Abstract

Dentists, like most managers, believe that unanticipated team results are evidence of poor performance on the part of employees. While this can be the case, it is much more likely that most variation is inherent in the system and is probably not under the control of staff. The dentist, as the manager, has full control and full responsibility for guaranteeing that the office runs effectively and for improving its operation.

Dr. Precise has been frustrated with his assistants. He has a high-end reconstructive practice and the quality of impressions matters. His assistants prepare the material, but Dr. Precise takes his own impressions. What bothers him is the consistency of the material — sometimes a bit too viscous, sometimes too stiff. Dr. Precise is a pro, so he knows how to make adjustments at chairside. He prides himself on never allowing these problems to interfere with the outcome; the few “failures” have been the result of unforeseen patient complications and other matters out of his control. It is just annoying to have to put up with any sloppiness on his staff’s part. Usually Dr. Precise lets his assistant know about the problem, in a kind way of course. “Jane, this one is a bit runny. I would suggest you cut back about three drops on the water next time.” The fault is obviously not in the material, since problems occur with all products. Conversations with his colleagues confirm his suspicions that staff in general are “not very bright” and “don’t seem to have high standards.” Dr. Precise can confirm this because he has let a few assistants go because they “didn’t get it.”

Dr. Precise is not a perfectionist, but he is certain that his patients deserve the highest standard of care possible. He is equally certain that staff should be expected to use his feedback to improve their performance and that they should be terminated if they can’t consistently come up to standard. Dr. Precise is a model of professionalism in these regards. He is also almost certainly dead wrong.

Understanding Variance

America is preoccupied with averages. Dentists got into dental school with high GPAs and DATs. They earned a license with passing averages on National Boards and initial licensure examinations. Their retirement hangs on the Dow Jones. But here’s the irony — dental care is not a matter of averages. Quality in the dental office is determined on a case by case basis. Regardless of what insurance companies or CE gurus might say, substandard care on one patient cannot be justified by excellent results in general. Must dentists understand this intuitively, and that is why they are reserved in accepting the claims of both researchers and manufacturers that are based on averages.

Averages are theoretical constructs. I have yet to meet the “average dentist.” Dentists like to know the average as a general reference point, but they usually want to know more than that. If your stock broker explains that your portfolio dropped by 10%, but the average of all the portfolios he was managing actually rose by 2%, this would be the cause for some hard questions, not an acceptable explanation. The average just helps us set expectations.

What do practical people want besides averages? Having watched carefully in many settings, I have come to the conclusion that practitioners (anyone who works on individual cases in a semi-customized setting and continually strives for improvement in function and esthetics) are guided by two landmarks. Practitioners seem to have a reasonably clear image of the level of quality they are aiming to achieve. Lying aside the hype about “nothing is every good enough,” there is some standard that is the target. This is called a design specification by engineers. Design specifications differ across dental offices based on patient expectations, economic considerations, extent of training, the personal philosophy of practitioners, and many other factors.

Dentists can “feel” design specifications when they walk into a colleague’s office. The other landmark is called, again by engineers, a tolerance. Tolerance is the level of quality that one is willing to accept. Obviously the public defines tolerance in dentistry as a minimal standard of care. Dentists who are professional set per-
Think of your commute, your golf game, how late you run each day, accounts receivable, or the viscosity of impression materials. Variation is inherent in the nature of processes, not in our intentions about them. If we want a process to succeed a tolerance is the relative costs of doing it. Inevitably, the term is defined as the square of the standard deviation. Standard deviation is a value reported routinely in the literature or available with a few clicks on any spreadsheet.

Think of variance as a spread of outcomes around some typical value in a process. Most of the impression mixes in Dr. Precise’s office were at a certain viscosity level, some were too stiff and some too loose. It is desirable to have this average of the outcomes, the center of the variance, correspond to the design specification. But that is not the essential point. What matters most is that the “low tail” of the spread of variance does not overlap with the tolerance. In the case at the beginning of this article, Dr. Precise never rejected a mix; all the variation was above the tolerance line, in an area that didn’t matter (expert to the dentist’s personal sense of exactness).

The question on which quality achieved in a dental office hangs is how far above tolerance should the design specification be set. The factor I want to focus on here is personal tolerances above the legal limit. The operational definition of tolerance is the level of work that would trigger a dentist to take corrective action. It is a personal standard, and it can also be recognized by one’s colleagues.

Obviously, design specifications must be set higher than tolerances. (If the reverse is the case, we have a *prima facie* case of unethical or possibly illegal practice.) Dr. Precise has a design specification in mind for the viscosity of impression materials. He has a tolerance. Because he never received a mix that he could not work with, the assistants’ work was always above tolerance, but frequently below design specification.

The question on which quality achieved in a dental office hangs is how far above tolerance should the design specification be set. One of the primary factors in determining the optimal distance a design specification should exceed a tolerance is the relative costs of letting an error go and of correcting it. Big costs associated with uncorrected mistakes entail large design specification/tolerance gaps. Too small a gap invites frequent rework or a reputation for shoddy work. Too large a gap creates redundancy and other forms of unnecessary cost. Both extremes mask lack of understanding and control in practice. Somebody has to for this ignorance.

There are methods that can be applied to determining the optimal gap between design specification and tolerance. They tend to be complex. The point in this column is to make dentists aware that such a gap exists and to explore what it means. Practitioners are intuitively very savvy about these things and often come close to optimization without using formal methods.

The factor I want to focus on here is system variance. All processes contain natural variance. In pure systems, this variance is normally distributed, bunching near some central value with more extreme deviations becoming less and less likely. The more complex the process, the more normal the variation will be. But there will always be variation. Think of your commute, your golf and first recognized by Al Shewhart in the 1930s. When Dr. Deming told the captains of industry in America that managers, not employees, were responsible for poor process outcomes and that tweaking processes generally causes more harm than good, he was received with the same incredulity that most readers probably felt at the top of this article when I said Dr. Precise was dead wrong to fiddle with the dosages in impression mixes and to let his staff go because they could not meet his design specifications. In Japan, the highest national prize (something like the Nobel Prize) is called the Deming Prize, and Deming is generally given credit for the miraculous post World War economic boom in Japan (but he cannot be held accountable for the dubious banking practices that have the country in such a slump today).

**Red Beads**

Deming had a hard time convincing folks that processes contain inherent variation. Although we are willing to admit this possibility in nonpersonal settings such as annual rainfall, the spread on sporting events, or even the stock market, when our fingerprints are on the process, we hedge. Our reservations are not symmetrical. Psychologists call this the Fundamental Attribution Principle, and it works something like this. I will take credit for outcomes of processes I am involved with if they are successes, otherwise, it is random error. I will blame others if they were involved with unwanted outcomes, otherwise I will hold my peace. Review the case at the beginning and note that Dr. Precise took pride in being able to work with any mix his assistants prepared, except for those rare cases that were beyond his control, while he was willing to terminate an assistant who could not get it right.
In order to demonstrate his principle, Deming developed a “game” known as the Red Bead Demonstration. It is famous in quality circles and he probably used the demonstration thousands of times with the top executives in this country. It goes something like this...

It is both shameful and ignorant to attribute outcomes to employees or oneself that belong to the process itself.

The equipment required consists of a paddle or small shovel with fifty small symmetrical depressions in it and a large bowl containing hundreds of beads, 80% of which are white and 20% red. The participants in the demonstration are managers and some convenient number such as ten to twenty workers work well.

The stage for the demonstration is set by a leader, such as Deming himself. He characterizes the situation as one where a firm selects and ships white beads. Each day six sets of fifty beads are selected and shipped. The firm is paid only for white beads. The company breaks even at an average of forty white beads per order. Members of the group are selected to play various roles. Six willing workers are chosen, each to draw one set of beads per day by sticking the paddle into the large bowl to fill each of the depressions in the paddle. One or more auditors are chosen to count the number of white beads per sample and record the results. A strategic planning team might be selected to set production goals. An HR group and an overall management team will also be chosen. One of Deming’s favorites was team charges with writing slogans and speeches to motivate the willing workers. Sometimes there is a director of training who demonstrates how to draw samples.

On the first day of productivity, six samples are drawn and the number of white beads in each sample is counted and the average across the six samples is calculated. Attention is drawn to the fact that some of the willing workers are both effective and motivated based on the fact that they have drawn more than forty white beads. Those workers whose samples were deficient (fewer than forty white beads) are counseled to “try harder.” The process is repeated several more times. The criticism of those workers with defective samples is intensified. Those who have repeated defective samples are treated especially harshly. Those who “slack off” from their previously acceptable performance are singled out. There is even a bonus paid on the third or fourth “day” for those who seem to be getting the point. The trainer is let go (just as any practice management consultant who cannot demonstrate sustained improvement in a situation such as this should be). The slogan committee is disbanded. Management is sweating because there is only enough revenue to pay the employees and nothing left over for profit. Finally, in a humanistic gesture on the part of management, it is decided to run on half shift and to retain only the effective willing workers. On the sixth day, the top producers are retained and all others are dismissed. The process continues several more days.

The red bead demonstration doesn’t always produce the same exact distribution of beads, but in the long run it will look something very much like this. The average number of white beads will be forty (exactly on the break even point) and that number will fall between 37.7 and 42.3 99.9% of the time. It will either improve or get worse in any systematic fashion. The typical willing worker will draw samples with forty white beads. Ninety-nine point nine percent of the time individual willing workers will draw samples with between 34.4 and 45.6 white beads. Half of the time, their samples will be below the break-even point, but there will be no pattern to these defects.

How do we know these facts? Deming tells us that we must first study the nature of the process itself, entirely independent of the efforts and skills of the workers and the effort and aspirations of management. The expected results reported above can be calculated precisely from the known characteristics of the process itself. Any deviation from the variation inherent in the system could be attributed to employees, management, or breakdown in the process. But there will be no deviation. I have run the demonstration often enough myself to confirm the obvious insight that everything in this demonstration depends on the design of the process. All the flapping of management and effort of the employees (even those who recognized the true nature of the situation still strive to beat the odds) amounts to complete waste at best and will damage self-worth in most cases.

“But wait,” I can hear you saying. “This is a completely artificial situation. Certainly realistic processes are subject to influence by sloppy workers, inspiring leadership, and other forces beyond the random.” That is true. But it is equally true that the manager doesn’t know which of these human factors are operational or the extent of their effect until he or she first understands the variance inherent in the system. It is both shameful and ignorant to attribute outcomes to employees or oneself that belong to the process itself. And now that this fact is known, there is no excuse for not trying to study the process. Quality engineers use the simple rule that human factors and process breakdown should be investigated if a single outcome falls outside the average or if seven successive outcomes fall above or seven successive outcomes fall below the mean or if seven successive outcomes all get better or worse than the previous ones. The rule is that 99.9% of the standard devia-
tion is due to the process. Management should get excited when that is not the case. Management should also get excited when the system is designed to produce an unacceptable number of failures. In the red bead demonstration, half of the samples will be defective. That was a design failure and is entirely the responsibility of management.

In the case of Dr. Precise, he should first determine the variation in the viscosity of the impression mixes. He should satisfy himself that he can work with anything that is three times the standard deviation above or below the mean (the tolerance). This means he should reject one tray out of every 1000. Then he should sample the outcomes of his assistant’s mixes. If a job applicant can’t consistently stay within the limits set by three standard deviations above and below the average, he or she should not be hired. If an existing employee cannot stay within the limits he or she should be retrained, or reassigned, or terminated — in that order. Dr. Precise owns the system, not the employees, only he can change it. Blaming others does not fix the process. In the case of Dr. Precise, he should have been suspicious when each new employee had the same shortcomings.

**The Funnel**

Tweaking the system is an itch. As is true of itches, tweaking does nothing to correct the problem and usually makes matters worse. We just can’t help ourselves. We are leaders and we have to do something. If we can’t improve the system because we do not yet understand it, at least we can look good managing the symptoms. Dr. Precise tweaked the mix by suggesting adjustments to the impression mix based on the results he was given.

The funnel demonstration was developed by a man named Lloyd Nelson, but was frequently used by Deming. The equipment required is a stand, such as those used in laboratories, with a funnel attached to it so that it would be about eighteen inches above a surface such as a carpet over which is spread a bed sheet. In the middle of the bed sheet there is an x, and the funnel is placed over the x. A marble is released in the funnel and its final resting point on the sheet is marked.

This can be conceptualized as a fixed process (the sightings, the stand and funnel, the carpet, and the marble) with random variation added as a consequence of unknown factors interacting with the characteristics of the process. The randomness of the outcomes of the process can be demonstrated by repeating the process fifty (or some other convenient number of times) and noting the distribution of the marks made on the bed sheet. An example is shown in Figure 1. Ninety-nine point nine percent of the marks will fall within three standard deviations of the x in the middle. If the stand with the funnel on it is raised or the surface under the bed sheet is harder, the circle will be bigger, but 99.9% of the marks will still be within a circle drawn three standard deviations from the center x. We can call this approach “design specification grounded.”

Now let’s tweak the system. Assume that the first marble dropped rests three inches directly south of the x. Move the funnel three inches north of its location on the x. If the next drop is four inches to the right, move the funnel four inches left of the location where the funnel is situated. In the Dr. Precise example, this would be equivalent to the dentist telling the assistant, “This mixture has five too many drops of water; make the next batch with five fewer than this mix.” We get x, shouldn’t we move the funnel two inches south of the target? This could be called “target grounded tweaking.”

In the Dr. Precise example, it would be equivalent to the dentist saying, “This mix is about five drops of water to stiff; add five drops to whatever it says on the directions on the box.”

There is yet one more version of tweaking that is quite passive and has the technical name of “random walks.” This rule says move the funnel to a position directly over where the marble rests after each drop. If Dr. Precise had said, “like the result you have here on this impression, try to match it next time,” he would be creating a random walk.

By now you have already sneaked a peak at the pattern of outcomes from the three tweaking rules and compared them to the design specification rule. Figure 2 shows the effects of tweaking grounded in results. The rule is “compensate for the results by adjusting in the opposite direction.” As the pattern of results in Figure 2 shows, this rule produces a pattern of outcomes that is stable. Approximately 99.9% of marks will fall within three standard deviations of the x, and the x will remain in the center of the pattern. The problem is that the circle is about one and a half times as large as the circle resulting from the simple rule of making no adjustments. The reason for this is that a new ingredient has been added to the process, the tweaking. But since the tweaking is driven by a random outcome, it can’t improve the process. It only makes it sloppier.

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will call this tweaking “results grounded tweaking.”

But there is something troubling about this approach. Shouldn’t we be referencing our adjustments to some standard, say the target itself? If the marble rests two inches north of the target, improve the process. It only makes it sloppier.

What about the target grounded tweaking in Figure 3? Surely there must be some mistake. The adjustment is being grounded in the original rules of the game. But the typical pattern is one of
wild and increasing swings, usually in two directions from the target. This is caused by overcompensation. Now the adjustment introduced in response to random fluctuations is systematic and compounding. Target grounded tweaking is especially likely in medicine and very dangerous. It is a chief cause of over-medication. Some of the malpractice observed in faulty orthodontic, occlusal, or TMJ treatment is created in this fashion.

Random walks, shown in Figure 4 have no particular pattern at all. Certainly all control is gone. Before anyone objects that random walks are too silly for anyone to seriously consider using them, they should ask themselves two questions: Have they ever sold stocks because the price was dropping? Have they ever let one of their office members train his or her replacement?

*Moral*

The boss owns the process. The boss is responsible for improving it based on an understanding of what the process is supposed to do (design specification), what is acceptable (tolerance), and the wobble inherent in the system (variance). It is useless and unfair to hold employees accountable for results that belong to the design of the process. Improvements in quality come from redesigning the system not demanding that people work harder with broken equipment.
**Recommended Reading**


This is one of many popularizations of the work of W. Edwards Deming, with "official" introduction. The central message is that management is in charge. It can improve quality by taking a long view of constant improvement of the processes that create goods and services. There are nice descriptions of the red bead and funnel demonstrations. Extensive discussions of the folly of trying to fix problems by blaming everyone or changing everything else besides what matters — the process. The book is light on the statistical foundations and heavy on the politics of management's misuse of workers (a Deming view) and the dangers of competition (Aguayo's own view). Aguayo is a banker and consultant who was inspired by taking a course Deming taught on a regular basis at New York University. Most trade books use a combination of clear statements of major points and examples to develop these ideas. Aguayo is long on examples and explicit statements of theory are hard to find.


Deming's attempt to make his thinking accessible to a larger audience. Somewhat more organized than *Out of the Crisis* and shorter, this treatment still fails to systematically present a coherent picture of quality thinking. He now calls it "The Deming System of Profound Knowledge" — said to have four components (appreciation for a system, knowledge about variation, theory of knowledge, and psychology) but no discussion is offered and these four components are not treated individually in the book. His anger at the system is still evident: "The purpose of a school of business should not be to perpetuate the present style of management, but to transform it." The red bead and the funnel experiments are explained in detail.


This is the best window into Deming's mind. Less a book than a collection of thoughts, bits of speeches and the notes for them, anecdotes and newspaper clippings, and lists — some of the material is excerpted from documents supplied by friends. Some ideas are incomplete (a list of six "diseases of American management style is given in the introduction to chapter 3, but only five are discussed; some material is repeated, verbatim in various parts of the book. The writing is disjointed and the grammar badly flawed. "The aim of this book is transformation of the style of American management."


One of about a dozen books published between 1985 and 1990 expounding Deming's views on quality. Most, like this one, were authorized by Deming and carry, like this one, a one-page introduction by Deming. This book is also typical in presenting the political or HR side of Deming's position and downplaying the statistical foundation. "Unless a change is made in the system (which only management can make), the system's process capability will remain the same. This capability will include the common variation that is inherent in any system. Workers should not be held accountable for or be penalized for common variation; it is beyond their control." The book is loosely organized on Deming's Fourteen Points.

**Quality Progress.**

A monthly magazine published by the American Society for Quality. The articles are short and effort is made to present technical ideas in a fashion accessible to general readership. ASQ can be contacted at www.asq.org.


A highly technical book. But it is listed here because it is the best discussion available regarding the way tolerances (minimal standards) should be set.

**Editor's Note**

Summaries are available of the three recommended readings preceded by an asterisk (*). Each is about four pages long and conveys both the tone and content of the book through extensive quotations. These summaries are designed for busy readers who want the essence of these references in fifteen minutes rather than five hours. Summaries are available from the ACD Executive Office in Gaithersburg. A donation to the ACD Foundation of $15 is suggested for the set of summaries on red beads and funnels; a donation of $50 would bring you summaries of all the 2001 leadership topics.

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