Insights and Innovations via the Expanded Funnel Experiment

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Abstract

Deming's 14 Points for Management are widely cited or included in most of management texts or articles; unfortunately, often superficially without a context. As a result, some of these points are perceived as just a theory or an ideal. In the Expanded Funnel Experiment, additional instruments and factors are introduced. The funnels will have three different sizes each attached with a different length of string. Instead of marbles, green (or red) beans are used. The target with the bull's eye in the center has two different dimensions. With different permutations of various instruments and rules of funnel adjustment, a wide range of scenarios are devised. For example, this rich experiment allows us to physically illustrate each of the 14 Points, and can vividly demonstrate Common Cause and Special Cause, as well as the concept of Tampering. Thus, for example, Points #10 and #11 of the 14 Points become plain to all. Another significant outcome is to provide a relatively robust mechanism to explain Deming's management and philosophy as a foundation to Peter Senge's The Fifth Discipline. Further, it offers an enlightening perspective to understanding the limitations of Kaplan and Norton's Balanced Scorecard, and Motorola's Six Sigma. A discussion of the 4 elements of Deming's System of Profound Knowledge is also an important aspect of the Expanded Funnel Experiment.

1. Introduction

Deming's 14 Points for Management are widely cited or included in most of operations and quality management texts or articles. However, they are often presented in a superficial fashion without a context. Although some of these points are not difficult to understand, some others are not so comprehensible. They are perceived as just a theory or an ideal. Over the years, one of the major difficulties encountered in teaching Deming's management philosophy to my MBA/EMBA or executive students, is that the students are usually unable to accept Points #10 and #11 of the 14 Points [See Table 3]. When it comes to Point #12 suggesting abolishment of the annual or merit rating, the reaction is even stronger, protesting at times. The reality seen in the corporate world seems enormously distant from the ideas embedded in these points. Managers and executives groomed and developed in the prevailing corporate system almost have no chance to experience the other side of the world that subscribes to Deming's management philosophy. Time and time again I struggled to present Deming's principles and management method as a viable alternative to the prevailing system of management that is so deeply entrenched in the modern corporate world. The characteristics of the prevailing system of management are the symptoms developed from the deadly diseases identified by Deming (2000). More recently, Peter M. Senge (2006) echoes Deming's foresight by characterizing these features into eight basic elements, namely, management by measurement, compliance-based cultures, managing outcomes, "right answers" vs. "wrong answers," uniformity, predictability and controllability, excessive competitiveness and distrust, and loss of the whole. Due to the widespread influence of the Western media and publications, the practice of the prevailing system of management not only afflicts most companies in the Western world, as Deming pointed out long ago, but also many of the Asian companies and organizations today.

Troubled by executive students' lukewarm response to my delivery, I sought to improve the way the funnel experiment was conducted. As I standardized the experimental settings, I was able to achieve the intended purpose of the original experiment more consistently. Over the years in the process of fine-tuning the experimental procedure, innovative ideas were gradually incorporated into the experiment. I discovered that the expanded experiment is not only able to illustrate the concepts of tampering, special/assignable causes and common/unassignable causes, but also very effective in explaining the 14 Points. Particularly, the obstacles to appreciating Points #10 and #11 often can be overcome.

The purpose of this paper is to share how the Expanded Funnel Experiment can be used to teach Deming's 14 Points and System of Profound Knowledge. The expanded experiment may serve as a relatively robust mechanism to explain Deming's management and philosophy as a foundation to Peter Senge's The Fifth Discipline. Through the hands-on experience of the expanded experiment and the lessons learned, it becomes clear to the students why most companies failed in adopting management approaches such as Kaplan and Norton's Balanced Scorecard, Motorola's Six Sigma, Toyota's JIT, and many others.

2. The Original Funnel Experiment

The purpose of the original funnel experiment (Deming, 1994, pp190-206; Deming, 2000, pp327-332) is to demonstrate by theory the losses that are caused by tampering – management by results.

2.1. Materials required
1) A funnel
2) A marble that will fall through the funnel
3) A table with a cloth on it
4) A holder for the funnel

2.2. Procedure
1) Indicate a dot on the tablecloth as the target
2) Apply one of the rules, drop the marble through the funnel
3) Mark the spot where the marble comes to rest
4) Continue through 50 drops (using one marble).

2.3. Rules
1) Rule 1: Always aim the funnel at the target.
2) Rule 2: At each drop, move the funnel from its last position to compensate for the last error. (the decision, local, micro level)
3) Rule 3: As each drop, use the target as the reference, move the funnel an equal but opposite distance from the target. (the policy, systemic, macro level)
4) Rule 4: After the first drop, set the funnel right over the last drop.

3. The Expanded Funnel Experiment

The purpose of the Expanded Funnel Experiment is in addition to demonstrating the losses that are caused by tampering; it further physically illustrates each of the 14 Points.

3.1. Material required

1) A funnel of the three different sizes (large, medium, or small) each attached with a string of a given length
2) A string: one of the three different lengths (30cm, 26cm, or 17cm)
3) A target: one of the two different dimensions (circle or oval)
4) 30 pre-allocated green beans
5) A transparent plastic ruler
6) A record form

3.2. Procedure

1) Form groups of 3 members each assigned with a role as the funnel holder, the bean releasr, or the hitting-spot recorder
2) Allocate each team with a unique set of experiment instrument (6 possible settings as listed in the 6 rows of Table 1)
3) Apply Rule 1:
    a. Draw a bean from the container and drop it naturally (without exerting force or aiming at the hole) along the rim of the funnel
    b. Mark the spot where the bean first hits the target
    c. Continue the above process of draw-drop-mark until all 30 beans are done
    d. Summarize the distribution of the 30 spots in the record form
4) Repeat the experiment applying Rule 2 and Rule 3 respectively

3.3. Rules: Rule 1, Rule 2, and Rule 3

Figure 1: The instruments used in the Expanded Funnel Experiment

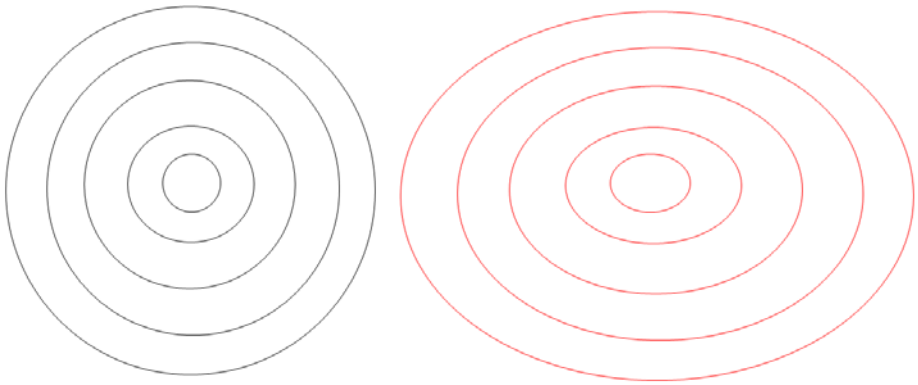

Figure 2: The targets

4. Experimental Result and Analysis

The results shown in Tables 1 and 2 are summarized basing on the Expanded Funnel Experiment conducted by selected groups[1] from my MBA, executive MBA, and General Management Program executive classes at National University of Singapore Business School from 2012 to 2014. As opposed to the original experiment of mere 4 scenarios, namely, one fixed setting applying four rules, the expanded experiment has a total of 18 scenarios, namely, permutations of 3 funnel sizes/string lengths, 2 target dimensions, and 3 rules. The numbers of marks (hits) in the bull's eye, in each of the rings, and beyond the target were recorded, respectively. Ten groups were selected for each of the six funnel-target-height combinations. A total of 1080 (180x6) raw statistics, i.e., the number of marks (hits), were collected. Each of the summary statistics, e.g., average and standard deviation, shown in Tables 1 and 2 was derived from 10 raw observations. Obviously, these observations can change significantly due to human errors or variability introduced during the experiment. Nevertheless, the general pattern of marks/hits distribution is rather clear as seen in Table 1 and Table 2. For example, the "out" column in Rule 1 shows 0.00 bean hits outside the 4 rings, whereas in the out column for Rule 2 and Rule 3, we see more and more beans hit outside the 4 rings.

Table 1 The Expanded Funnel Experiment: Average hits in each ring of the target based on 10 (T: the bull's eye; Out: outside of Ring 4).

μ			Rule 1						Rule 2						Rule 3					
Funnel	Target	Height	T	Ring 1	Ring 2	Ring 3	Ring 4	Out	T	Ring 1	Ring 2	Ring 3	Ring 4	Out	T	Ring 1	Ring 2	Ring 3	Ring 4	Out
L	Circular	30cm	4.00	11.80	10.40	3.60	0.20	0.00	3.40	10.20	11.70	4.00	0.40	0.30	1.70	4.10	9.50	7.50	4.10	3.10
M	Circular	26cm	7.00	16.70	5.90	0.40	0.00	0.00	5.30	10.30	10.70	2.90	0.70	0.10	4.90	10.00	8.20	3.90	2.40	0.60
S	Circular	17cm	19.30	9.40	1.30	0.00	0.00	0.00	17.30	11.10	1.50	0.10	0.00	0.00	12.00	10.10	7.10	0.80	0.00	0.00
L	Oval	30cm	5.20	12.20	11.10	1.40	0.10	0.00	4.80	10.30	10.60	3.70	0.50	0.10	3.00	6.80	7.60	5.20	4.30	3.10
M	Oval	26cm	10.50	15.10	4.00	0.30	0.10	0.00	6.80	12.90	7.10	1.60	1.20	0.40	4.30	8.30	6.30	5.00	2.80	3.30
S	Oval	17cm	21.13	6.71	0.44	0.09	0.03	0.00	15.81	10.10	2.34	0.50	0.31	0.11	11.84	9.61	4.11	2.45	0.97	0.63

[1] Outlier groups, referring to groups with known human errors or not following the rules during the experiment, were excluded from consideration. A total of sixty groups were selected.

Table 2 The Expanded Funnel Experiment: Standard deviation of hits in each ring of the target (T: the bull's eye; Out: outside of Ring 4).

σ			Rule 1						Rule 2						Rule 3					
Funnel	Target	Height	T	Ring 1	Ring 2	Ring 3	Ring 4	Out	T	Ring 1	Ring 2	Ring 3	Ring 4	Out	T	Ring 1	Ring 2	Ring 3	Ring 4	Out
L	Circular	30cm	3.20	5.14	4.33	3.92	0.42	0.00	1.84	3.16	2.11	3.27	0.52	0.67	1.83	3.73	4.53	3.92	4.25	4.89
M	Circular	26cm	4.37	3.23	3.31	0.97	0.00	0.00	3.37	3.65	3.86	2.81	1.57	0.32	3.81	5.89	4.02	3.28	4.12	1.35
S	Circular	17cm	8.27	5.62	3.43	0.00	0.00	0.00	8.56	6.89	2.59	0.32	0.00	0.00	7.99	5.11	7.03	1.32	0.00	0.00
L	Oval	30cm	2.97	2.86	4.01	1.07	0.32	0.00	2.10	3.83	3.10	2.58	0.85	0.32	3.46	5.49	4.30	3.19	4.60	4.89
M	Oval	26cm	4.38	3.78	2.79	0.95	0.32	0.00	4.92	4.09	4.72	2.50	3.46	1.26	5.23	4.74	3.20	5.93	2.62	3.97
S	Oval	17cm	3.01	2.91	0.42	0.00	0.00	0.00	5.82	4.03	2.69	0.95	0.00	0.00	8.80	5.55	3.99	3.63	1.48	0.95

4.1. The effect of the size of the funnel (i.e., your machine or equipment)

The funnel may be considered equivalent to the machine or equipment employed to produce the product or service, which is marks (hits) distribution in this experiment. A smaller funnel (fitted with a shorter string) represents an organization adopting a machine with higher precision or performance (and following a better defined operating method). As shown in Table 1, the mean of the distribution of marks (hits) congregates towards the bull's eye as the funnel size/height (string length) is reduced from large/30cm to medium/26cm, and to small/17cm. The pattern is similar for both the circular target as well as the oval one. The standard deviation of the distribution of marks (hits) also follows the similar pattern as revealed in Table 2.

4.2. The effect of the size/shape of the target (i.e., your customer's specification)

The target may be considered equivalent to the customer's specification. The bull's eye represents the ideal or target requirement or performance. Moving away from the bull's eye towards outer rings represents the performance deteriorates or deviates further from the ideal state. It is no longer acceptable to the customer when it goes beyond the outermost ring. Two types of target are considered in the experiment, namely, circular and oval. Oval represents the specification of a normal requirement. Circular represents a tighter specification with a slightly more stringent requirement. Under Rule 1, it is clear that a less stringent specification produces more hits on the bull's eye, and generally the distribution concentrates more towards the bull's eye, too. The pattern, however, is not consistent when Rule 2 or Rule 3 is adopted; especially when a small funnel is used. Apparently interaction among factors is at work. More will be discussed later.

4.3. The effect of the height at which the funnel is held (i.e., your method/execution)

The height at which the funnel is held or the length of the string attached to the funnel may be considered equivalent to the level of consistency or precision of the execution or the method employed. The shorter the string is, the more consistent/precise the method/execution is. To keep the experiment scenarios more manageable, we attached a long (30cm), a medium (26cm), and a short (17cm) string to the large, medium, and small funnel respectively. The pattern of the distribution is observed as described in Sec 4.1.

4.4. The effect of the rules on different funnel sizes/heights (i.e., decision/policy)

The rules may be considered equivalent to the different decisions or policies adopted by managers or companies. Rule 1 represents constancy of purpose. It may also mean that a decision or policy is always upheld until there is a valid reason, based on reliable evidences, for otherwise. Rule 2 represents a decision or policy is made hastily in reaction to any visible changes in outcomes, with a memory of what has just been done earlier. Rule 3 is similar to Rule 2, but has no memory of what has just been done, or the past. It is based only on a vague memory of the initial state. As shown in Table 1 and Table 2, both the concentration and the dispersion of the marks (hits) distribution generally increase as the decision/policy changes from Rule 1 to Rule 2, and to Rule 3. The overall distribution patterns are similar to what's presented in Deming (2000, p328). It is notable that the impact of the rules on different funnel settings is different.

4.5. Interaction effects

Any interactions among the above studied factors represent complex dynamics of decision making and actions taken in any organization. The same decision or policy adopted in different organizations will have different impact or outcomes. For instance, the effect of Rule 2 or Rule 3 on the marks (hits) distribution is more obvious in a system of a larger funnel /a longer string; it is not as evident or consistent when the funnel/string is small/short. In other words, the concentrating effect produced by a smaller funnel is somehow offset by using Rule 2 and Rule 3. On the other hand, Rule 2 and Rule 3 are much more disruptive in a system of a larger funnel /a longer string. The above observation seems to reverse for the interaction between targets and rules. For instance, the effect of Rule 2 or Rule 3 on the marks (hits) distribution is more obvious in a system of a more stringent target, e.g., circular. In reality, poor decision/policy making would certainly anger or frustrate your customer more easily.

4.6. Special Causes [aka: Assignable Causes] vs. Common Causes [Un-Assignable]

In the experiment, the adoption of Rule 2 or Rule 3 represents tampering a system. That is, the act of making adjustments without understanding the true cause of the variability in the distribution of marks (hits). How the funnel is handled, how the string is handled, how stationary the target is relative to the funnel, how beans are released into the funnel, and how hits are observed and marked are the causes that directly contribute to the variability and can be immediately attributed to a member of the operating system. They are special (or assignable) causes. On the other hand, funnel size, string length, target shape and dimension, and beans are inherent to the system, i.e., given, they are common causes. The rule adopted can be considered a common cause or a special cause. Special/Assignable causes demand immediate attention, while common causes require a longer-term commitment from management. Distinguishing special/assignable causes from common causes is the key to improving the system.

5. Deming Management Philosophy Enlightened

5.1. The 14 Points

In Table 3, we list some of the reactions, comments, approaches, decisions, or policies that might be observed in the Expanded Funnel Experiment that correspond to each of Deming's 14 Points. We present the managerial insights gained from the experiment.

Table 3 Insights on Deming's 14 Points from the Expanded Funnel Experiment

Point	Deming's 14 Points	Insights from the Expanded Funnel Experiment
1	Create constancy of purpose toward improvement of product and service.	***"Let's try different rules or deploy different persons to hold the funnel."*** The experimental setting must remain consistent throughout the experiment rather than alternating roles, shifting targets, changing funnel height, or marking spots inconsistently.
2	Adopt the new philosophy.	***"No need to be exactly 30 beans; as long as more than 25 is good enough."*** Specific to the experiment: the experiment can be improved by adopting a new way of thinking, e.g., adopting a disciplined approach to carrying out the experiment throughout (as opposed to a casual attitude). In general: adopting the new philosophy of management as described by Deming, will transform results so they are continually improved.
3	Cease dependence on inspection to achieve quality.	***"Select relatively well-rounded beans only."*** The experimental outcome will not be improved by inspecting every green bean. Understanding variation and how to reduce it is a key.
4	End the practice of awarding business on the basis of price tag.	***"Just use the least expensive markers (beans) would do."*** Procurement of green beans (markers/pens) based the lowest price may lead to more variability (or muddled recording) in hits distribution. Forge a collaborative partnership with your suppliers.
5	Improve constantly and forever the system of production and service.	***"Come on; aim (at the target) more precisely."*** ***"Throw the beans more gently please."*** Specific to the experiment: the experimental outcome can only be improved by reducing special/assignable causes (short-term) and common causes (long-term). In general: the Deming Chain reaction via a focus on quality and improvement will result in better economics, jobs, jobs, and more jobs.
6	Institute training on the job.	***"Your string is not touching the target surface."*** ***"You should not aim at the hole of the funnel."*** Specific to the experiment: All group members must be trained to conduct the experiment correctly and consistently. In general: training in continual improvement techniques via an understanding of variation, for example, is very important.
7	Institute leadership.	***"Let's try Rule 2, it should be better."*** ***"No, how about Rule 3, it's more intuitive."*** Leadership must emerge in the group to improve the system rather than tampering with Rule 2 or Rule 3. That leadership needs to be based on the new Deming philosophy of management.
8	Drive out fear, so that everyone may work effectively for the company.	***"What happened to your hands, the funnel is not aiming properly!"*** ***"Quick! Or we may not have a break."***

		Blaming the culture or the people, establishing arbitrary numerical goals, incentives, or "zero tolerance" for failures will drive group members to misrepresent the data. Therefore, the data collected will not reflect the true outcome. In general: fear is debilitating, harms people, and harms the organization and because it causes dysfunctional behaviors.
9	Break down barriers between departments.	***"It's here – Ring 1!"*** ***"No, it's here – Ring 2!"*** Creating internal competition and different goals assures that group members are very unlikely to work towards achieving the common goal of the experiment, that is, objective and correct outcome.
10	Eliminate slogans, exhortations, and targets for the workforce asking for zero defects and new levels of productivity.	***"100% bull's eye"*** A target is demoralizing especially when workers are without the power to reduce the size of the funnel, shorten the length of the string, or even ensure a more consistent dimension of green beans, etc.
11	a) Eliminate numerical quotas on the factory floor. Substitute leadership. b) Eliminate management by objective. Eliminate management by numbers, numerical goals. Substitute leadership.	a) ***"5% more hits on the bull's eye than the other two groups"*** Numerical quotas are meaningless if the experimental conditions are not taken into account. The capability of the process determines the outcomes. Numerical quotas do not cause effective and efficient sustainable improvement. b) ***"10% improvement on consistency next time"*** Management by such an objective is irresponsible if the funnel remains big and the string long. Understanding variation, what causes it, and what to do about it is much more powerful than MBO as it is typically practiced.
12	a) Remove barriers that rob the hourly worker of his right to pride of workmanship. The responsibility of supervisors must be changed from sheer numbers to quality. b) Remove barriers that rob people in management and in engineering of their right to pride of workmanship. This means, among other things, abolishment of the annual or merit rating and of management by objective.	a) ***"Progressive incentives for more hits on the bull's eye."*** ***"Zero downtime – finish the experiment as fast as possible."*** ***"Holding the funnel is no-brainer, get him to do it."*** Management is robbing group members of their right to pride of workmanship if their pleas to fix the system (the funnel, the string, the green beans, or mostly critically people) are repeatedly ignored. b) ***"Managers will be promoted based on improvement on consistency over the three trials (rules)"*** Such policy is robbing group managers of their right to pride of workmanship if their pleas to fix the common causes of the system (the funnel, the string, the green beans, or mostly critically people) are repeatedly ignored.
13	Institute a vigorous program of education and self-improvement.	***"As long as 30 marks are recorded is fine."*** The knowledge and understanding of the better ways to get improvement need to be taught. In addition, the group members must be equipped to conduct the experiment in the correct way.
14	Put everybody in the company to work to accomplish the	***"Let the leader (able) play all three roles."*** ***"I just make sure 30 well-round beans are provided."***

	transformation.	Unless all group members are aligned to achieve the common goal of the experiment, i.e., to demonstrate tampering and Deming's 14 Points, the experimental data collected are not true data, of little use.

5.2. A System of Profound Knowledge

In Table 4, we show some interesting aspects of the Expanded Funnel Experiment effective in explaining and teaching Deming's System of Profound Knowledge.

Table 4: Insights on Deming's System of Profound Knowledge from the Expanded Funnel Experiment

A System of Profound Knowledge	**Insights from the Expanded Funnel Experiment**
Appreciation for a system	To improve the outcome of the experiment, that is, producing quality data that are of great learning value, all group members must treat the experiment as a system consisting of the funnel, the string, the target, the beans, the markers, and most critically the group members. All group members must share the vision (goal) and collaborate with one another. They must be able to work within an organization that values and practices Deming's Management Method. Below are some examples of undesirable element behaviors that work against the common objective of the system: • A tilted funnel would shift the whole distribution of marks away from the bull's eye even if the relative distribution remains similar. • A shifted target results in a similarly undesirable outcome. • An altered (shortened or overstretched) string distorts the true distribution of marks. • Pre-selected beans with a consistent dimension introduce biases to the distribution of marks (a lack of true randomness). • A big (not fine enough) felt-tip marker could render the task of marking impossible in certain experiment setting, e.g., small funnel/short string. • Inconsistent practices or casual attitudes towards the experiment could result in invalid experimental outcome. • Unclear roles or responsibilities introduce additional sources of variability.
Knowledge about variation	Without the knowledge about special/assignable cause and common cause variation, the system is often tampered with via different rules (decisions and policies). The outcome is worse! Variation is highly dependent on common causes and special (assignable) causes. Common causes: • Funnel size, String length, Target shape and dimension, Beans Special/Assignable causes: • How the funnel is handled • How the string is handled • How stationary the target is relative to the funnel • How beans are released into the funnel • How hits are observed and marked
Theory of knowledge	How can we predict the distribution of marks under different experimental settings? By using theory of knowledge. As reflected in the data collected, greater variation is

	observed as the funnel size is increased, the string is lengthened, or Rule 2 and Rule 3 is adopted. However, as experienced during the experiment, there is no true value of the location of a mark. Did we mark the spot where the bean first hit the target or where it rested? Which angle did we observe from? What size or type of marker did we use to mark the spot? Which group member observed or marked it? The answers to the above questions, among others, determine the final outcome of the distribution of marks. That is, the operational definitions of "hitting the target" and "marking the spot" determine the eventual observed measurement. Without theory (comparable to the concept of *know-why, as well as know-what, and know-how*), the interpretation of the data collected becomes meaningless. So does prediction become meaningless.
Psychology	Fear (of various types), or a sense of inferiority (superiority) in the mind of any group member affects the interpersonal dynamics within the group. Joy in work is out of the question. For instance, the reward of a performance bonus to a bean-releaser could inadvertently affect his/her funnel-holder's performance in handling the funnel. Within the group, the funnel-holder would wonder why his/her bean-releaser was rewarded for more hits on the bull's eye even though all beans had to pass through the funnel that he/she held. Between groups, other bean-releasers would challenge why they were penalized for more dispersed distributions of marks due to using a large funnel/a long string. As a result, greater variation was observed due to a special/assignable cause, i.e., inconsistent funnel handling or bean releasing, on the surface. Probing deeper, the behavior is actually caused by the common cause of the incentive policy in place. Over-justification is observed as well: for example, why should this bean-releaser be rewarded because he/she was using (given) a system with a small funnel/a short string? Teamwork is out of the question, too!

6. Additional Insights

It is through the hands-on experiment that certain aspects of Deming's management principles and philosophy become plain to students. For example, why is it unwise to manage only with visible figures alone (Deadly Disease #5[3])? As experienced in the experiment, what was observed in the record form is not the whole picture, let alone an accurate one. As highlighted in Sec 5, the observed measurement is the product of the experimental system. The way the whole experiment was carried out including the layout, 5S-compliance or readiness, how marking was done, and the discipline of group members throughout the whole process matters. The data quality of the observations recorded may be compromised if the rigorous procedure was not followed through (Deadly Disease #1[4]). Using such outcomes to judge the performance of various groups can be mistaken. Awards or incentives based on such outcomes are even worse (Deadly Disease #3[5]). It is misleading, misjudging, and destructive. Management by use only of visible figures is deficient can also be illustrated with the outcomes of the almost identical numerical distributions (from the bull's eye to Ring 4), e.g., (5, 8, 10, 6, 1) vs. (4, 9, 10, 6, 1) of the two experiment runs conducted by a group. By looking at the

[3] Deadly Disease #5: Management by use only of visible figures, with little or no consideration of figures that are unknown or unknowable.
[4] Deadly Disease #1: Lack of constancy of purpose to plan product and service that will have a market and keep the company in business, and provide jobs.
[5] Deadly Disease #3: Evaluation of performance, merit rating, or annual review.

figures, they have little difference. By computing the actual deviations from the bull's eye, the sum of squared deviations reveals slightly additional information, but still not insightful. It is only when one looks beyond the visible figures presented and examines the plots of the raw distributions, the vast difference in distribution is revealed. The former (adopting Rule 1) though more concentrated but not centered at the bull's eye, the latter (adopting Rule 2 – an act of tampering) is centered at the bull's eye but more dispersed. Clearly, both the special/assignable causes and the common causes must be identified and distinguished. Only then can the system be improved.

The different sizes (lengths) of the funnel (string) used in the experiment provide a powerful illustrative setting to explain the whole purpose of Motorola's Six Sigma methodology (Harry and Schroeder, 2000). That is to reduce the variability of the outcome by improving the system. The process of finding ways to make the funnel smaller, the string shorter, the beans more consistent, the group members more process-disciplined, and the target in the customer's and your favor in the long term is what Six Sigma methodology is supposed to follow through. The distributional data collected serve as hands-on data to quantify variability. As shown in Table 1 and Table 2, the concepts of σ and 6σ can be easily illustrated. The Expanded Funnel Experiment explains Six Sigma graphically, statistically, and methodologically.

The Expanded Funnel Experiment can also be used to illustrate powerfully why the underlying principles critical to The Balanced Scorecard (Kaplan and Norton, 1996) are absent in most organizations. The key idea of the Balanced Scorecard approach is balanced with a longer term perspective towards converting an organization's intangible assets, i.e., human capital, information capital, and organization capital, into tangible outcomes. An organization employs "the large (long) funnel (string)" and adopts "Rule 2 or Rule 3" is difficult to consistently pay attention or devote resources to "the internal business perspective" of the Balanced Scorecard approach, let alone "the learning and growth perspective." It is not difficult to understand why most of the companies that claimed to adopt the Balanced Scorecard, Lean or JIT, or Six Sigma failed.

Peter M Senge (2006) recognizes and acknowledges the above limitations in a more explicit manner when he revised his popular book *The Fifth Discipline*. Senge spent many years, after Deming's passing, thinking and talking with a group of business and education innovators to identify his version of the "deadly diseases" prevailing in the modern world of corporation.

> "Today, most managers probably regard the "Quality Management revolution," like the organizational learning fad of the early 1990s, as history, far from the frontiers of today's challenges. But is that because we have achieved or abdicated the transformation Deming advocated? It is hard for me to contemplate a list like this one and not feel that these maladies still afflict most organizations today,…"

7. Closing Remarks

The Expanded Funnel Experiment has been carried out by over 1000 students in the executive programs, executive MBA, and MBA classes in the Business School at National University of Singapore since 2004. The design of experiment evolved over time to its present form around 2011-2012. Over the years, students often questioned why my funnel experiment not equipped with better instruments, e.g., a fixture for holding the funnel, improve the traceability of the beans, etc. Introducing human elements into the experiment is intentional. It injects life into the otherwise

mechanical exercise. It brings about realism to demonstrate the dynamics and complexity in a real system in any organization. It makes possible explaining the key principles embedded in Deming's teaching graphically.

The lessons and insights from the Expanded Funnel Experiment are much richer than what has been written in this paper. The Expanded Funnel Experiment clearly demonstrates that a more robust system (organization) is significantly less sensitive to any external or internal shocks. With Deming's System of Profound Knowledge as the framework and the 14 Points as specific directions of leadership and management efforts, organizations will be able to cultivate such a robust system and move toward the genuine transformation.

References

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