The Thought Map

Cheryl Hild, Doug Sanders, and Bill Ross
Six Sigma Associates

Key Words: Thought Map, Process Improvement, Statistical Process Control (SPC), Process Map, Critical Thinking, Parallel Paths of Work, Data Collection Strategies, Design of Experiments (DOE).

Abstract

Statistical techniques such as Design of Experiments (DOE) and Statistical Process Control (SPC), as well as many non-statistical quality tools, are instrumental in improving many processes and products. A potential weakness in the use of these methodologies is that they are often placed within an artificial framework or roadmap commonly referred to as a “model for continuous process improvement”. These roadmaps are most often defined as sequential paths of activities and decisions required to achieve improvements in process outcomes or parameters. The sequential nature of the defined improvement path provides limitations in thoughts and work. Many questions, thoughts, and ideas are generated in a random or sporadic fashion. The tendency is to structure these thoughts in a sequential framework. However, the very essence of parallel thinking and learning is a critical asset in identifying the key areas associated with the necessary work to improve process or product. The thought map is invaluable in any focused work effort in order to capture the multitude of questions that arise, the many possible paths that need to be considered in obtaining solutions, the work performed, and the solutions obtained.

Published Quality Engineering 1999-2000 12(1)

Hild (865) 909-0319
Sanders (865) 448-3002
Ross (303) 494-8521

Introduction

There are three common mistakes with respect to process or product improvement projects that usually lead to sub-optimal or wrong solutions. The first mistake is starting with one proposed solution as opposed to generating alternative paths and understanding the questions that need to be answered. Consider the issue of increasing capacity at a bottleneck. An engineer is assigned to this project. The reality of the project is that the assignment is to justify the purchase of new equipment, not to understand the critical factors contributing to the performance at the particular line location. Another common mistake is the attempt to use an existing historical data set to gain useful information to solve the problem. The information in a data set is determined by the way in which the data is sampled. The sampling plan is dictated by the questions needed to be answered. Rarely do historical data sets provide sufficient relevant information for current problems.

A third mistake in process improvement work evolves by starting the work with a set of technical or statistical tools believed to be useful for solving the particular problem. Consider the flowchart for process improvement provided in Figure 1. The roadmap assumes that SPC is the appropriate tool for any improvement activity. It also states that the first major step for process improvement is to collect data. What initial questions drive the need for process investigation? What alternative paths are available--outsourcing, materials, design? What are the critical response variables? Is the relationship between process factors/variables and process performance understood? Without considering such questions, the application of statistical or technical tools will yield weak and irrelevant information.

As illustrated in the flowchart of Figure 1, a sequential path of activities is frequently associated with the use of statistical and quality improvement tools. For those individuals with technical backgrounds, the idea of a "roadmap" or flowchart is consistent with their educational training that has taught them that there exists a formula, methodology, or piece of equipment that provides the "right" solution for any problem. *More often than not, it is not the formula, equipment, or roadmap that leads to the solution; it is the questions that are asked*. If we want to obtain innovative solutions, we must think "out of the box" and, should we say, structure our thoughts "out of a sequential flow". True solutions, as

Cheryl Hild (865) 909-0319
Doug Sanders (865) 448 3007
Bill Ross (303) 494-8521

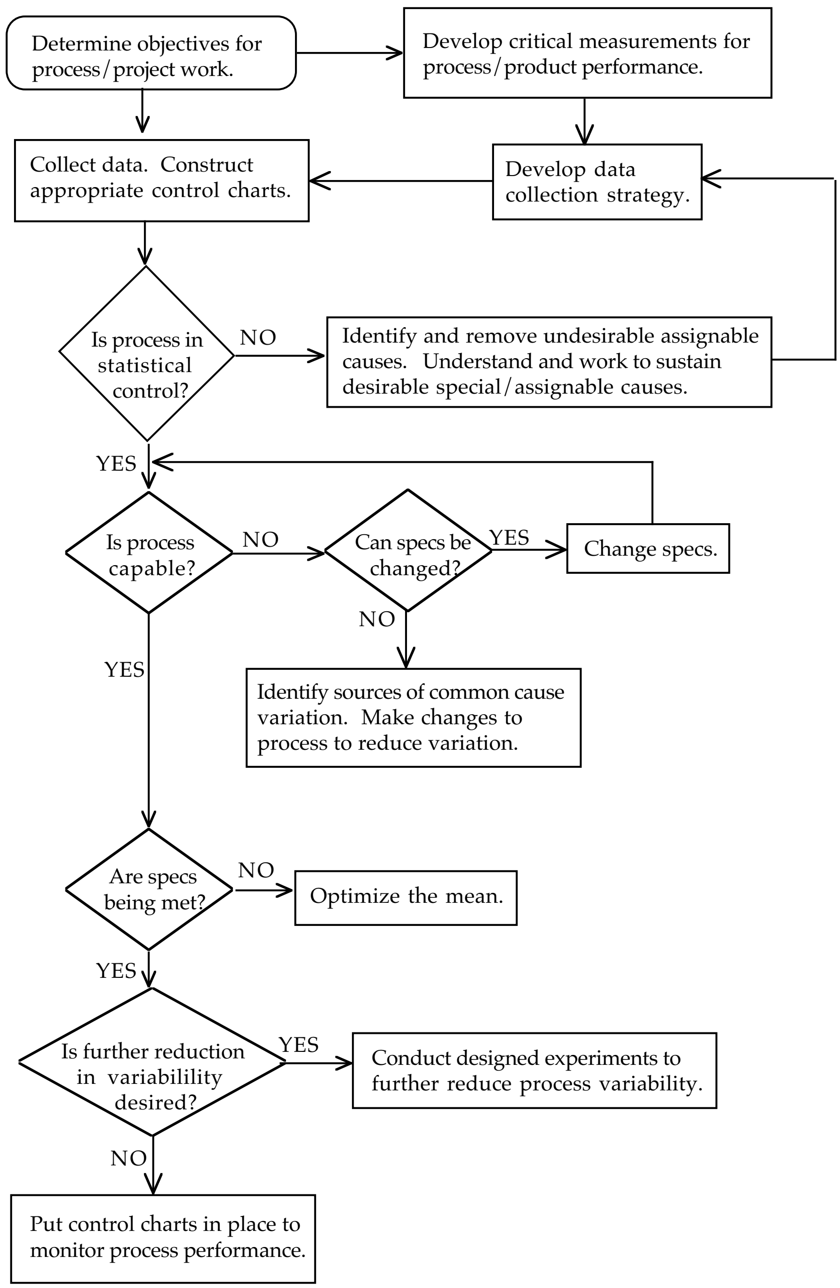

Figure 1. A Flowchart of a Strategy for Process Improvement

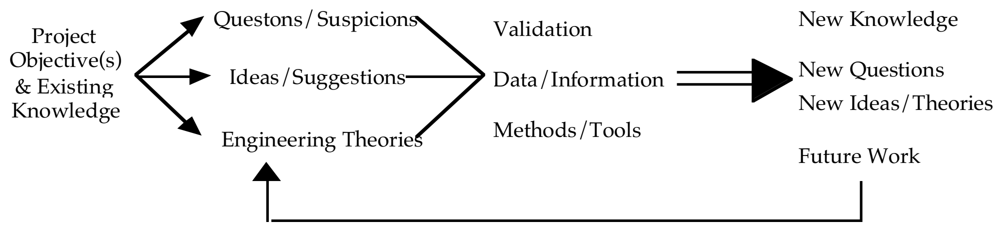

Figure 2. The Ongoing Nature of the Thought Map

opposed to repairs or fixes that often add complexity, come by asking new and different questions. The investigation of multiple questions requires the consideration of alternative paths of work. A single path is rarely the "right" path for all problems and issues involved. Single paths ignore unasked and potentially unanswered questions.

If we want to excel in improving products or processes, we must rely on our own thought processes (assuming logical ones) to guide the usage of technical or statistical tools. Without a doubt, engineering knowledge of a process or product is essential to being able to make innovative change and thereby drastic improvements. The success in improving processes is not as much in the application of tools as it is in the knowledge that exists concerning the process. As shown in Figure 2, existing knowledge (or ideas or suspicions) drives questions which drive the type of information needed and work pursued (SPC, DOE, etc.) which, in turn, provide answers that supplement existing knowledge and lead to new questions.

What is a Thought Map?

A *thought map* is an ongoing documentation of existing knowledge, the questions asked, the parallel paths of work needed to answer those questions, tools applied to answer questions, knowledge gained from work performed, and the direction of future work. Figure 3 shows the initial phase of a thought map concerning the performance of an injection molding process. The objective of the work as initially communicated was to improve the Cpk of an injection molding process. As seen in this map, the first

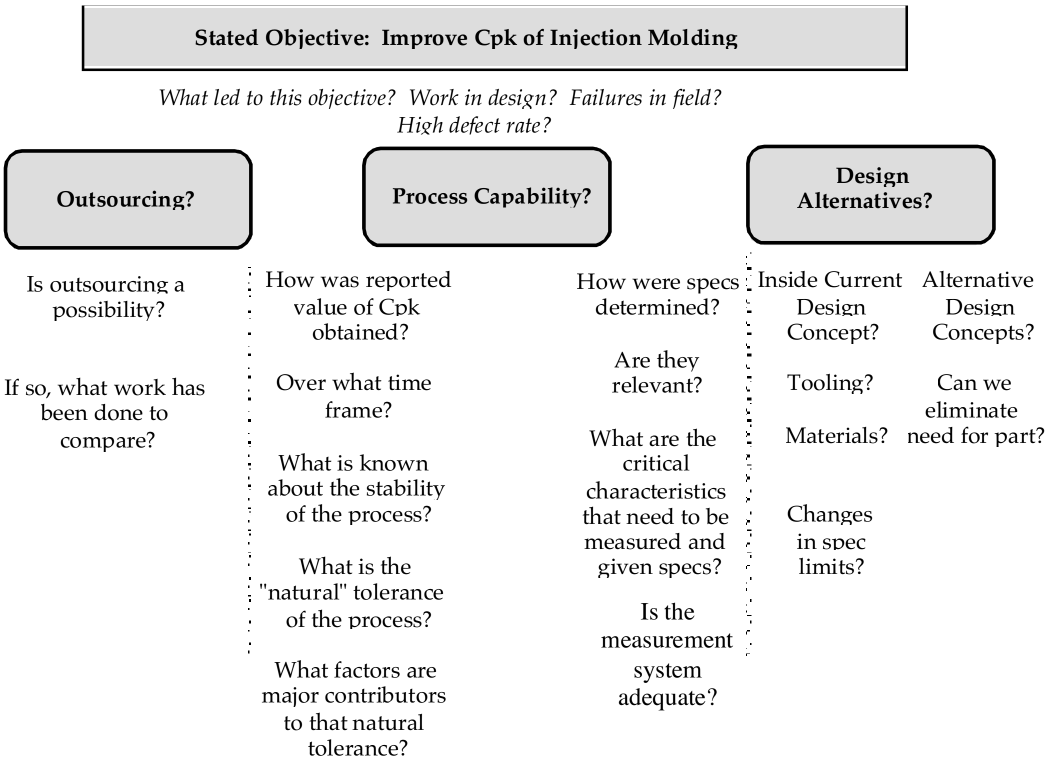

Figure 3. The Beginning of a Thought Map

level of thought considers the major alternatives that exist (outsourcing, design changes, and improvement of injection molding process). It also questions the relevance of the stated objective. The next level contains questions that are generated from the consideration of each of these alternatives. Without the documentation of these major alternatives and associated questions, work down the single path of improving the injection molding process might forego the consideration of other key alternatives.

One of the difficulties that people have with the development of thought maps is that there is no “right” way to construct a thought map. There is no “right" way because there are multiple ways to improve understanding and to gain new knowledge. Box, Hunter and Hunter best state this idea:

"Notice that, on this view of scientific investigation, we are not dealing with a *unique* route to problem solution. Two equally competent investigators presented with the same problem would typically begin from different starting points, proceed by different routes, and yet could reach the same answer. What is sought is not uniformity but convergence."[1]

Even though there is no step-by-step instructions for constructing a thought map, there is a set of critical elements that ensure that the thought map is effective in guiding work. These elements are:

- An overall quantifiable objective of the project or process work being undertaken;
- Major alternatives and initial questions to be considered (questions lead, answers follow);
- Parallel paths of questions and subsequent work;
- Prioritization of questions to be answered;
- The tools and methodologies used to seek answers to questions (encouraging the appropriate applications of tools and methods);
- A history of work performed to obtain answers;
- Documentation of answers to questions;
- Evolution of metrics and their relationship to the work being performed.

The Benefits

Thought maps require the documentation of information most often retained in the minds of those who own the process or the improvement work. The evolutionary nature of the maps requires those working on a process or product to evaluate the logic of their thinking and actions with respect to the goals and objectives of the work. In turn, there are several key benefits associated with the use of thought maps. These benefits include:

1) The expression of unanswered questions prior to the proposal of the solution(s).
2) The documentation and maintenance over time of parallel questions and ideas. Since the mind processes large amounts of information and sensory data simultaneously, the mind generates multiple questions about different issues within seconds. Often, a majority of these questions and ideas are lost.

3) The “best” solution is obtained because multiple approaches are considered and appropriately evaluated. Thought maps help to overcome the more common tendency to communicate questions and issues in a step-by-step series.
4) Provision of a structure for sequential work within parallel paths and thoughts.
5) Description of the breadth and scope of the work required to obtain effective solutions. They encourage consistency in depth of work along the various paths, reducing the tendency to focus on a single path without simultaneously considering other options.
6) Provision of an excellent mechanism to communicate strategies, tactics and activities to peers, other functional areas, suppliers, customers, management, etc.

Ultimately, thought maps are like any other tool or methodology. They are only as valuable as the information captured. So, if a key path of thought is missed, then suboptimization in process or product performance can result.

The Thought Map as a Communication Tool

A typical question that is asked by those working on a project team is “Where should we go next?” A typical question asked by others working within a process area or product design group is “What changes are they making to the process/project and why?” A typical question asked by managers is “How can I keep track of the progress and work being done by the engineering staff?” Often, notebooks full of copied documents and formal presentations are kept to provide information on the work performed on projects. However, these notebooks rarely aid in communicating to others what questions have been asked, what solutions have been obtained, and the breadth of work required to come to those solutions. In fact, the work necessary to prepare for a presentation is often a distraction from the work performed to gain process knowledge. Consider the thought map provided in Figure 4 on pin angle variation. Immediately, one can understand where the work is directed. The next steps are evaluation of the measurement process and the construction of a process map. Also, one quickly identifies the reasons for this work -- to understand if we can accurately measure pin angle and to understand factors affecting pin angle. With a quick look at the thought map, one can understand the main objective, the direction of work, and the reasons for this work.

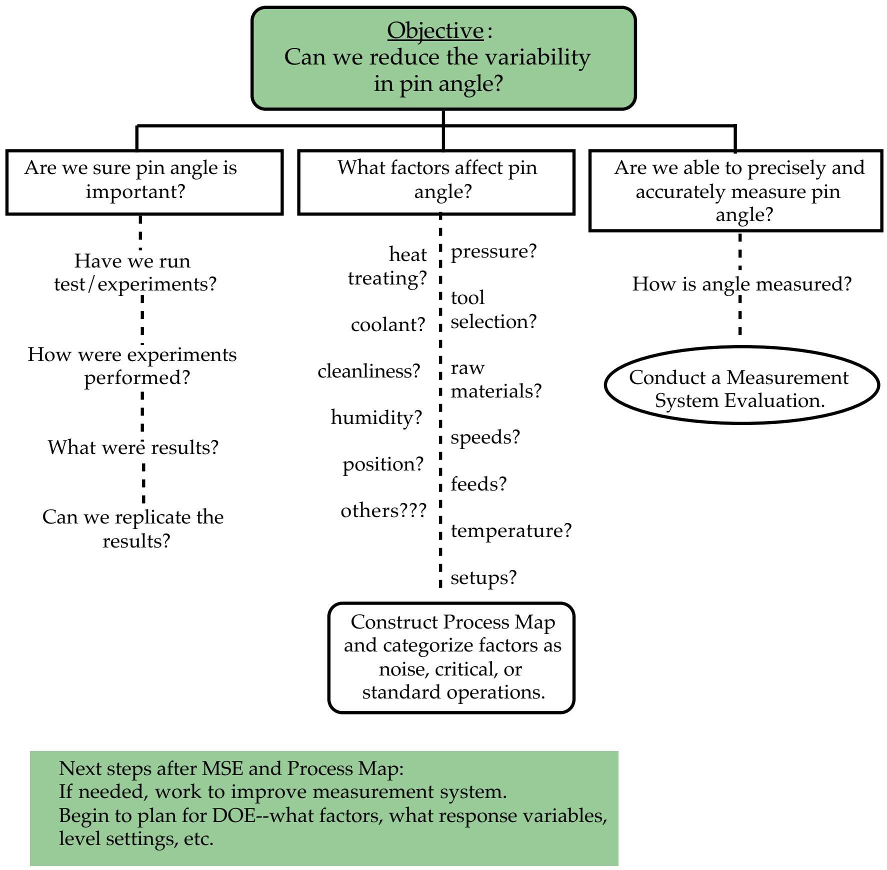

Figure 4. A First Thought Map for Reduction in Variability in Pin Angle *

Thought maps allow for transfer of process/product knowledge and for handing-off components of work. They communicate the hierarchical nature of project work and the many factors/questions/issues associated with the overall objective. Therefore, they are useful for communicating and directing work across a team of individuals working on different paths within the same project. As the thought map indicates (via the questions that are asked) the parallel paths of work required, the team members can each work on a path while maintaining linkages between the parallel paths. The map provides a means of providing feedback on the work of others within the team and for developing an understanding of how individuals arrive at specific conclusions. The evolving nature of the thought map brings all of the knowledge gained back to a central location, from which new ideas and questions can be generated.

Cheryl Hild (865) 909-0319
Doug Sanders (865) 448 3007
Bill Ross (303) 494-8521

Thought maps are also effective at communicating where efforts can be combined to more efficiently arrive at solutions. For example, in the project work depicted in Figure 3, a data collection strategy can be planned to include information on the stability of the process, the capability of the process with respect to the specifications, and the possible factors that are contributing to the overall variation in the process. The thought map provides information on where and how efforts can be combined, thus reducing redundancy of work efforts.

Thought maps are powerful communication tools in engineering and at design review meetings. When they are used to introduce the technical information to be presented, others can better understand why and how the data was collected and, therefore, the interpretation of the results. When other technical staff members understand the questions one is attempting to answer, they are able to provide inputs, knowledge, and support for the project work. Consider the thought map shown in Figure 4. Imagine its use to preface a technical presentation. Knowing the engineer's initial questions opens the door for useful communication about previous experimentation, critical factors impacting variability, etc. In design reviews, they aid in an understanding of how a product will perform under various conditions, what questions must be addressed in the design process, what tradeoffs have been made and why. The communication of unanswered questions, planning stages prior to data analysis, and inconclusive results provides greater opportunities for learning and developing new ideas and knowledge.

When used as a communication tool for management, the thought map allows managers to understand the true scope of work required to complete a project. They also communicate priorities and needs, thus allowing for informed decisions regarding resource allocation (including dedication required for project completion, priorities on laboratory resources, overtime needs for experimentation, etc.). A great discredit to the work of engineers is the fact that many times only the results get communicated to management. In fact, a common comment heard from engineers is "My manager only wants to hear the results; he doesn't care about how the results are achieved." However, without knowledge of the breadth of work involved to obtain true, sustainable solutions, it is impossible to effectively prioritize and schedule resources as well as to put systems in place to sustain the changes required over time.

Failure Modes and Useful Tips

In the use of thought maps in the technical or engineering community, there are typically two responses: either they find them extremely powerful or they fail to understand the relevance of the map to their work. Thought maps are extremely powerful tools. When their power is not realized, it is almost always due to two primary failure modes. The first major failure mode is that they are treated as a static document, done once and left as is throughout the project work. The intent of the tool is to be used as an evolutionary document, guiding the paths of work through documenting questions that need answering and new knowledge as gained.

A second related failure mode is that questions and theories are not explicitly defined and stated. Therefore, the work is not guided by rational and logical questions for defining data collection strategies and choice of analysis. Recently, an engineer gave a presentation on a technical analysis performed to understand the variability in paint thickness on various product types. Several pages of data were shown and the results from an experimental design. However, the results were primarily inconclusive. What followed was a series of questions from those observing the presentation. How did you set up the experiment? Why did you choose those factors? What questions were you interested in answering? Are you trying to be robust to lot-to-lot variation? What sources of variation are you attempting to understand? How did you collect the data? etc. In essence, all of these questions led to the conclusion that the analysis was not providing relevant information because the data collection and analysis was not designed to answer specific questions. Obviously, the presence of an *evolutionary* thought map was absent. In fact, the thought map had been developed *after* the data had already been collected.

A third failure mode is only using thought maps to guide the technical components of improvement work. It is important to keep in mind that the thought map provides the documentation, the linkages, and the organization of thought. It does not contain all of the vital backup information and data. Thus, the thought map should include references to actual data and supporting documentation.

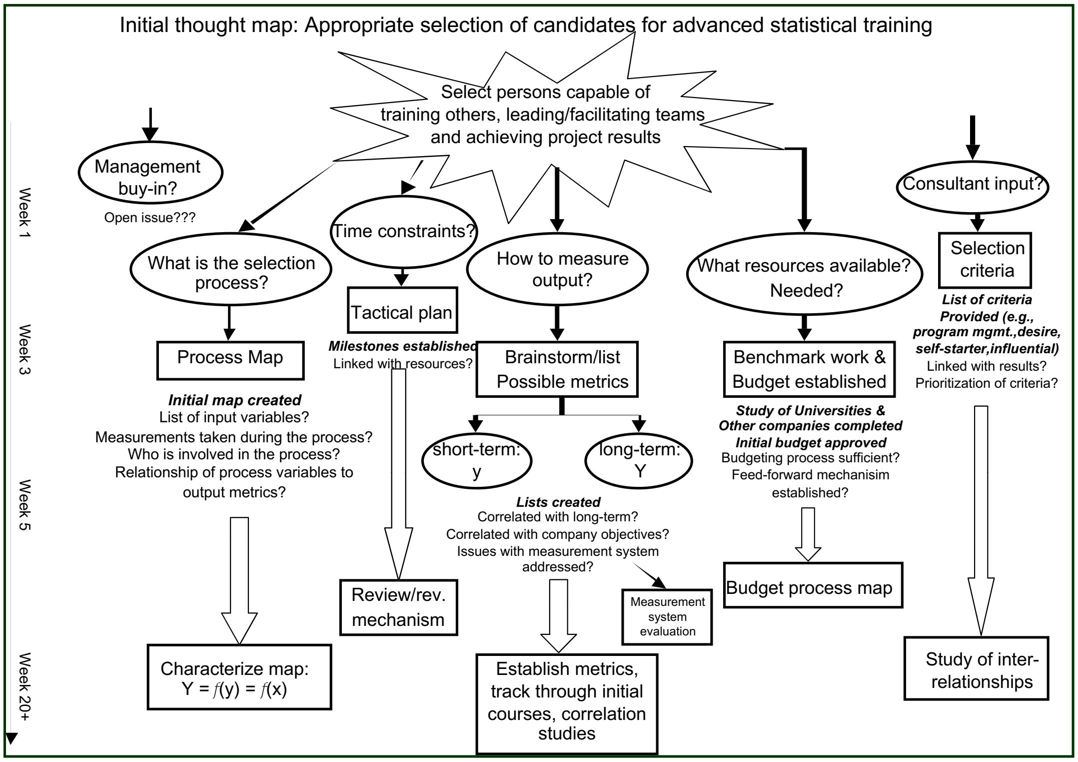

Figure 5: An initial thought map for a non-manufacturing activity

Thought maps are designed for any type of problem-solving or improvement activity. Thought maps may be used virtually everywhere. Figure 5 is an example of a thought map applied to a training function. This map represents one branch from an overall training development/delivery thought map. The main question of interest is that of candidate selection. This objective leads to some first level questions (in ovals) that, in turn, lead to activities (in boxes), results from these activities (in bold), and further questions.

The thought map in Figure 5 provides technical guidance in the construction of thought maps. The first tip to note from this map is the use of different symbols, fonts, or formats. Even with a large number of simultaneous activities and parallel thoughts contained on the map, one can easily differentiate the main objective, initial questions, work performed, etc. A second useful tip is the noting of unresolved issues or issues outside the immediate sphere of influence. The issue of management buy-in is included on the map and noted as a potentially

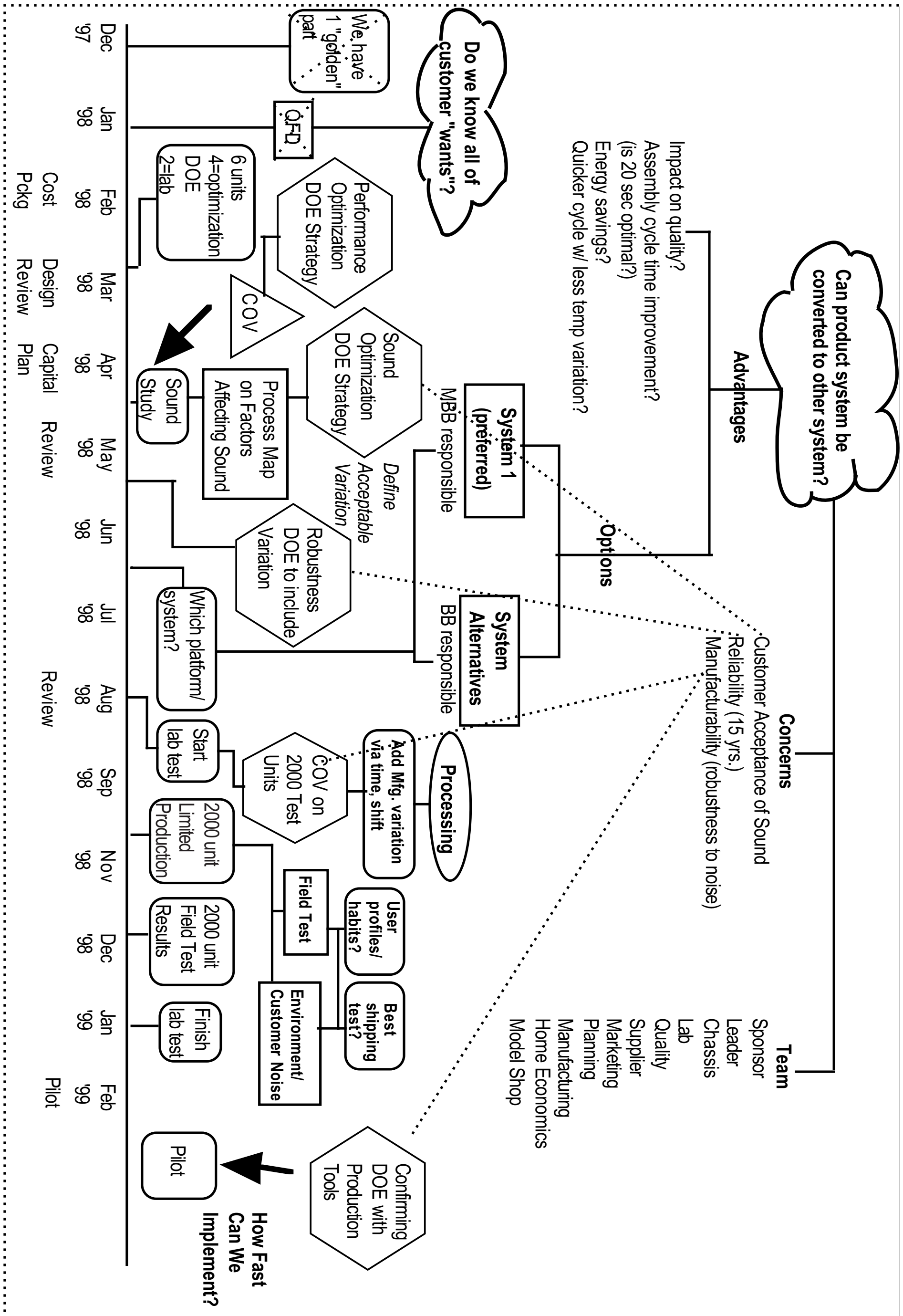

Figure 6. A Thought Map on a Design Project **

Cheryl Hild (865) 909-0319
Doug Sanders (865) 448 3007
Bill Ross (303) 494-8521

unresolved issue. Documenting and maintaining this and similar issues on the map will help the investigator to prevent ignoring potential roadblocks or inappropriate assumptions.

The thought map in Figure 6 is from a design project dealing with the evaluation of different systems while maintaining reliability of product and the customer acceptance of the noise levels of the units. This thought map serves as a powerful communicator of the overall project plan, the major questions outstanding, and the many paths of work that need to be investigated. Three additional useful tips are effectively demonstrated in this thought map:

- The consideration of the multiple functional areas needed to be included in the work;
- The timeline associated with the activities to be performed;
- Identification and documentation of responsible parties for alternative paths of work (MBB is identified to work on the understanding of System #1 while the BB is identified to understand and study alternative systems).

Conclusion

The ability of employees to think logically, rationally, and creatively is an asset to any organization. While suggested improvement models are intended to fuel this creativity, it is the authors' experience that it too often stifles creativity and innovation. Improvement activities become limited to those that "fit within the box". Engineers are more motivated (and rewarded) to *check the box* on the list of tools applied than to approach each situation as an investigation. We encourage the use of thought maps to guide critical thinking in the planning of data acquisition. It is through carefully planned data acquisition that the needed information is gleaned from data analysis. The relationship between the many statistical tools that exist and the critical thinking process is illustrated in Figure 7***. Sequential knowledge building is based on the ability to ask and answer the right questions, to develop and test theories, and to understand and document untested assumptions. Thought maps have been found to improve idea generation, communication, tool application effectiveness, and ultimately problem resolution efficiency.

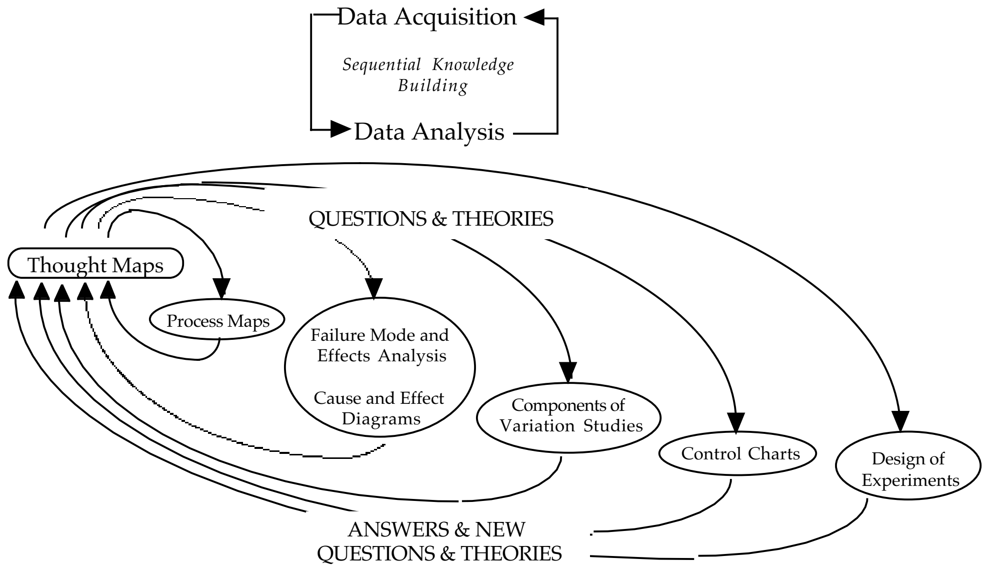

Figure 7. The Nature of Critical Thinking

Endnotes

* Notes on the Thought Map provided in Figure 4:

1) The process map is a tool that enhances flowcharting techniques by associating a causal structure with the major stages of the process. For a complete description of process mapping, refer to "The Process Map" by D. Sanders, W. Ross, and J. Coleman (1997).

2) Evaluations of the measurement systems should always be performed prior to SPC or DOE. However, there do exist simultaneous paths of work. For instance, you can be developing the process map while evaluating the measurement system.

** The map provided in Figure 6 is from the project work of Cy Connors.

*** The diagram in Figure 7 is from Phil Molloy. We appreciate his contributions.

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1. George Box, Hunter & Hunter, Statistics for Experimenters: An Introduction to Design, Data Analysis, and Model Building, Wiley, 1978, p. 5.

2. Doug Sanders, W. Ross, and J. Coleman, "The Process Map", accepted for publication in Quality Engineering, Vol. 11, No. 4, 2000.