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Evolution of the PDCA Cycle

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Summary

The PDCA cycle had its origin with Dr. W. Edwards Deming's lecture in Japan in 1950. Where did he get these ideas and how have these ideas evolved since those lectures?

This presentation will move from the 1600's with Galileo and the philosophy of science through the evolution of the scientific method and the science of improvement. Walter Shewhart in 1939 applied the scientific method with his cycle: specification-production-inspection. W. Edwards Deming in 1950 modified the Shewhart cycle: design of the product, make it, put it on the market, test it through market research, then redesign the product."

The Japanese interpretation of the "Deming wheel" in Dr. Deming's lectures of 1950 and 1951 lead to the plan-do-check-action or PDCA cycle. This cycle was integral to the Japanese QC, TQC, and QC circle activities. Deming introduced his Shewhart cycle for learning and improvement in the USA in 1986. Dr. Deming introduced a more abbreviated PDSA cycle in 1993.

In 1994, the PDSA cycle was accompanied by three questions to aid in the planning step of the PDSA Cycle. In 1996 and 2009 publications, the PDSA cycle was broadened to include strategies and methods to develop, test, and implement changes that would result in improvement. This version was called the "Model for Improvement." As an introduction to a framework for improvement, the model for improvement has been found to support improvement efforts in a full range from the very informal to the most complex.

Keywords

Scientific Method, W. Edwards Deming, PDCA, PDSA, Model for Improvement

1. Introduction to the Scientific Method (1600-1900)

When did the science of improvement begin? Juran [1] states that the origin of handicraft industries and their quality control in China's history can be traced back from the 16th century B.C. Galileo is often credited with being the father of modern science and the first person to begin the development of the scientific method[i]. Other authors give the credit to Aristotle for the beginning of the method. Recently, Steffens [2] has credited Ibn al-Haytham (965-1040) as being the first scientist. Morgan [3] has also described the contributions of Ibn al-Haytham and the use of empiricism and learning through testing at around 1020:

> *…The core lessons of his writings is that science must be based on empirical methods. As far as we know, Ibn al-Haytham is the first scholar to absolutely apply this principle of empiricism without mercy. While the Greeks had understood*

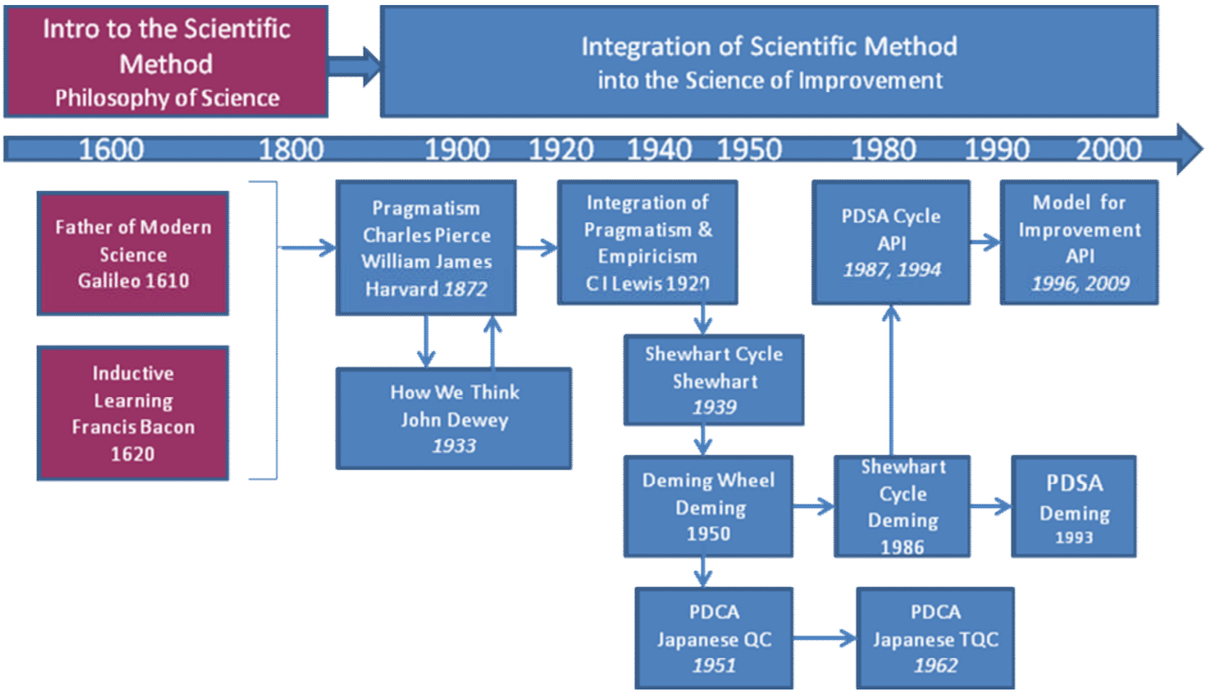
experimentation and empiricism, they were too often prone to proving their point through intellectual theorizing.

Ibn al-Haytham knows better. No human mind, no matter how brilliant, is capable of theorizing the physical world. It must be measured and observed. Throughout his writings, he will make clear that he questions all scientific assumptions until proven by testing. Like the scientists of a thousand year later, he will take no scientific statements on faith.

In studying the history and evolution of the scientific method it is very difficult to assign a birth year and inventor. The method evolved with many contributors from philosophy and the sciences starting with Ibn al-Haytham.

In this section we will give a brief sketch of the evolution of the scientific method beginning with Galileo in 1610 up to the early 1900's. In the next section we will integrate the scientific method into the science of improvement with the Deming wheel, the PDCA Cycle, and the PDSA Cycle evolving in the last 100 years. Figure 1 depicts both of these two timeframes.

Figure 1 – Evolution of the Scientific Method



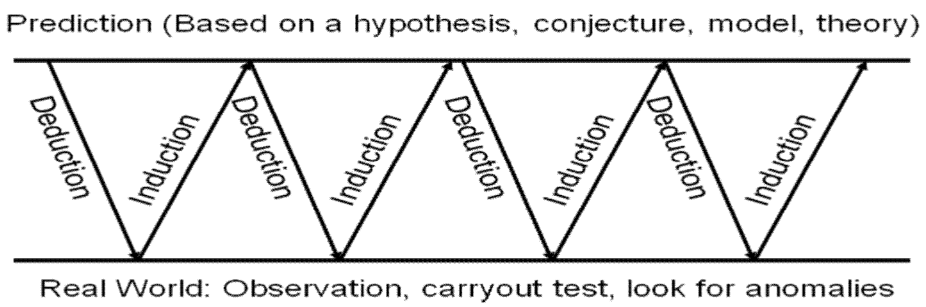
1.1 Development of the Engine for the Scientific Method: Deductive and Inductive Logic

Galileo Galilei (1564-1642) is considered by many to be the father of modern science. Galileo made original contributions to the science of motion and strengths of materials by combining designed experiments and mathematics. Conducting designed experiments are a cornerstone of science and the scientific method. These experiments were documented in Galileo's final book, *The Discourses and Mathematical Demonstrations Relating to Two New*

Sciences[ii]. As Galileo carried out experiments on the strengths of materials and the study of objects in motion, he established a major part of what we know as the scientific method.

Galileo and Francis Bacon (1561-1626) could not be more different. Galileo was first and foremost a scientist. Bacon will make his contribution as a philosopher who is very concerned about the manner in which knowledge is developed. Bacon believes that the generation of knowledge needs to follow a planned structure. Science at the time depended on deductive logic to interpret nature. Bacon insisted that the scientist should instead proceed through inductive reasoning, from observations to axiom to law. Bacon's contribution completed the interplay between deductive and inductive logic that underlies how we advance knowledge. Figure 2 describes this movement from theory to observation and back again.

Figure 2: Interplay between Deductive and Inductive Reasoning[iii]



1.2 The Scientific Method Becomes Pragmatic

A group of young men met in Cambridge outside of Harvard in January of 1872 to form a discussion group called the "Metaphysical Club." This group of people would forever be linked with the uniquely American philosophy that we call "pragmatism." Pragmatism can be defined as:

> *"…an American movement in philosophy founded by C. S. Peirce and William James and marked by the doctrines that the meaning of conceptions is to be sought in their practical bearings, that the function of thought is to guide action, and that truth is preeminently to be tested by the practical consequences of belief[iv]"*

Charles Peirce recalled the formation of the study group in 1907:

> *"It was in the earliest seventies that a knot of us young men in Old Cambridge, calling ourselves, half-ironically, half-defiantly, The Metaphysical Club, -- for agnosticism was then riding its high horse, and was frowning superbly upon all metaphysics,--used to meet, sometimes in my study, sometimes in that of William James."*

The group had become disenchanted with typical approaches to philosophy. In 1872, William James had a breakthrough in studying the work of the French philosopher, Charles Renouvier. Menand [4] notes that Renouvier had taught James two things[v]:

- Philosophy is not a path to certainty, only a method for coping,
- What makes beliefs true is not logic but results.

Pierce too was influenced by Immanuel Kant (1724-1804). Kant's book, *Critique of Pure Reason* was probably the source of the term "pragmatism." Menand quotes Kant, "Such contingent belief, which yet forms the ground for the actual employment of means to certain actions, I entitle *pragmatic belief*...that is firm belief—is betting...Thus pragmatic belief always exists in some specific degree, which, according to differences in the interests at stake, may be large or small."[vi] Later in the 20th century, Dr. W. Edward Deming, who was very much influenced by the pragmatist philosophy, would often refer to his belief in a prediction as being "high or low," in effect placing his bets on the future.

1.3 John Dewey Delivers Pragmatism to the 20th Century: Furthers the Need for Experiments

Dewey [5] also notes that Pierce credits Kant with the distinction between *pragmatic* and *practical*, "The latter term applies to moral laws which Kant regards as *a priori*[1], whereas the former term applies to the rules of art and technique which are based on experience." Dewey elaborates further on the thinking of Pierce, "As a logician he was interested in the art and technique of real thinking, and especially interested, as far as pragmatic method is concerned, in the art of making concepts clear, or of construing adequate and effective definitions in accord with the spirit of scientific method."[vii]

While the founders of pragmatist school of philosophy started in the 19th Century, a follower of these founders would become a giant in the philosophy of how we learn and act on our beliefs in the world. John Dewey (1859-1952) became a leading proponent of *pragmatism* and his works would influence philosophy, education, religion, government, and democracy around the world. The pragmatism of James and Dewey could be summarized in the statement: people are the agents of their own destinies[viii].

Dewey drew a strong distinction between how philosophy was practiced and the intent of pragmatism; Menand noted, *"Dewey thought that ideas and beliefs are the same as hands: instruments for coping. An idea has no greater metaphysical stature than, say a fork. When your fork proves inadequate to the task of eating soup, it makes little sense to argue about whether there is something inherent in the nature of forks or something inherent in the nature of soup that accounts for the failure. You just reach for a spoon."*[ix] In this regard, Dewey [6] observed, "The scientific experimental method is…a trial of ideas; hence even when practically—or immediately—unsuccessful, it is intellectual, fruitful; for we learn from our failures when our endeavors are seriously thoughtful."[x]

1.4 C.I. Lewis Builds on the Pragmatist Model and Provides a Bridge for the PDCA Cycle

Clarence Irving Lewis (1883-1964) an American pragmatist educated at Harvard and was heavily influenced by both William James and Charles Pierce. Lewis would go to teach at

[1] Definition: *a priori* - based on hypothesis or theory rather than experiment. Aristotle maintained that women have fewer teeth than men; although he was twice married, it never occurred to him to verify this statement by examining his wives' mouths - Bertrand Russell (1872-1970), *Impact of Science on Society (1952).*

the University of California from 1911 to 1919 and at Harvard from 1920 until his retirement in 1953. His first book, *Mind and the World Order,* would have enormous influence on Dr. Walter A. Shewhart and Dr. W. Edwards Deming. Lewis set out three main ideas in *Mind and the World Order* to further the pragmatist's influence[xi]:

1. *a priori* truth is definitive and offers criteria by means of which experience can be discriminated;
2. the application of concepts to any particular experience is hypothetical and the choice of conceptual system meets pragmatic needs; and
3. the susceptibility of experience to conceptual interpretation requires no particular metaphysical assumption about the conformity of experience to the mind or its categories.

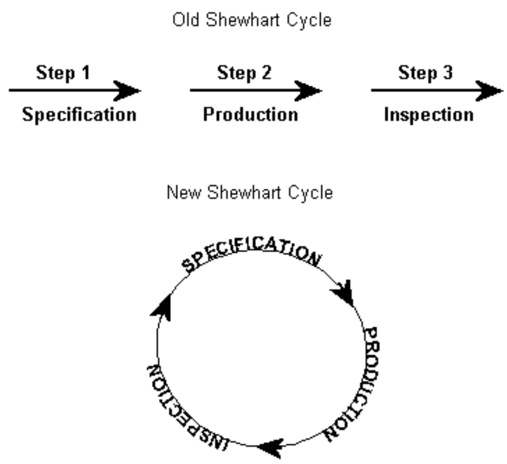
2. Integration of the Scientific Method and Improvement (1900-2009)

In this section the work C.I. Lewis forms the basis of the Shewhart Cycle, the Deming Cycle, the PDCA Cycle, and the PDSA Cycle.

Dr. Walter A. Shewhart [7] displayed the first version of the "Shewhart Cycle." Figure 3 contrasts the idea of the cycle with the old view of specification, production, and inspection. Shewhart wrote,

> *These three steps must go in a circle instead of in a straight line, as shown . . . It may be helpful to think of the three steps in the mass production process as steps in the scientific method. In this sense, specification, production, and inspection correspond respectively to making a hypothesis, carrying out an experiment, and testing the hypothesis. The three steps constitute a dynamic scientific process of acquiring knowledge.*

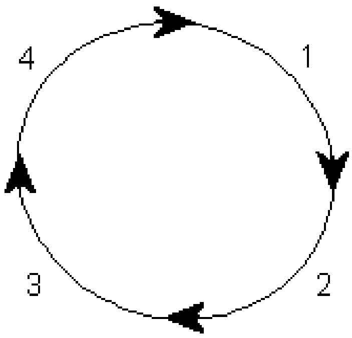
Figure 3 – Shewhart Cycle, 1939



Shewhart's 1939 book was edited by a 39-year-old W. Edwards Deming. In 1950, Deming [8] modified the Shewhart cycle at a Japanese Union of Scientists and Engineers (JUSE) sponsored eight-day seminar on statistical quality control for managers and engineers. His straight line: Step 1- Design, Step 2 – Produce, Step 3 - Sell was converted to a circle with a forth step added: Step 4 - Redesign through marketing research.

Deming stressed the importance of constant interaction among design, production, sales, and research and that the four steps should be rotated constantly, with quality of product and service as the aim. Deming's Shewhart cycle was modified slightly in 1951 and is shown in Figure 4.The Japanese called this the "Deming wheel."

Figure 4 – Deming Wheel, 1951



1. Design the product (with appropriate tests).
2. Make it; test it in the production line and in the laboratory.
3. Put it on the market.
4. Test it in service, through market research, find out what the user thinks of it, and why the non-user has not bought it.
5. *Re*-design the product, in the light of consumer reactions to quality and price.
Continue around and around the cycle.

2.1 The PDCA Cycle is Born

Imai [9] stated the Japanese executives recast the Deming wheel from the 1950 JUSE seminar into the Plan-Do-Check-Act (PDCA) cycle. Imai shows the correlation between the Deming wheel and the PDCA cycle in Figure 5.

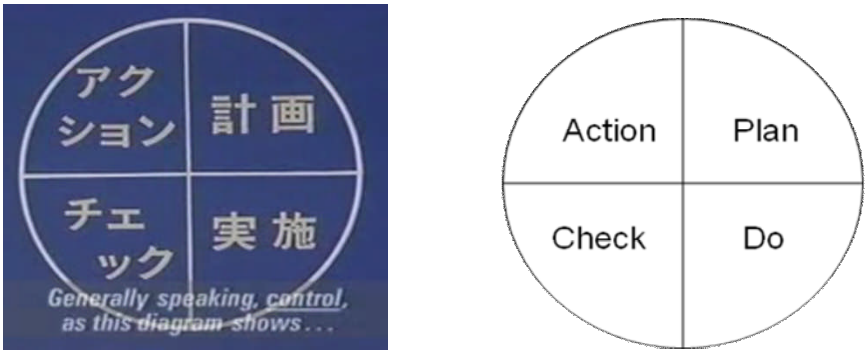
Figure 5 – Correlation between the Deming Wheel and the Japanese PDCA Cycle

1. Design -- Plan	Product design corresponds to the planning phase of management
2. Production -- Do	Production corresponds to doing-making, or working on the product that was designed
3. Sales -- Check	Sales figures confirm whether the customer is satisfied
4. Research --Action	In case of a complaint being filed, it has to be incorporated into the planning phase, and action taken for the next round of efforts

Imai didn't provide any details as to who and how the executives translated the Deming Wheel into the PDCA Cycle. However, we found no evidence to dispute Imai's translation.

The resulting PDCA cycle is shown in Figure 6. The four step cycle for problem solving includes planning (definition of a problem and a hypothesis about possible causes and solutions), doing (implementing), checking (evaluating the results), and action (back to plan if the results are unsatisfactory or standardization if the results are satisfactory). The PDCA cycle emphasized the prevention of error recurrence by establishing standards and the ongoing modification of those standards. Even before the PDCA cycle is employed, it is essential that the current standards be stabilized. The process of stabilization is often called the SDCA (standardize-do-check-action) cycle. Ishikawa [10] stated: “If standards and regulations are not revised in six months, it is proof that no one is seriously using them.”

Figure 6 – Japanese PDCA Cycle, 1951



Ishikawa redefines the PDCA cycle to include determining goals and target and methods for reaching the goals in the planning step. In the do step, he includes training and eduction to go with the implementation. He say good control means allowing standards to be revised constantly to reflect the voices of consumers and their complaints was well as the requirements of the next process. The concept behind the term control (kanri) is deployed throughout the organization.

By the 1960’s the PDCA cycle in Japan had evolved into an improvement cycle and a management tool. Lilrank and Kano [11] state the 7 basic tools (check sheet, histograms, Pareto chart, fishbone diagram, graphs, scatter diagrams, and stratification) highlight the central principle of Japanese quality. These tools together with the PDCA cycle and the QC story format became the foundation for improvement (kaizen) in Japan.

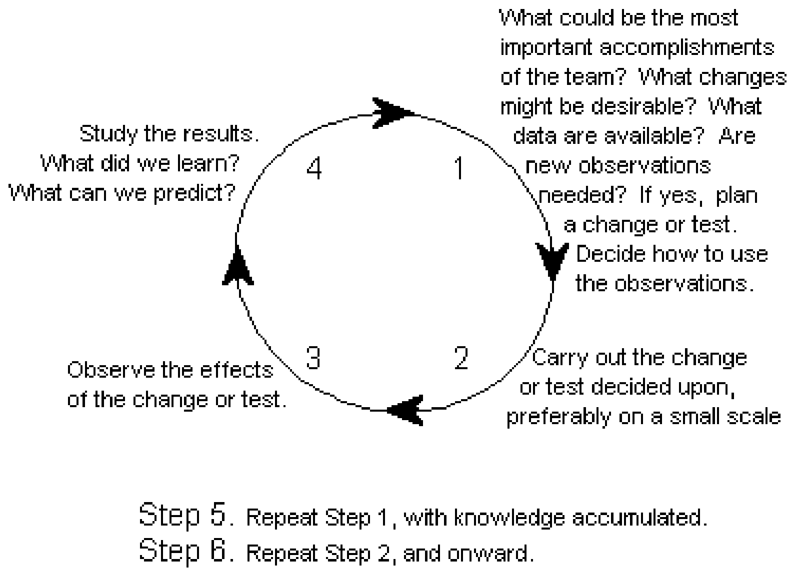
2.2 Deming Develops the PDSA Cycle

Deming [12] reintroduces the Shewhart cycle in 1986. He states that it came directly from the 1950 version. Figure 7 illustrates this procedure to follow for improvement. He states:

> *Any step may need guidance of statistical methodology for economy, speed, and protection from faulty conclusions from failure to test and measure the effects of interactions.*

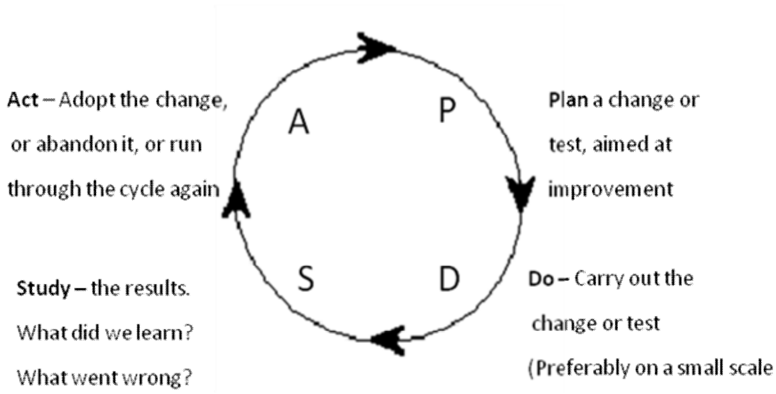
In his 4-day seminars in the 1980’s, Deming presented this version. Also, he warned Western audiences that the plan, do, check, and act version is inaccurate because the English word “check” means “to hold back.” Deming stated [13] in the Moen, Nolan, and Provost [14] manuscript, “… be sure to call it PDSA, not the corruption PDCA.”

Figure 7 – Shewhart Cycle: Deming, 1986



Deming [15] again modified the Shewhart cycle in 1993 and called it the Shewhart cycle for learning and improvement- the PDSA cycle. He described it as a flow diagram for learning, and for improvement of a product or of a process. It is illustrated in Figure 8.

Figure 8 – PDSA Cycle: Deming, 1993



In 1987 Moen and Nolan [16] presented an overall strategy for process improvement with a modified version of Deming's cycle of 1986. The planning step of the improvement cycle required prediction and associated theory. The third step compared the observed data to the prediction as a basis for learning.

Langley, Nolan, and Nolan [17] refined the improvement cycle and called it the PDSA Cycle. This API, 1994 version is given in Figure 9. The use of the word "study" in the third phase of the cycle emphasizes that the purpose of this phase is to build new knowledge. It is not enough to determine that a change resulted in improvement during a particular test. As you build your knowledge, you will need to be able to predict whether a change will result in improvement under the different conditions you will face in the future. In addition, they added three basic questions to supplement the PDSA cycle:

1. What are we trying to accomplish?
2. How will we know that a change is an improvement?
3. What changes can we make that will result in improvement?

2.3 The PDSA Cycle Grows a Framework

Langley, Moen, Nolan, Nolan, Norman, and Provost [18, 19] combined the three questions and the PDSA cycle to form the basis of the API Model for Improvement (see Figure 10). The three questions define the aim, measures, and possible changes. Seventy-two change concepts are given to provide a starting point for use of the PDSA cycle for developing, testing, implementing, and spreading changes that result in improvement. The model can be applied to the improvement of processes, products, and services in any organization, as well as improving aspects of one's personal endeavors. The model attempts to balance the desire and rewards from taking action with the wisdom of careful study before taking action.

Figure 9 – PDSA Cycle, 1994

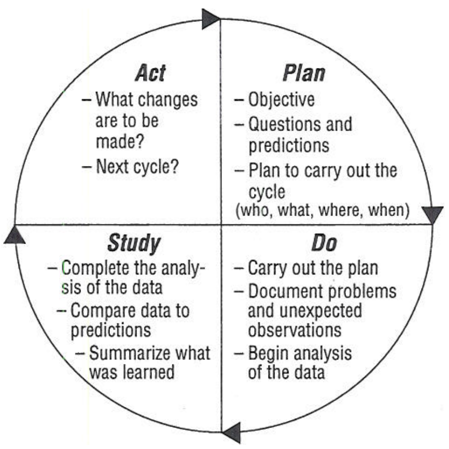
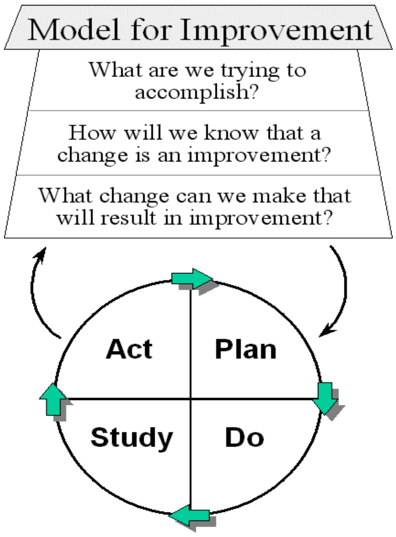


Figure 10 – Model for Improvement, 1996, 2009



The model is both widely applicable and easy to learn and use. The model supports improvement efforts in a full range from the very informal to the most complex (e.g. introduction of a new product line or service for a major organization).

3 Conclusions

The PDCA, PDSA, and the Model for Improvement have their roots in the scientific method and the philosophy of science that has evolved for more than 400 years. We believe that the Model for Improvement is an important evolution of the PDCA cycle. Experience with the model since its development in 1994 shows that it:

- Is applicable to all types of organizations and to all groups and levels in an organization
- Provides a framework for the application of improvement methods and tools guided by theory of knowledge:
    - Encourages planning to be based on theory
    - Theory leads to appropriate questions which provide the basis for learning.
    - Questions lead to predictions which guide the user in identifying the necessary data, methods and tools to answer the questions relative to the theory in use.
    - Emphasizes and encourages the iterative learning process of deductive and inductive learning.
- Allows project plans to adapt as learning occurs
- Provides a simple way for people to empower themselves to take action that leads to useful results in the *pragmatic* tradition of learning.
- Facilitates the use of teamwork to make improvements

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[ii] Unlike the *Dialogue Concerning the Two Chief World Systems* (1632), *The Discourses and Mathematical Demonstrations Relating to Two New Sciences* (1638) was not published with a license from the Inquisition. In 1633 the Roman Inquisition had banned publication of any work by Galileo, including any he might write in the future. The Two Sciences was finally published outside the jurisdiction of the Inquisition in The Netherlands.
[iii] Figure is adapted from *Statistics for Experimenters*, George Box, William Hunter, and Stuart Hunter, John Wiley & Sons, NY, 1978.
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