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Pitching Pennies: An Interactive Learning Tool for Quality Management Instruction

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ABSTRACT

Total Quality Management uses statistical concepts extensively. While students have learned them to get through one or two semesters of statistics, they still seem to struggle to apply them in applications. Shooting a coin at a target, or pitching pennies, is used as a tangible simulation of real world processes. Each coin tossed at a target represents the manufacture of a product, an interaction with a customer, or a customer delivery.

We present a simple interactive exercise that helps students

- judge quality performance of processes
- understand the basis of process capability
- visualize both accuracy and precision
- understand/determine sources of variation
- internalize the concept of the "cost of poor quality" and Taguchi loss function

This activity uses readily available props and provides involvement and entertainment to keep students' interest with a hint of competition. The teaching points are clear and relevant to the course of study.

Introduction

Activity based learning has been shown to provide students (and employees) a better way of learning (Gloeckner, Love, & Mallette, 1995). Lewis and Maylor (2006) identified over 200 games used in teaching Operations Management alone. Heineke (1997) noted that activities in the classroom provide three benefits to learning including motivating learning, providing a common experience base, and illustrating concepts or ideas that are abstract or complex.

Variability and the concept of variation are concepts that are typically difficult for many students to grasp through reading and lecture alone. Berenson, Levine, and Krehbiel (2006) define variation as, “the amount of dispersion or scattering of values away from a central point.” This simple definition leads us to an activity that begins with variation and extends to the many applications of variation, and variation reduction, utilized in operations everyday.

We use this activity in the classroom, though it can easily be adapted to training of manufacturing employees who need a better understanding of variation. This activity is typically used in our Total Quality Management Course for teaching sources of variation (including the distinction between Shewhart’s (1931) assignable cause and chance cause variation), accuracy & precision, quality control, process capability analysis, & loss functions. It can be easily adapted to other related courses or for training manufacturing or service employees. Through this exercise, students take different roles and can easily see how variation of a process happens, even when consistency is the goal. The actual student handout for the activity is provided in Appendix A.

Personnel

Three students begin the exercise, one in the role of the production worker, one as the inspector, and one as the data recorder. The production worker is responsible for performing the task of pitching, flicking or shooting the coin using one finger. The worker's job is to shoot coins from shot zone (w/in 3" of edge) to the yardstick. The objective of the worker is to hit the target value marked on the yardstick. The inspector stands behind worker and reads measurement, which is announced to the recorder at the computer (we set up an Excel spreadsheet ahead of time for recording data and for calculations, see Figure 2). Other students watch, and wait for a job to open for their turn.

The Setup

The materials required for this exercise are minimal: a yardstick, a table, some coins, a pencil, some tape, and a computer with Microsoft Excel. The yardstick is attached to a desk or table top 24 inches from one edge. Using a pencil, we draw lines on the desktop 3 inches and 21 inches from the yardstick (see Figure 1). The nominal dimension or Quality Target is the 18" mark at the center of the yardstick. The coin must land within 3" of yardstick or it must be shot again.

The Process

The worker shoots 10 times, representing the production of 10 units. Although "Management" hasn't supplied a strict production rate quota for this job, the "manager" (instructor) is expecting the worker to produce 10 shots per minute. As Montgomery (2004) points out, any manufacturing process will have some level of inherent variation, and cannot produce two units of product that are identical. From our process, students can readily begin to understand this concept. After 10 shots, the shift ends and a new set of employees repeat the process. You can repeat the cycle for the amount of time available, capturing data for each worker.

The Learning

After collecting enough data, students are given a set of questions related to the exercise (Figure 3). Through the activity, students get a first hand look at the sources of variation. Students are asked to come up with suggestions to reduce the variation seen in their activity. Using the data collected, we show the students the concept of capability, performing the calculations, and discussing how capability measures the relationship between specification and process performance.

We sometimes allow the students to answer the questions as a class, using the spreadsheet to analyze the data collected. In smaller classes, groups can be organized to work together in the role of the Quality department to analyze and interpret the "production" data, where students can create and plot control charts (Figure 4). In our spreadsheet, we calculate $\overline{X}$ and s for each "shift" (person), as well as the loss associated using the specification or "goal post" method and the loss associated using the Taguchi Loss Function. Occasionally, we set up multiple tables so that students at each table can act as competing companies.

Students are also exposed to and shown the concepts of precision and accuracy. By reviewing the performance data, student managers can assess which production workers are more precise than others, and which are more accurate. This is followed by a discussion of how to better train and equip the less precise and accurate employees so that they can perform at a higher level.

<u>Our Conclusions</u>

After all the groups have answered the set of questions, we lead the students through the analysis phase and let them draw conclusions and explain their answers. This activity becomes a form of collaborative learning (Delucchi, 2006); where students work to help each other better understand the "process," and how they might work to improve it. More advanced students can then look at the application of design of experiments to improve the process. The use of activity based classroom instruction, simulating real world situations through hands on participation, provides the students a better opportunity of learning at the level of transfer, allowing them to transfer the experience to other similar situations, which Ormrod (2004) concluded that the consensus of contemporary theorists agree that this type of activity based learning is the approach necessary for transfer of learning in problem solving.

From performing this activity with our class, we have found that it provides several benefits to the students. First, it breaks up the monotony of the daily lectures, which can get stale and flat for both the students and the instructor. Second, it provides a hands-on approach to the learning, giving students a more easily understandable method of learning. Finally, the students get a real sense of variation and all that it affects, not just in a manufacturing process, but in any type of process. Students find the activity informative, educational and maybe most importantly, fun. Adapting this type of classroom activity is not difficult, and the rewards are well worth the effort.

References

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Figure 1: Table Top Setup

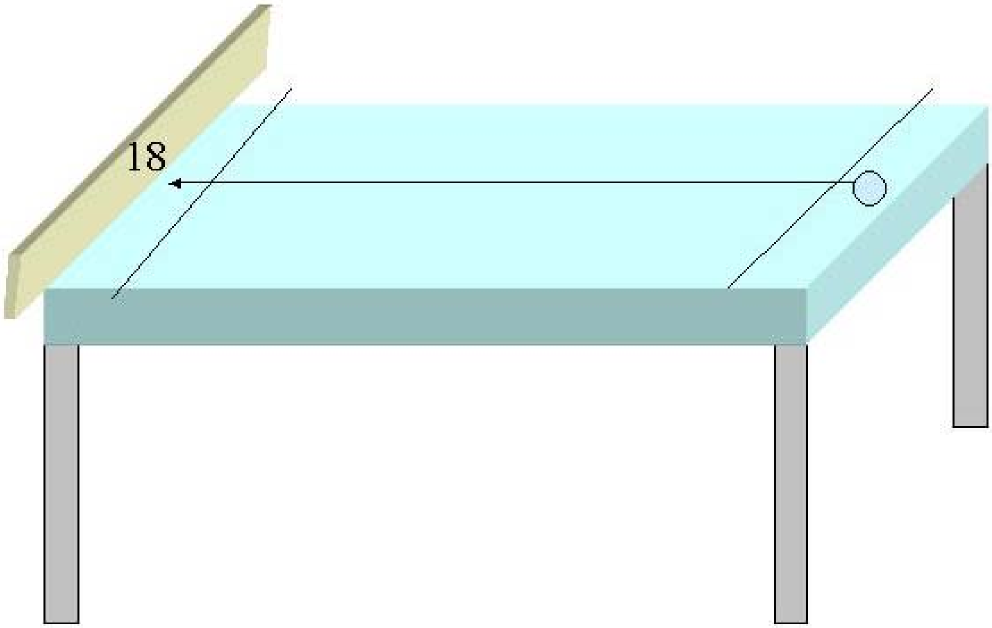


Figure 2: Spreadsheet Example

Raw Data				Shot ("Unit")									
	Name	1	2	3	4	5	6	7	8	9	10	Xbar	std-dev
1	Janie	18.5	19.8	17.3	18.2	21.2	19.5	16.5	17.0	19.0	20.0	18.7	1.41
2	Jordan	16.5	21.5	20.5	19.5	15.5	18.5	19.5	19.0	17.0	18.0	18.6	1.75
3	Tim	19.0	16.0	18.0	18.5	18.0	17.5	17.5	18.5	19.0	18.0	18.0	0.84
4	Sally	21.0	16.5	21.3	18.0	20.5	17.0	15.5	16.5	16.0	17.5	18.0	2.04
5	Joe	22.0	15.3	19.5	14.8	21.3	18.0	19.0	17.8	18.3	21.3	18.7	2.32
										OVERALL		**18.4**	**1.78**
Loss with Goal Posts					**Target:**	**18**	**Limits**	**15**	**21**	**Cost:**	**$10**	**Total**	
1	Janie	0	0	0	0	10	0	0	0	0	0	10.0	
2	Jordan	0	10	0	0	0	0	0	0	0	0	10.0	
3	Tim	0	0	0	0	0	0	0	0	0	0	0.0	
4	Sally	0	0	10	0	0	0	0	0	0	0	10.0	
5	Joe	10	0	0	10	10	0	0	0	0	10	40.0	
											Total	**70.0**	
Taguchi Loss Function:				**Loss = k*(X-T)^2**			**k =**	**1.11**	**=L15/((J15-G15)^2)**				
1	Janie	0.28	3.40	0.63	0.06	11.38	2.50	2.50	1.11	1.11	4.44	27.41	
2	Jordan	2.50	13.61	6.94	2.50	6.94	0.28	2.50	1.11	1.11	0.00	37.50	
3	Tim	1.11	4.44	0.00	0.28	0.00	0.28	0.28	0.28	1.11	0.00	7.78	
4	Sally	10.00	2.50	11.74	0.00	6.94	1.11	6.94	2.50	4.44	0.28	46.46	
5	Joe	17.78	8.40	2.50	11.74	11.74	0.00	1.11	0.07	0.07	11.74	65.14	
											Total	**184.3**	

Figure 3: Student Questions

A. Variability:

1. What are the sources of variability?
2. How could variability be reduced?

B. Capability:

1. If the specifications for this process are 18 ± 3 inches, is the process capable?

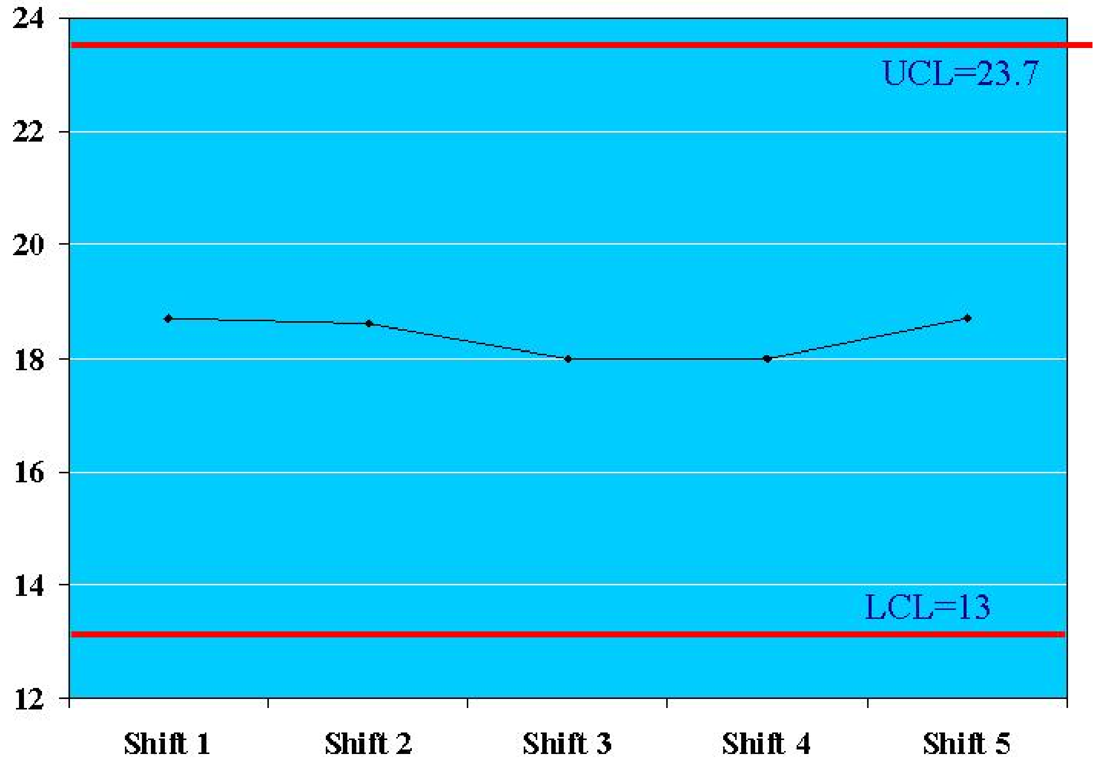
C. Statistical Control: If this process were stable, where would you put

1. The 3 sigma control limits for individual events?
2. The 3 sigma control limits for the groups of 10?

D. Personal Performance:

1. Who is most accurate?
2. Who is most precise?
3. Who generated the minimum loss using the specifications as goal posts and assuming a $10 cost associated with shot outside specs?
4. Who scored the best using the Taguchi Loss Function?

Figure 4: Control Chart Example



Appendix A

Ch12 Class Exercise – Coin Shot NAME __________________________
Subjects: Sources of Variability, Accuracy, Precision, Control, Capability, & Loss

Yard-stick attached to desk top 24 inches from edge.
Draw lines in pencil on desk top at 3inches and 21 inches.

Participants: Willing worker, Inspector, Recorder

Workers job is to shoot coins with finger from shot zone (w/in 3" of edge).
Quality Target is the 18" mark on yardstick.
Coin must land within 3" of yard-stick or it is a redo.
Inspector stands behind worker and reads measurement and relays to recorder at PC.
Worker shoots 10 times. Management hasn't supplied a strict production rate quota for this job, but your manager is expecting you to do 10 shots per minute.

Everybody then gets a promotion. Willing worker moves over to inspector, inspector moves to recorder, recorder moves to management (audience).

After all play is complete and results are tallied on xl sheet record you answers to these discussion questions:

A. Variability:
   What are the sources of variability?

   How could variability be reduced?

B. Capability:
   If the specifications for this process are 18 ± 3 inches, is the process capable?

C. Statistical control: If this process were stable, where would you put
   The 3 sigma control limits for individual events?

   The 3 sigma control limits for the groups of 10? (SQRT of 10 = 3.16)

D. Personal performance:
   Who is most accurate?

   Who is most precise?

   Who generated the minimum loss using the specifications as goal posts and assuming a $10 cost associated with shot outside specs?

   Who scored the best using the Taguchi method?