11 Problem-Solving Myths That Limit Results

Charles W. Lipp ▪ Lake Innovation LLC
Darrell Velegol ▪ Penn State Univ. and The Knowlecular Processes Co.

Avoid some common stumbling blocks when solving both simple and complex problems.

A portion of what you know about problem-solving is probably wrong. More importantly, this so-called knowledge can lead to slow and ineffective resolutions. Along the path of problem-solving, certain myths seem to appear again and again, which act as bottlenecks and sometimes lead teams to abandon sound fundamentals.

This article pulls from our decades of experience in industry and academia to describe indications and warnings that will alert you to these myths and get you back on the path to sound fundamentals. Identifying these myths will be helpful for young engineers just starting their careers and mid-career professionals looking for new opportunities.

Several methodologies exist for solving problems, and Figure 1 provides one version of the classic formula *(1)*. Other similar methods include the Plan-Do-Check-Act (PDCA) method, the well-known scientific method, or John Boyd's Observe-Orient-Decide-Act (OODA) Loop *(2)*.

This article highlights 11 myths within the framework of the problem-solving steps presented in Figure 1. Each myth begins with a story from the authors' experience, describes the reality, and closes with a key point to remember. Many excellent resources are available for learning more about problem-solving methodologies, a few of which are listed in the Literature Cited at the end of this article.

DEFINE THE PROBLEM

Myth 1. The economic value of this project is not important or is not the concern of the technical team.

Example. When presenting an environmental project to management, an engineer chose to begin with a single slide on the cost of the expensive abatement equipment. The known high capital cost was eye-opening; therefore, the managers gave careful attention to the technical detail that followed. The technical team gained solid management support to develop and demonstrate solutions, saving large and complex capital expenditures.

Reality. In business, and oftentimes in academia, engineers and researchers sometimes assume that it's someone else's job to worry about the money. However, engineers must remember that their decisions have significant economic impact. Therefore, when defining the problem or presenting a potential solution to managers and leaders, you must also describe how solving the problem will make or save money — for example, by enabling greater throughput, by gaining net unit return when a plant is shut down, or by reducing the raw material cost of a yield improvement project.

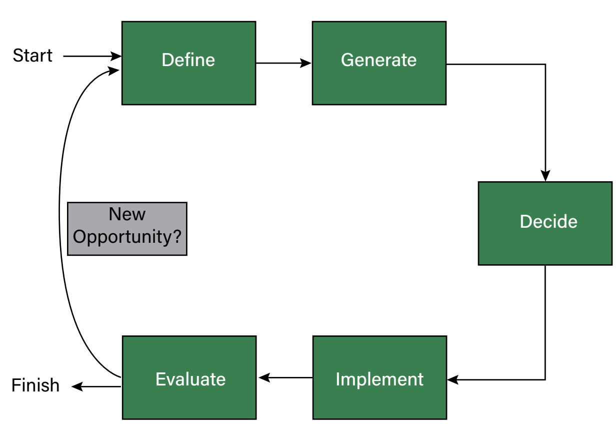
Before starting a project, the team must know the weighted average cost of capital (WACC) for the company. The cost of capital considers the cost of debt, the expected return on capital investment, and the corporate tax rate. If the internal rate of return (IRR) for a project is such that IRR < WACC, then this indicates that the project is not feasible. Alternatively, some companies consider the payback time for an investment and judge the feasibility if the payback time is less than the benchmark. The team should have a good handle on these benchmarks before beginning the problem-solving process.

Key point. Understanding the economic impact of solving a problem is essential to attain and maintain leadership support.

Myth 2. We should wait for others to give us all the details in the problem brief.

Example. "The business leaders keep changing their minds about what the customers want," complained one research and development (R&D) team member. He was fed up with continual changes from the business leaders, legal, manufacturing, marketing, regulatory, and other stakeholders. At a later progress meeting, the R&D team member facetiously showed a slide with a photo of a "top secret" problem brief. He explained: "It's so top secret that nobody in the company actually knows it, and so it has been our job to figure out what should have been in the brief."

Reality. You've most likely been part of a team where the efforts diverge and even contradict because the definition of a problem statement is unclear. When problems are dynamic, nonlinear, or highly dimensional, team members typically should not wait to be handed the final problem statement by management or operations. They must instead work jointly



▲ **Figure 1.** The classic version of the problem-solving method begins by defining the problem to be solved and generating potential solutions. From there, the team decides on the best solution, implements the solution, and evaluates the results. The cycle begins again if the team determines that there is a new opportunity. Source: Adapted from *(1)*.

as a team to assemble the problem from multiple perspectives (*e.g.,* R&D, manufacturing, marketing, legal, regulatory, sustainability, supply chain) in an iterative fashion.

Key point. The first step in problem-solving is to ensure that the team understands what needs to be solved. Define the characteristics of success and constraints (*e.g.,* success is a reactor yield of 99.5%) with the stakeholders and decision-makers. The team must strike a balance between having too little detail, so that the problem statement is incomplete, and too much detail, so that the problem statement is obfuscated by the details.

GENERATE POTENTIAL SOLUTIONS

Myth 3. It's too expensive and time-consuming to create multiple hypotheses if our job is just to kill those hypotheses.

Example. At one company, a consultant had the idea of creating multiple hypotheses *(3, 4)* to identify substrate molecules that could serve as substitutes in a cooperative binding chemistry. Those seated at the table remained quiet, until one person objected that the team didn't have time to create a bunch of hypotheses when it took so long to "confirm just one." Nothing came of the consultant's idea at the time, but over a year later, the same scenario arose with this same team; several molecules were proposed and tested, including successful substitutes.

Reality. A hypothesis is simply a proposed explanation as a starting point for further investigation. A good hypothesis is framed so that it is possible to show its falseness or implausibility when challenged with data. If a comprehensive list of hypotheses is not generated at the outset, then a charismatic team member might come into the team later and scramble the entire project by asking questions and proposing a different solution.

Equally important for speed in problem-solving is generating multiple hypotheses (even some wacky ones) at the beginning. Then, remember that you can never confirm or validate a hypothesis, only disprove it or show that it is a weak alternative. Seek first to disprove it by using the literature, simple calculations, existing observations or data, or simple experiments. Then, if you must conduct more expensive experiments, you may need only one or two to disprove the incorrect or implausible ideas, which is much cheaper than doing 20 experiments to confirm your hypothesis. When the solution space is simple, with few decisions or alternatives, using trial-and-error to confirm a hypothesis might work. But when the solution space is highly dimensional and/or dynamic, the non-systematic method will almost certainly be too slow.

Each hypothesis can usually be phrased as a question that can be answered with data in a plot or table. For a plot, you can draw a curve that represents your hypothesis (*i.e.,* your educated guess) ahead of time. Another advantage of framing ideas as questions and hypotheses is that they externalize the idea from the person, making it more palatable to discard implausible ideas.

Key point. When generating potential solutions to a problem, the discipline of expressing all hypotheses and working to discredit incorrect or implausible hypotheses is speedier and will yield a better answer than only investigating one solution. Of course, there is no guarantee that you have the correct hypothesis at this stage in the problem-solving process, so creating multiple hypotheses has another advantage.

Myth 4. That option has already been tried, and it didn't work.

Example 1. A team was tasked with forming trimers of spherical colloidal particles. A few months previously, they had tried to fuse a third particle onto the colloidal doublet, but the technique didn't work after the density separation. Therefore, they assumed that it would be impossible. However, an expert suggested that the agent they were using to give the water a higher density — sucrose — might be to blame. Indeed, the week previous, another researcher had found that the 99.9%-pure sucrose might have a bit of surfactant in it. When she made the solution and shook it, it foamed up a bit, indicating the presence of a surfactant. At the suggestion of the expert, the team tried to perform the trimer separation with glycerol. The new density agent worked.

Example 2. Sometimes people believe they know what is *not* causing the problem. In one example, any of several specially designed atomizing nozzles could have been used for a certain spray-drying process. Operations assured the consultant and the team that the nozzles were identical. But a close examination with a trained eye showed subtle but important differences. Using the best nozzle made a dramatic difference in product yield and reduced operational difficulties. The consultant demonstrated that statistically the change was well beyond normal variation. The team could recreate the problem by using the nozzle that was expected to have the poorest performance and resolve the problem by changing back to a good nozzle.

Reality. Portions of a solution may have already been tried, so tailor those results to your situation rather than neglecting a useful solution scenario hypothesis. Think to yourself: What can change? For system-wide problems, what failed in one case might not fail in another. Some problem solutions are only useful in certain ranges. If your current problem pertains to a different range (*e.g.,* of Reynolds number) than the previous case, the outcome can change.

Key point. Keep asking questions to clarify what precisely has been tried, and then check the results to see if they correspond to the current problem.

DECIDE ON THE BEST ALTERNATIVE

Choosing the best solution among the options involves multiple factors. Often, a Pugh matrix is used *(5)*, in which a spreadsheet lists the options and factors. The factors may be quantitative or qualitative, or sometimes they are simply ranked.

Myth 5. The constraints on the process will be given to us.

Example. You may have noticed that fishermen return to a certain part of a lake because the fish tend to be caught in that area due to its specific underwater characteristics and constraints, like tree roots or other bounding terrain. In a similar manner, the solutions that problem-solvers desire are usually near constraints.

The late Richard Hamming — a highly-regarded mathematician and researcher at Bell Labs — used this illustration of fishing in the ocean decades ago: If one goes to a random location and selects a random depth, the most probable outcome is that no fish will be found *(6)*.

Reality. Optimal solutions often occur near the boundaries of constraints, so identifying constraints that can be nudged may open new avenues of thought that create tremendous value for customers and for companies.

Constraints are often incorporated into facilities as hardware limitations or as control software limitations (*e.g.,* maximum feed temperature). Other constraints include governmental regulations or internal corporate accounting systems that determine who gets to claim the financial impact. The importance of a complete understanding of the impact of constraints is masterfully expressed by Goldratt *(7)*.

Key point. Problems are solved within a network of constraints. Identifying the constraints that are not hard boundaries and formulating solutions that use this freedom often yield breakthrough results.

Myth 6. We can solve anything with statistical analysis or machine learning.

Example. An engineer conducted a design-of-experiments (DOE) experimental plan with two independent parameters of gas flow and liquid flow and "proved" statistically that the gas-to-liquid ratio was the critical factor. He unknowingly proved what the technical community already had established and proved 40 years previously. A better experimental design would have used the gas-to-liquid ratio and liquid flow as the two parameters in the experimental

We have heard and personally realized the saying "A month in the lab can save you a day in the library." Today, the "library" is as close as your keyboard.

plan. This would have resulted in more insight into the problem for the same cost.

Reality. It is often important to have a model for how a process works, but there are two extremes of overtrust and under-trust:

• trusting your current model so much that you become data-driven and the model then overrides the common sense of the group and prevents further learning

• requiring your model to be perfect, and if it is not, abandoning a proper attempt to establish your intuition into a fact-based model.

As George E. Box said, "All models are wrong, but some are useful." Generate a useful model — perhaps with a spreadsheet at first — and be data-guided. If a simple spreadsheet model has predictive capability, use it and build upon that base. Keep testing for the effectiveness of the prediction and the boundaries of validity.

Key point. A simple mathematical description of the key portion of the system may guide decisions, spotlighting areas of low return. Fundamental models are preferred, but simple empirical models can also be quite useful.

Myth 7. The information is expensive to attain.

Example. An engineer needed to understand the oxygen solubility in brines at high temperature and pressure. To his great surprise, the geological literature had already developed this knowledge. However, he specifically needed the vapor pressure effect. Adding a simple Antoine water vapor pressure model to the existing framework provided the complete conceptual understanding to direct the project focus.

Reality. We have heard and personally realized the saying "A month in the lab can save you a day in the library." Today, the "library" is as close as your keyboard. The key is attaining the correct information to quickly understand and better test the most critical hypotheses.

As Douglas Hubbard describes in his book *(8)*, the cost of gathering information must be less than the "estimated value of perfect information." Anyone can gather information from government databases or even internet searches. Hubbard's "Rule of 5" shows that gathering just five random sample measurements can provide the median 93% of the time between the high and low numbers.

A related question: How precise does the information need to be to make the decision that is required? ±1%? ±20%? ±100%? Establishing this baseline will save time and money associated with lab testing.

Key point. Perfect information does not exist! The critical question is: What is the range of uncertainty needed to make a robust decision that is worth the cost?

IMPLEMENT THE DECISION

Myth 8. We can quickly fix issues as they develop.

Example. In a process safety course, the instructor emphasized how important it is to identify problems early with the fire triangle. He told the class, "If you create a design in which the fuel and the oxygen have a chance to combine, God will provide the spark!"

Reality. Considering what new problems may be created by a change is essential from both a process and personal safety perspective. If you are responsible for the solution, these and other possible outcomes must be considered.

A design failure modes and effects analysis (D-FMEA) should be used to recognize and evaluate potential product or system failures *(9)*. This is a bottom-up method that seeks to identify failure modes that can lead to hazards. If you don't understand the mechanisms of failure and systematically work to eliminate or detect problems early on, they may find you! Although D-FMEA analysis can seem tedious, it is necessary to design early-detection of hardware failure into the system.

Key point. Exposing potential problems early allows for unbiased consideration, early detection, and mitigation, which can be much less expensive than fixing the problem later, if it can be solved then at all.

Myth 9. The handoff to the implementation is easy.

Example. A small group had designed a unit for a large demonstration plant, which was then contracted to two different suppliers. When it came time to install the unit, the two pieces did not fit together. This was a critical path to restarting the unit. The next 24 hours were intense as the group sought a solution that did not cause additional problems. They did find a solution in the end, but only after an extremely stressful day.

Reality. Implementing a solution often involves people and groups who were not involved in the problem-solving process. In the normal course of events, many projects are packaged and sent off to others for implementation. This may involve manufacturing, construction, marketing, legal, or regulatory stakeholders, depending on the nature of the problem. Avoid thinking that the problem is solved once the handoff occurs.

The handoff should be thought of as part of the overall problem-solving effort. As such, the handoff can be fraught with many issues. Unknown constraints may be identified, and the detailed implementation may identify new questions that impact the original design.

Key point. The core of the problem-solving team needs to remain fully engaged for implementation of the solution to take place in a timely manner. Perhaps more importantly, including the people or groups who will be involved in implementing the solution is critical to success.

EVALUATE THE RESULTS

Myth 10. Don't worry about the report until the project is completed.

Example. Professor George Whitesides (Harvard Univ.) describes writing not only as an archival device for storing a completed research program but also as a structure for planning research in progress.

Reality. Using a "Whitesides outline" *(10)* from the start of the project aligns the efforts toward an agreed-upon problem, focuses energies toward attaining the proper data and testing, and enables adaptation when unexpected events arise. We consider the best documentation to be a paragraph-formatted document. Although slides may be a useful starting material, they lose context and most of their meaning in a few years. Some companies have limited the use of slides in favor of paragraph-form writing *(11)*.

When the project is done, you are probably already working diligently on the next project or projects. So, when do you write the report? It is best to start writing the report as soon as the project has started. Many consultants consider a short, written report as a key deliverable and begin writing portions of the report when the project begins. Reports are not necessarily scientific papers; rather, problem-solving reports are meant to capture the essence of resolving the problem, the thought process, what worked, and what was assessed to be a cause. Projects often end by fading slowly. As the project slows, the major task is to edit the report and fill in the gaps. There will be new insights and knowledge developed in solving many problems that seem subtle but are important to your business.

Key point. Begin writing the report the day the project begins, and little by little summarize the methodology and results.

Myth 11. The financial improvement is based on the most recent starting point rather than the initial starting point.

Example. A project involved two years of a series of incremental improvements to solve a complex problem. The overall improvement of the plant from the first changes improved total capacity by 5%. But the plant manager remembered only the last cluster of improvements, which had resulted in a 1% improvement. One department touted an improvement (5% total) that was not credible with the process owner.

Reality. Take a cue from the Six-Sigma work process: The project is complete when you measure the actual economic impact against the initial situation, not just the most recent situation. The impact is better stated as the difference between the start and end states. Emulating this discipline of proving the economic impact is essential; therefore, baseline

▲ **Figure 2.** Innovative problem-solving has a number of deeply held myths that hinder progress. The facts point in the opposite direction of the myths presented in this article.

Literature Cited

1. **Fogler, H. S., and S. E. LeBlanc,** "Strategies for Creative Problem Solving," Prentice-Hall, Hoboken, NJ (1995).
2. **Bazin, A. A.,** "Boyd's O-O-D-A Loop and the Infantry Company Commander," *Infantry*, pp. 17–19 (Jan.-Feb. 2005).
3. **Platt, J. R.,** "Strong Inference: Certain Systematic Methods of Scientific Thinking May Produce Much More Rapid Progress Than Others," *Science,* **146,** pp. 347–353 (1964).
4. **Liker, J.,** "The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer," Chapter 19, McGraw-Hill, New York, NY (2004).
5. **Burge, S.,** "The Systems Engineering Tool Box Pugh Matrix," https://www.burgehugheswalsh.co.uk/uploaded/1/documents/pugh-matrix-v1.1.pdf (accessed Oct. 7, 2020).
6. **Hamming, R. R.,** "Art of Doing Science and Engineering: Learning to Learn," Richard R. Hamming Original 1997 E-book available from CRC Press, Boca Raton, FL (2014).
7. **Goldratt, E. M., and J. Cox,** "The Goal: A Process of Ongoing Improvement," North River Press, Great Barrington, MA (1992).
8. **Hubbard, D.,** "How to Measure Anything," Wiley, Hoboken, NJ (2014).
9. **McDermott, R. E., *et al.,*** "The Basics of FMEA," 2nd Edition, Taylor and Francis, Milton Park, U.K. (2009).
10. **Whitesides, G. M.,** "Whitesides' Group: Writing a Paper," *Advanced Materials,* **16,** pp. 1375–1377 (2004).
11. **Rossman, J.,** "The Amazon Way: 14 Leadership Principles Behind the World's Most Disruptive Company," Brilliance Audio; Unabridged edition (audio book) (2014).

information is as important as end-of-project information.

Key point. The hard data avoids the interdepartmental squabbling about economic impact. The delivered results may be less or greater than the initial project estimate. Building a clear account and record of problem-solving results and their economic impact is valuable for individuals and also for departments. Maintaining credibility is vital for future projects.

Closing thoughts

One of the most underappreciated aspects of problem-solving is to bring in a skilled, fresh perspective. Hiring a consultant provides not only technical expertise, but also a fresh exposure to the problem and eyes that are neither biased nor constrained by previous discussions in the same ways those close to the problem are influenced. We structured this work to allow you to easily scan the myths and find something that catches your attention — each is summarized with a "key point."

Using sound fundamentals in problem-solving is important, but anyone can be diverted by one of the myths presented in this article (Figure 2). No one is immune to blind spots, and it can be challenging to avoid the blind spots and myths that you might be relying on to find the best solutions. There is no simple recipe for improving problem-solving skills. However, we suggest being systematic and using your time to resolve problems of the most significance, whether the issues you face are simple or complex. CEP

CHARLES "CHUCK" W. LIPP, the Principal Consultant at Lake Innovation LLC, focuses on spray technology and complex fluid mechanics (www.lakeinnovation.com; Email: chuck@lakeinnovation.com). The confidential consulting practice includes technology development, training development, and plant problem-solving to identify solutions. He authored two books, *Practical Spray Technology: Fundamentals and Practice* and *Spray Drying Essentials: An Introduction to the Process Technology*, and wrote several spray technology articles. Before starting Lake Innovation LLC, he was a technical leader with The Dow Chemical Company's Engineering and Process Sciences Fluid Mechanics and Mixing group. During his 35-year career at Dow, he worked on numerous processes, including coal gasification slurry atomization. He led the development and scale-up of manufacturing process technology projects that resulted in over 15 U.S. patents. He earned a BS in chemical engineering from Iowa State Univ.

DARRELL VELEGOL, PhD, is President of the Knowlecular Processes Co., which helps companies improve their innovation processes to be faster and deliver higher value (www.kpco.us; Email: darrell@knowlecular.com). He earned his PhD in chemical engineering at Carnegie Mellon Univ., has been a faculty member at Penn State Univ. for more than 20 years — currently Distinguished Professor — and has been a student of innovation processes since 2013. Velegol's research for 25 years has been in colloidal systems, active matter, chemically driven transport, and surface chemistry. He has published over 100 papers, and he has authored a book *Colloidal Systems*. His current research is in innovation processes and econochemistry. He teaches a variety of undergraduate and graduate courses, and his goal is to help students to imagine great dreams, pursue great disciplines, and win great victories.