and the *interpretant;* the *interpreter* may be included as a fourth factor. These terms make explicit the factors left undesignated in the common statement that a sign refers to something for someone" (Morris, 1938:3).

Morris described the psychological, sociological and pragmatic use of signs and how different disciplines used them to convey meaning. Consider the imagery of the control chart, and how it functions as a means of communication. The vertical axis stands to project the scales of the variation in the thing being measured; straight line with symbols, probably numerical. The base of this line connects to the vector, often representing time. The two lines form the axis of the chart on which the data may be plotted. Then we have the mean or median, drawn parallel to the vector, representing the 'heart' of the process being measured. The mean appears static and could be thought of as the substance or 'being'. However, we know it is not static, and subject to being moved when positive or negative shifts in performance are recorded.

Control limits, proudly guard their 3 sigma boundaries. Unknown but constant systems of chance causes reside safely in the limits. Their destiny unfolds before them. Present, predicted future, historical data, repeated - ad infinitum. Low betide the known assignable causes which appear unwittingly outside the control limits, their fate now unknown.

An (almost) insignificant datum appears on a chart. A dot, a star or a square, it matters not. Yet where the dot falls, determines the fate of the process' future, while relating to its past performance. Equally, the dot represents the precise and accurate measuring process that has taken place, determining its position on the chart. The dots are connected, normally with straight lines. They represent connectedness, relationships and the spatial and temporal nature of the thing being measured. But more importantly, they are a symbol of being, in the flux of becoming.

The control chart is a sign conveying messages from a process. The chart had to be designed, so that it would convey flux, constant systems of chance causes and known assignable causes. It had to be effective for engineers and scientists to use on a daily basis. Dwiggins (1928/48), a major contributor to advertising design, provided some interesting ideas for effective communication. For instance he described a concept called rhythm:… "the thing that puts life into design keeps it from being dead and mechanical. In graphic space design it may be crudely defined as a living ratio or size relation among various parts" (p.51). So a badly designed chart may not convey the meaning of flux and assignable causes. The mean and the control limits can be very effective in this respect.

Next we should consider what he called 'unity'. If we made both axis of a time series chart the same length, this would be unity. However, this might portray the variation and the time in unequal doses and convey the wrong image and message. It's about what catches the eye. "What happens at this critical instant may be called the question of 'primary contact and reaction'….the reader's eye is caught by the *spots* in the first flash of perception and is attracted or repelled, and that he then takes cognisance of their meaning"(ibid.:69). So, for instance, is a chart that shows data rising to the far right corner, good, or bad? If the data on the scalar are presented in inches instead of feet, the chart may be far more dramatic in appearance. So while we accept the notion of the control chart as an effective semiotic device, we should also be aware that if it is designed badly it may convey the 'wrong' message.

Conclusion

The aim of this paper was to uncover some of the ideas behind Shewhart's work. For many, Shewhart is a reference point to some distant past. Shewhart's work is clearly a major academic and practical thesis, which has still to achieve universal acclaim. What this paper has shown, is a collection of some of the less well known sources of material, that Shewhart used to construct his thesis. I have deliberately avoided the main stream texts of Fisher and Keynes for example, and tried to focus on the philosophy of science behind his work. Indeed, it is my contention, that to fully understand Shewhart's work, one needs to understand the notions of being and becoming and the associated arguments behind these metaphysical concepts.

What this paper has shown, is that Shewhart was a skilful writer, and he wove a very tight thesis, avoiding the paradoxes and solipsist traps, that await the less wary adventurers in this field. I have called his style of writing a *discourse of flux,* providing a few of the numerous examples of this composition. It would seem logical to focus on Shewhart's style of writing in the teaching of his theories, for they are part and parcel of understanding the philosophical concepts behind his ideas. By combining the theories from the philosophy of science, statistical and probability theory, he broke new ground. More significantly he made his work accessible to engineers and scientists who could use their 'judgement pragmatically' with his inventions of the control chart and chance and assignable cause systems.

Bibliography

Blankenship, B. and Petersen, P.B., (1999) W.Edwards Deming's Mentor and Others Who Made an Impact on His Views During the 1920s and 1930s. *Journal of Management History.* Vol 5, No 8, pp 454-467. MCB University Press.

Deming, W.E., (1986) *Out of The Crisis,* MIT Press, Cambridge, Massachusetts.

Deming, W.E. (1991) "A Tribute to Walter A. Shewhart On the Occasion of the 100th Anniversary of His Birth" *SPC INK Newsletter* Winter 1991. SPC Press, Inc.

Deming, W.E., (1993) (2nd edition) *The New Economics,* MIT Press, Cambridge, Massachusetts.

Dukich, T. (2002) Alfred North Whitehead's "Philosophy of Organism" as the Foundation of W.Edwards Deming's "New Philosophy". Adventure of Whitehead's Metaphysics in 21st Century Reality. *Proceedings of the 8th Annual Research Seminar* Fordham University, New York. (February: 2002)

Dwiggins, W.A., (1928/48) Revised edition. *Layout in Advertising.* Harper and Brothers. USA.

Eddington, A.S. (1928/9) *The Nature of the Physical World.* Cambridge University Press. London

Fisher, R.A. (1925/48) *Statistical Methods for Research Workers.* Oliver Boyd and Son, Edinburgh

Goodwin, H.M., (1908/1920 edition) *Elements of The Precision of Measurements and Graphical Methods.* McGraw-Hill Book Company, New York.

Guthrie, W.K.C., (1971) *A History of Greek Philosophy. Volume 1: The Earlier Presocratics and the Pythagoreans,* Cambridge University Press, Cambridge

Keynes, J.M. (1921) *A Treatise on Probability*. Macmillan Company: New York.

Lewis, C.I., (1929/1956) *Mind and The World Order: Outline of a Theory of Knowledge.* Dover publications: New York.

Lowe, V. (1990) *Alfred North Whitehead, The Man and His Work, Vol II.*

Mauléon, C. and Bergman, B. (2002) On the Theory of Knowledge in the Quality Movement- C.I. Lewis' Contribution to Quality Pioneers. *Proceedings of the 8th Annual Research Seminar* Fordham University, New York. (pp 156-164: February: 2002)

Morris, C.W., (1938) Foundations for the Theory of Signs. *International Encyclopaedia of Unified Science.* Volume 1. Number 2. The University of Chicago Press, Chicago, Illinois.

Plato, (1934)(Edited by Cornford, F.M) *Plato's Theory of Knowledge: The Theaetetus and the Sophist translated with a running commentary.* Routledge &Keegan Paul, London.

Shewhart, W.A., (1931/1980) *Economic Control of Quality of Manufactured Product* ASQC: Milwaukee.

Shewhart, W.A., Deming, W.E., (ed) (1939/1986) *Statistical Method from The Viewpoint of Quality Control.* Dover Publications: New York.

Stebbing, L.S. (1930/45) *A Modern Introduction to Logic.* Methuen and Company. London.

Whitehead, A.N. (1929/60) *Process and Reality* The MacMillan Company. New York.

Wilcox, M. (2002) Whither the Pragmatism? *Proceedings of the 8th Annual Research Seminar.* Fordham University, New York (pp 258-269: February:2002)

Wilcox, M. (2003) Prediction and Pragmatism in Shewhart's Theory of Statistical Control *Management Decision (Focus on Management History)* (forthcoming)