

# Improving Open-Ended Problem Solving : Lessons Learned in Industry

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## 1. Introduction

Quantitative literacy counts! It counts in surveys, at the ballot box, and at the cash register. People address issues where "compelling", but sadly deficient, data are used to sway opinion. Examples cover the controversies of smoking and public health, murder and capital punishment, economic growth and environmental impact, and abortion and right-to-life. Daily, individuals must wade through advertising claims, choose quantities of products to stock, evaluate personal performance, and determine if the car needs a tune-up.

The need for literacy is recognised but the need for quantitative literacy is not. Our schools are not lax in addressing language skills. Literacy training focusses beyond learning the alphabet, definitions, and grammar to emphasise understanding and exchange of ideas. Teaching of mathematics, however, rarely progresses beyond syntax and isolated, individual activity. From basic arithmetic facts to complex engineering applications, quantitative answers are always unique. This limits discussion. Teaching, by practice and by inference, associates words with ideas and numbers with facts. We need to understand the nuances of numbers. Teaching must move mathematics from methods to meaning.

What's needed to excite interest in mathematics? We've found a common approach useful both in industry and the schools. Focussing on open-ended problems reveals both the practical impact of quantitative thinking and the role advanced numerical methods play in improving the quality of decisions. Using examples drawn from industry, a framework will be provided to introduce statistical thought into asking questions and getting answers.

## 2. Perspectives

### 2.1 *Myths*

Mathematics is viewed as a dead language. By focussing on manipulative precision rather than alternative quantitative formulations, what is learned? Myths! Common misconceptions:

- All problems have one correct solution.
- Use only the available data.
- Getting more and more (of the same) data is better.
- Doing something is better than doing nothing.
- Focus on the number summary.
- Evaluate one factor at a time.

These myths are propagated on a naive understanding of variability, sampling, control, and design of experiments. Mathematics, K-12, must address the appropriate use of quantitative description, argument, comparison, and inquiry. This focus on concepts and critical application is the essence of quantitative literacy.

### 2.2 *A simple example*

In American industry, this failure to think quantitatively is our top problem. The common practice in decision-making is to focus on two types of errors - rejecting the truth or accepting the false. Dr Deming ("Quality, Productivity, and Competitive Position") reminds us that error of the third kind - answering the wrong question - is often more critical. Examples are myriad.

Salt is salt but try spicing your food with road salt or "thawing" an icy walk with table salt. Does particle size make a difference?

Generic drugs are sold as equivalent. This equivalence extends to the active chemical agents. Differences in tablet geometries, particle size distributions, particle morphologies, and activation agents are not addressed. Are they important?

At the Ford Motor Company, the introduction of new high-speed gear-finishing equipment nearly shut down our vehicle assembly plants. Why? The metallurgical variability, not important to the old process, significantly affects the new computer-controlled machining.

The first step in developing quantitative literacy is understanding - identifying and quantifying - variability and assessing how it impacts the questions we ask and the measures we use. Often new measures are needed.

### 2.3 *Actions*

Are we to lose the battle to the big myth that mathematics is hard and that mathematics has little everyday use? Be a myth-buster and expand your students' conceptual base. Select applications, tailored to grade level, that nurture quantitative literacy within the context of your existing syllabus. Choose problems that are open-ended. Encourage discussions.

This workshop presents examples developed for Ford engineers and managers *and* classroom tested (5th grade). Graphical methods are emphasised. The intent is to focus quantitative skills on problem-posing, separating data from information, and selecting a course of action. Discussions provide the opportunity to pinpoint the potential (and the pitfalls) of more sophisticated computational approaches.

### 3. **The workshop**

- (i) *An illustrative situation:* Often many companies are in competition as potential manufacturers. A key step in the selection process is evaluation of a short-term production run. During this process, data is collected on the important quality characteristics and quantity produced. This data can be a measurement or a count. Counts result if the number of defects observed or quantity produced is monitored.
- (ii) *Organisation:* The participants are grouped in teams of four. Each group represents an individual company in competition with all others. Each company is given the same task (but "slightly" different tools) and the company with the "best" performance wins. The instructions are kept purposefully vague ("You bid on this job, didn't you?") and the "instructor" must artfully dodge attempts at further clarification. (Conflict of interests and partisan preference, or its appearance, must be avoided.)
- (iii) *The specifics:* Each group is given a cup of popcorn and a spoon. The task, using the back side of the spoon's handle, is to remove popcorn from the cup. No practice is allowed. Twenty-five draws should be made. After each extraction, the count is recorded both on a tally sheet (histogram) and a time line (plot of counts in the order collected). Large sheets of paper should be provided for the data collection. The amount of popcorn removed represents the "day's production".
- (iv) *A demonstration:* The instructor, not touching the cup, demonstrates the procedure with the cup vertical on a table. The extracted popcorn is not returned to the cup. After each extraction a tally-and-time-line chart (Figure 1) is updated. After a few trials the groups are instructed to commence production. Note that the instructions *do not include* the restrictions used in the demonstration. The purpose of the demonstration is to familiarise the groups with the method of data collection and recording.
- (v) *Reporting:* Each group updates its time-line plot, monitoring stability, and its tally sheet, defining performance. After the production trial is complete, each group posts its tally and time-line charts. The instructor now queries the whole class for comments on each group's performance. Interpretation of the graphs is emphasised. Explanations of "significant" changes or trends is sought.

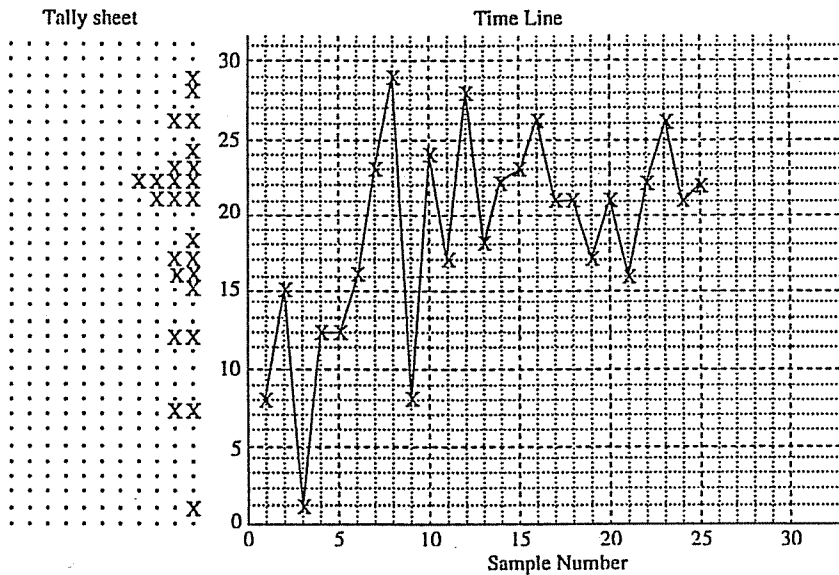


FIGURE 1  
Tally-and-time-line chart : popcorn simulation example

- (vi) *Discussion:* At this point differences in interpretation of instructions, tools available to the various companies, possible methods of evaluation (i.e. are these valid questions in a business setting?) and whether all data should be included (e.g. does initial data reflect a "learning" curve or represent "warmup" to be experienced every time?) provide a basis for discussion. The choice of the "best" is not trivial. Possible criteria include the greatest single count, the highest "average" count, the highest minimum count, or most consistent production.
- (vii) *An extension:* In the interests of fairness, and quantitative expression, the groups are requested to prepare a supplemental written proposal to submit with their charts. To explain why their "company" should be chosen, any improvements in operator instruction, material handling, or manufacturing equipment should be noted, and its impact assessed.

4. Conclusion

Life is a series of choices, and education must develop the critical thinking skills. Literacy skills, quantitative or otherwise, serve a four-fold purpose; to form appropriate questions; to collect the available data; to translate the data into information; and, to answer the question. Conceptual mathematical content ought not be restricted by computational methodology. The mathematics curriculum should be viewed as organic. Ideas planted early with pictures, can later be enriched with statistics and ultimately grown to provide risk assessment. One lesson of the popcorn example is that an increasingly sophisticated mathematical analysis of the available data may not be the best approach to drive improvement.

The K-12 curricula in the United States can be described as over-stuffed and under-nourished. This workshop is offered to suggest a palatable possibility - strengthen conceptual content within developing computational skills. Robert Hooke's book, *How to Tell the Liars from the Statisticians*, offers a much richer plate of examples. Our in-service training, however, suggests that more than additional detailed materials are needed. Issues of funding, curricula change, in-service training, methods of assessment, and community support will have to be addressed. While these institutional changes will take time, much can be done in the interim.

Local initiatives, exposing teachers to the needs of industrial workers, help. At Ford we have teachers participate in training with our engineers and work as cooperative scholars. To an individual, each participating teacher recognises the issue is not more or less technology, but quantitative literacy. The task is to institutionalise this synergistic coupling of industrial experience and classroom expertise.

A joint task force, sponsored by the American Statistical Association (ASA) and the American Society for Quality Control (ASQC), is addressing this question. The Joint ASA-ASQC K-12 Task Force Charter is not to prepare new materials, but to build a process that stimulates the continuous improvement of the K-12 education process. A critical first step is to facilitate the interaction of concerned statisticians and lead teachers. If you are interested in developing this process in your own community, please contact the author.