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Solving Jigsaw Puzzles

Addressing large, complex and unstructured problems

WE ALL FACE problems in business, as well as in our personal lives and relationships. Despite the universal need for effective ways to address problems, there is surprisingly little agreement in quality or scientific literature on approaching problems in general.

Problem-solving frameworks tend to be designed for narrow, well-defined problems. Unfortunately, the most significant problems faced by modern society tend to be large, complex and unstructured. In other words, they're not well defined. How should we approach these types of problems?

Previously, the use of statistical engineering was suggested as a way to address such large, complex and unstructured problems.[1-3] Roger W. Hoerl and Ronald D. Snee defined statistical engineering as "the study of how to best use statistical concepts, methods and tools, and integrate them with IT and other relevant sciences, to generate improved results."[4]

This article focuses on what can be learned from diverse disciplines on addressing large, complex and unstructured problems. We therefore provide a broader context—coming from diverse disciplines—in which to view statistical engineering. In general, this broader viewpoint reinforced several observations by Hoerl and Snee, and also led to some unique insights.

How do other disciplines do it?

Virtually every discipline faces large, complex and unstructured problems. To obtain a sampling of this diversity, academics in math, psychology, engineering, economics and biology were interviewed, and numerous publications from these and other disciplines were reviewed. For the sake of brevity, only a few highlights from this research are noted.[5]

The problem-solving process in psychology typically focuses on brain activity and the personality traits that contribute to the way we solve problems. For example, Sascha Topolinski and Rolf Reber define and interpret the "a-ha moment"—that sudden moment of clarity in which a person realizes the answer to the problem he or she has been trying to solve.[6] The four key components of the a-ha experience are suddenness, ease, positive affect and the feeling of being right.[7]

In a popular problem-solving manual, Graham Wilson describes the way personalities affect decision-making styles.[8] He suggests that your preferences inherently affect the way you make decisions, which implies that sound problem-solving invariably involves diverse teams with different personalities. In terms of personality, a concern raised by economics professor Lewis Davis is that creativity cannot be effectively taught, but it is often what separates successful and unsuccessful problem solvers.[9]

A related consideration is who should be making the decisions. One pitfall to avoid during group decision making is a phenomenon called groupthink in which members "let their need to agree with each other interfere with their ability to think about the decision critically."[10]

According to psychology professor Erika Wells, one of the important aspects of problem solving is the size of the problem space.[11] The larger the problem space, the longer it takes for us to acknowledge all of our variables and alternative approaches and test them. Thus, we should always take steps to try to reduce our problem space as much as we can, which usually involves a subject matter expert.

An interesting twist on team problem solving and personalities comes from engineering in that a unique difference between engineering and other fields is the explicit emphasis on teamwork.[12] Most engineering problems require a significant amount of background knowledge in a variety of fields, which would be unreasonable for any one person to know. Therefore, combining effort from team members with unique expertise allows teams to develop creative and effective solutions. Of course, most disciplines require teamwork to be effective; according to mechanical engineering professor Brad Bruno, this need is just more explicitly emphasized in engineering.

In the context of big data analytics, Olaf Wolkenhauer and his co-authors note the need to have an interdisciplinary approach to solving large and complex problems in biomedicine: "Many scientific questions require a range of expertise from different fields. Therefore, integration across disciplinary boundaries is crucial. The expertise for particular technologies and experimental systems is rarely found in a single laboratory, institute or country, and this raises the need for standards and ontologies that support the sharing and integration of data and models."[13]

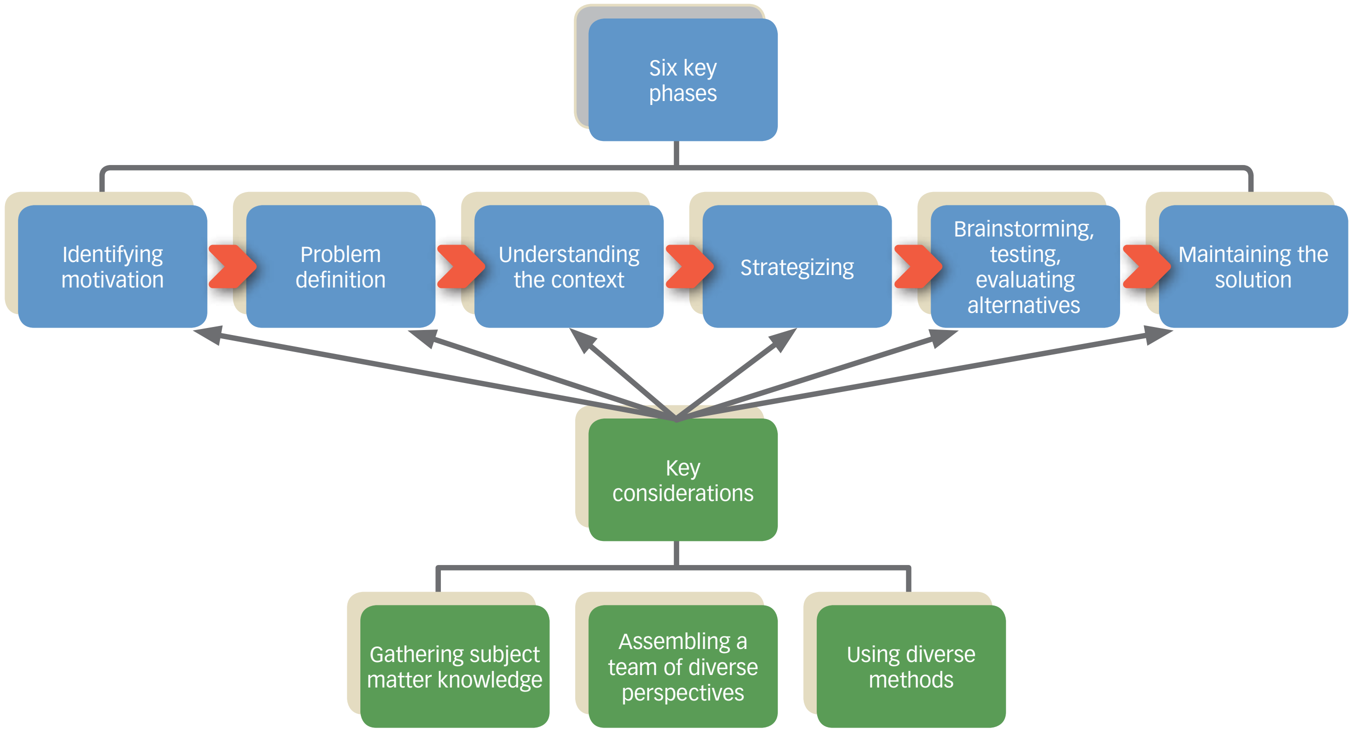
It is generally understood that solving complex problems requires some type of strategy or multi-step process. For example, Wilson suggests five steps to solve emergency problems: identify the problem, explore alternatives, select an alternative, implement the solution and evaluate the solution. Wilson notes that problem identification is often the most important and most difficult step in the decision-making process.[14]

Wilson emphasizes the importance of consciously considering all of these steps, while it may not always be necessary to write down or formally document all. Wilson breaks down each step into smaller pieces to make it clearer and easier to understand. This produces specific tactics within the overall strategy.[15]

Andreas Fischer and co-authors discuss another multi-step method called complex problem solving and explain how it applies to various fields.[16] They highlight five key points of this process: information generation, information reduction, model building, dynamic decision making and evaluation. These authors further note that one of the most important aspects of problem solving in any field is to have knowledge of the tools needed to actually solve the problem (that is, applying equations and models), and subject matter knowledge (or an expert nearby).

TRIZ, also commonly referred to as the "theory of inventive problem solving" or "TIPS," provides an alternative problem-solving method.[17] The basis of this method

Key problem-solving phases and considerations from review / FIGURE 1



is that we can use already-established principles and insights from other fields that may not necessarily be related to what we're studying. If they are similar enough, we can apply these techniques from other disciplines to solve our new problems.

TRIZ is often used where we have to somehow avoid an inherent conflict within our problem, such as creating a high-powered aircraft engine that is also light. These two qualifications seemingly contradict each other: The most high-powered engine we could make is probably large and heavy, while the lightest engine we could make is probably not high powered.

What have we learned?

There are several recurring themes that appear throughout literature on large, complex and unstructured problems. DiBenedetto organized them into two macro themes—the first being a set of six key phases that, regardless of the problem-solving method used, a researcher must pass through and consciously consider.[18] While not a formal process in themselves, these phases cannot be skipped and must be considered regardless of the type of problem.

The second macro theme contains critical considerations for problem solvers during all phases of the problem-solving process. These conclusions, shown in Figure 1 (p. 51) and Table 1, support those of Snee and Hoerl, who stress that statistical engineering applications require logical phases and there is an underlying theory of key principles for statistical engineering approaches, regardless of which specific problem-solving method is used.[19]

As shown in Figure 1, the six phases required are (in order):

1. Identifying the motivation for solving the problem.
2. Defining the problem.
3. Understanding the context.
4. Strategizing.
5. Brainstorming, testing and evaluating alternatives.
6. Maintaining the solution.

Within the second macro theme of crucial problem-solving considerations, the critical principles are: gathering subject-matter knowledge, assembling a team of diverse perspectives and using diverse methods. These principles are not unique to any of the phases but are important in each.

Advice for problem solvers

We can make recommendations for problem solvers beyond the points listed in Figure 1 (see Table 1). First is that the phases and critical considerations are not meant as a "cookbook" to be followed in "seven easy steps," or as the best or only way of solving a complex problem. They are meant, however, to provide structure and some underlying theory for people who don't know how to attack a large, complex and unstructured problem.

One issue within the quality and problem-solving literature is that it spends too much time defending preferred methods and arguing as to which techniques are best. This is misguided effort because no single method can solve every problem.

The second recommendation for those responsible for addressing big problems is to spend a significant amount of time gathering the right group of people to assist them during the problem-solving process. This step is often overlooked because natural teams can form through existing relationships and problem-solving teams of the past. Each problem should be considered individually, however, so that various personalities and experts can be assembled to form a diverse, cohesive and productive problem-solving team.

Similarly, effective problem solvers must be comfortable using tools and techniques that they were not previously familiar with. It is easy to rely on the tools that you know have worked in the past, but when dealing with large, complex and unstructured problems, it is important to look outside of your traditional toolbox to produce novel solutions.

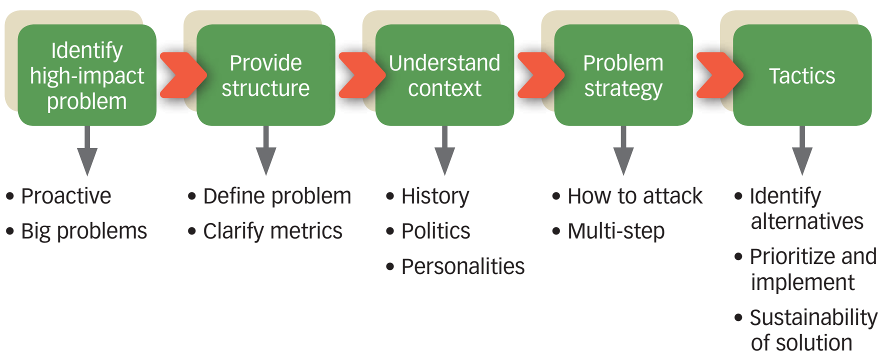
The next recommendation is to read Wilson.[20] This manual is intended to help people teach themselves problem-solving methods within the context of emergency situations. It may not seem relevant to the process of solving large, complex and unstructured problems, but it breaks down the process into its most basic definitions (that is, what do we define as a problem?), and provides various steps and methods for working through the problem-solving process.

The fourth recommendation is to give yourself more time than you think you might need to solve complex problems.

Recommendations for problem solvers / TABLE 1

1. Figures 1 and 2 show the phases of problem solving and are not meant as cookbooks, or suggested as the best or only ways of problem solving.
2. Project team selection is critical. Make sure that you have the right skills involved.
3. Become familiar with Graham Wilson's manual; it contains much useful advice.
4. Give careful consideration to project planning. Problem definition and solution identification, and data collection and preparation can be time consuming.
5. Make sure that the solution can be successfully implemented and sustained over time.

Phases of statistical engineering projects / FIGURE 2



Problem solvers should take the time to carefully define the problem, as this is the "make or break" aspect of the problem-solving process. Additionally, researchers and problem solvers could benefit from having time to create alternatives and analyze them, and have more time to contemplate these solutions and reflect on what they have accomplished. While modern society tends to schedule breakthroughs, solutions to large, complex and unstructured problems often take time.

A final recommendation is to make sure that after you have a solution, you can successfully implement and sustain the results. Our efforts would be futile if we spent our resources on solving a problem and could not implement and sustain the results. This implies that throughout the problem-solving process, including deciding which problems to work on, we consciously consider the long-term view of sustainability.

Statistical engineering

The results and recommendations discussed reinforce many of the conclusions of Hoerl and Snee. In particular, if you compare Figure 1 with previous models that Snee and Hoerl have proposed for the phases of statistical engineering projects,[21-22] you see a great deal of consistency. Therefore, we propose Figure 2 as integration of these previous models that hopefully combines the advantages of both. In particular, consider the last two phases of Figure 1 to be specific examples of the tactics you would employ in the final phase of Figure 2.

As this article shows, there are many problem-solving techniques used within various disciplines. The goal is to condense the literature on these methods to identify important themes that could help people solve big problems across disciplines. Collectively, we have attempted to integrate the key learnings of this external review into the previous work of Hoerl and Snee on statistical engineering. By using the guidelines and consciously considering the key themes proposed, you will have the framework necessary to successfully address large, complex and unstructured problems. QP

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