CHAPTER 1

# A Systems Mindset

*Like all systems, the complex system is an interlocking structure of feedback loops . . . . This loop structure surrounds all decisions public or private, conscious or unconscious. The processes of man and nature, of psychology and physics, of medicine and engineering all fall within this structure.*

—Jay W. Forrester, *Urban Dynamics*

*Each transaction of living involves numerous capacities and aspects of man's nature which operate together. Each occasion of life can occur only through an environment, is imbued with some purpose, requires action of some kind, and the registration of the consequences of action. Every action is based upon some awareness or perception which in turn is determined by the assumptions brought to the occasion. These assumptions are in turn determined by past experience. All of these processes are interdependent. No one process could function without the others.*

—Hadley Cantril, *The "Why" of Man's Experience*



A *systems mindset* is the connecting thread for the wealth-creation issues covered in this book. This chapter briefly covers the intellectual foundation underlying the systems mindset. We begin with an examination of the knowing process, the foundation for the systems mindset. Normally, we give no thought to how we know what we think we know. That is because in much of everyday life we take for granted the knowledge we use to guide our actions in order to achieve our purposes. A lot of the time we work on autopilot, as when we drive to work or tie our shoes. We don't have to think it through each time. So why invest time in exploring the esoteric topic of how we know what we think we know? Because there can be a big payoff from learning how a systems mindset helps one to develop better solutions to important complex problems (Sterman, 2000).

## HOW WE KNOW WHAT WE THINK WE KNOW

To a large extent, life consists of overcoming the problems we encounter in our attempts to achieve our purposes. Along with the easy problems in life are many enormously complex and difficult ones. These would be considerably less difficult if our notions about how the world works were more reliable.

It is comforting to have reliable knowledge to deal with problem situations that have straightforward, linear cause-and-effect relationships. For example, fixing a flashlight that no longer works by replacing the batteries poses little challenge to our knowledge of cause and effect. But, approaching complex problems with an overly simplistic linear mindset often makes matters worse instead of better.

Based on an analysis of the work of people, especially scientists, who have been extremely successful in solving complex problems, I have learned three lessons that are important to a better understanding of knowing:

1. Reality as we know it is just our perception of it—a kind of map of reality, not the true territory of reality.
2. Action is an integral part of cause-and-effect loops, with purpose playing a critical and often-overlooked role.
3. Identifying the strongly held assumptions (beliefs) that influence what we perceive and how we determine our actions in the world is vitally important to opening us up to perceiving new feedback information and to faster knowledge improvement.

Putting these lessons into practice takes conscious effort, because much of our life experience has been dealing with the outside world as independent components of reality for which one-way, or linear, cause-and-effect thinking is adequate.

## THE PAK (PERCEIVING-ACTING-KNOWING) LOOP

The *perceiving-acting-knowing* system can be visualized as a loop of intimately related components. Figure 1.1 illustrates the components of this system, which I refer to as the *PAK Loop*. A useful understanding of how this system functions requires a focus on the loop as a whole and not on the components in isolation.

As noted by the psychologist Hadley Cantril in the quotation at the beginning of this chapter, perceiving, acting, and knowing is an interdependent process. Nevertheless, a discussion of the PAK Loop requires some starting point. For convenience, we will begin at the point where an individual is trying to achieve a purpose within the context of the perceived world "out there."

### Purposes

Purposes are personal. They are the outcomes we, as individuals, seek from the actions we take. (This is not to say we always get what we seek.) The great bulk of our purposes are mundane. Consider all the specific, detailed purposes and related actions taken in driving to work—from as small, or low-level an action as moving the steering wheel a little to the left or right to counteract a crosswind so the car stays on our intended course. Some larger, or higher-level, purposes of driving to work would include: why you work

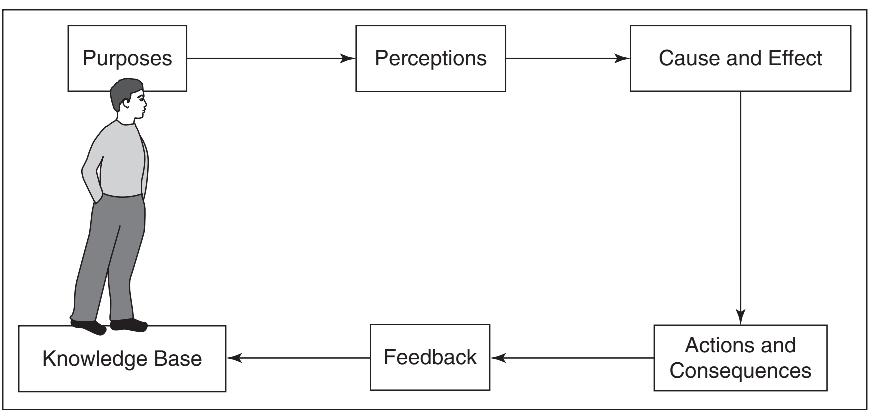


**FIGURE 1.1** PAK Loop
*Source*: Madden (2008b).

(survival? self-fulfillment? enjoyment?) and why you have a particular job (steppingstone to a better job? prestige? power?). It quickly becomes evident that we function within a hierarchy of purposes, with higher purposes guiding, or *setting*, lower purposes.

Being cognizant of higher-level purposes is especially relevant to business wealth creation. For example, in Chapter 7 I describe the decision of a Japanese pharmaceutical company's top management to align the firm's mission statement (purpose) with the higher-order purpose of genuinely helping patients that was widely shared by employees. One result was significant improved corporate financial performance.

Studies of brain activity suggest that many of the common things we do are not associated with brain areas that are responsible for awareness or consciousness. Apparently, we operate much of the time as if on autopilot (Gazzaniga, Ivry, and Mangun, 2008). This is highly functional, and indeed necessary. Otherwise, our consciousness would be overwhelmed by minutiae—*perceptual noise*. Evolution has equipped us to do things much more quickly than we could if everything required conscious mental processing. Many actions would be impossible. Think of all the things that require virtually instantaneous "muscle memory," such as getting out of bed, walking, or typing.

But being on autopilot has its downside. Consider two economists given the task or purpose of evaluating whether minimum wage legislation is good or bad for the economy. One economist is a believer in free markets and the other believes government regulation is necessary to prevent or fix market deficiencies. Because of their core assumptions, they are on different automatic pilot programs, and their expectations are already set to a large degree (Olson, Roese, and Zanna, 1996). The data they choose to consider (and ignore), the time periods covered, and the forms of analysis employed for the lower-level research purpose of evaluating the economic impact of minimum wage legislation are most likely to be biased.

Economists (and other inquirers) who have a genuine, higher-level purpose of better understanding cause and effect need to explicitly guard against being guided by their automatic thinking and acting templates. Such researchers would be well served by, at an early stage, explicitly working creatively to overcome the heavy hand of often-unconscious beliefs.

## Perceptions

Any discussion of perceptions raises the age-old philosophical question, "What is reality?" (Madden, 1991). Thinking that there is a pure, independent reality needs to be replaced with the concept that reality is actually dependent on an individual's past experience and current knowledge base, such that each of us is a participant in perceptions of what is "out there." This also helps put into practice one of the hallmark criteria of science, namely, that all knowledge is tentative and subject to revision.

In the 1940s and 1950s, Adelbert Ames Jr. and his colleagues initiated a paradigm shift away from the view of perception as a passive response to the external environment and toward the view of perception as a process actively carried out by the individual (Bamberger, 2006). Ames was frequently labeled a genius due to his path-breaking research in visual perception at the Dartmouth Eye Institute. Ames and John Dewey often exchanged ideas on Dewey's transactional approach to knowing as it related to perception (Cantril, 1960).

The Ames Demonstrations were a series of ingenious laboratory experiments that illustrated the dominating influence of observers' strongly held assumptions. For example, assumptions that floors are level, windows rectangular, bigger is closer, and the like, are particularly strong because of our extensive experience with actions being successful based on the validity of these kinds of assumptions. When an experiment falsifies a strongly held assumption, we nevertheless construct a visual "reality" that conforms to what we "know" to be true.

The Ames Demonstrations in visual perception were instrumental in showing that purpose, perception, and action are all parts of a single connected system.[1]

> [T]hese experiments . . . suggest strongly that perception is never a sure thing, never an absolute revelation of "what is." Rather, what we see is a prediction—our own personal construction designed to give us the best possible bet for carrying out our purposes in action. We make these bets on the basis of our past experience. When we have a great deal of relevant and consistent experience to relate to stimulus patterns the probability of success of our prediction (perception) as a guide to action is extremely high, and we tend to have a feeling of surety. When our experience is limited or inconsistent, the reverse holds true. . . . [P]erception is a functional affair based on action, experience and probability. The thing perceived is an inseparable part of the function of perceiving, which in turn includes all aspects of the total process of living.
>
> (Ittelson and Kilpatrick, 1951, p. 55)

The interdependent processes that contribute to visual perception are analogous to the components of the PAK Loop, which are best viewed as cross-linked together in a system that, for the most part, operates simultaneously as opposed to a mechanistic step-by-step procedure.

### Cause and Effect

Problems are perceived within a given context. Attention to context increases as one's knowledge base broadens and one is able to appreciate ever-greater complexities of cause and effect. This leads to wider avenues for drawing on patterns that were adequate in the past for connecting cause to effect. Some patterns, or assumptions, have proven so reliable in the past that we take them as non-debatable truths. For example, when driving we use assumptions about the size of cars. Consequently, when approaching cars are seen as getting bigger, we also perceive them as getting closer.

Experts have more patterns to draw on than do non-experts. When past experience seems insufficient (as with a new problem), one looks for additional information (creating a new purpose) and that can lead to hypotheses about a root cause. How a problem is formulated, the initial selection of variables to study, the first hunch at possible connections, and the criteria used for evaluating the evolving hypotheses do not arise in an objective, unbiased fashion (Argyris and Schön, 1996).

In analyzing cause and effect, decision makers need to be keenly aware of the deep pull of their existing knowledge base about how the world works, which has been built up over a lifetime of experience. Also, decision makers should be attentive to the organization's culture or way of doing things that has evolved to meet a variety of purposes that, in subtle ways, may interfere with the primary goal of the organization. Culture results in strongly held assumptions that influence how problems are perceived and the extent to which hypotheses about cause and effect need testing.

Consider two examples with horrific consequences due to faulty analysis of cause and effect:

1. Will the cold temperature at liftoff cause failure of the O-ring seals for the rocket that propels the *Challenger* space shuttle?
2. Will damage from the observed foam debris at liftoff for the *Columbia* space shuttle impair reentry?

The *Columbia* Accident Investigation Board approached their work with a systems mindset. The Board concluded for both disasters that "previous political, budgetary, and policy decisions . . . impacted the Space Shuttle Program's structure, culture, and safety system . . . these in turn resulted in flawed decision-making for both accidents" (CAIB, 2003, p. 195).

That improved cause-and-effect analysis leads to better decision making, there is little doubt. But cause-and-effect analysis is not performed in isolation, even though one might, at times, believe otherwise. Rather, the analysis of cause and effect is best viewed as one component of the PAK Loop.

## Actions and Consequences

The purpose of analyzing cause and effect is to learn to take actions that will yield desired consequences. As systems become more complex, so, too, does cause and effect.

Particularly in economic matters, decisions can have decidedly different near-term and long-term effects. A classic public policy example is when government officials employ an easy credit and money policy to stimulate near-term general income, output, and employment. Only sometime later do the negative effects appear in the form of rising prices and cyclical corrections of unsustainable resource allocations. A similar time delay of effects has been observed when a new CEO, noted for cost-cutting, makes large cuts in a firm's R&D budget and fires talented employees in order to improve near-term accounting earnings. But the loss of employee trust and talent reduces the firm's ability to create long-term wealth. The key point is that effects can occur with or without a time lag, or in a different physical location from the original cause, leading to erroneous conclusions about the consequences of particular actions.

Let's return to the foam debris issue that damaged the *Columbia* space shuttle to emphasize again the interrelated components of the PAK Loop. Many successful space shuttle flights, and pressure to meet flight deadlines, led to an assumption that the space shuttle was an operational vehicle and not an experimental vehicle. Within the context of being an operational vehicle, what was the consequence of earlier space shuttle liftoffs that generated foam debris? Those situations were categorized as a maintenance issue and not a flight-safety issue (Starbuck and Farjoun, 2005).

## Feedback

The earlier "Purposes" section commented on the human ability to operate on autopilot, allowing us to act much more quickly than if we had to think it through each time before we could act on anything. Acting without giving sufficient thought can also have unintended negative consequences. This is so common that it is called the *law of unintended consequences*.

A key question that arises is how to promote reliability when acting to achieve intended consequences—that is, How do we do a better job of getting what we want? Importantly, we do not face an intractable tradeoff of quick, but overly simplistic thinking versus ponderously slow thinking attuned more to the complexities of situations. *On the contrary, to improve one's knowledge base, the fundamental objective should be to implement habits that promote faster and more effective cycles through the PAK Loop*. In other words, improve feedback so that evidence of consequences is accumulated more quickly and processed more rapidly, as well as more accurately.[2]

The speed and effectiveness of cycles through the PAK Loop explain both failures and successes in solving tough problems and developing breakthrough ideas for wealth-creating opportunities. These are the tasks that especially concern design firms. IDEO is generally recognized as the top design firm. IDEO was instrumental in producing the first mouse for Apple, the first laptop, the Palm V digital organizer, a needle-free vaccine, the KickStart micro-irrigation pump to help African farmers, and a long list of award-winning innovations. Tim Brown, CEO of IDEO, described how his designers work:

> Design thinking is inherently a prototyping process. Once you spot a promising idea, you build it. The prototype is typically a drawing, model, or film that describes a product, system, or service. We build these models very quickly; they're rough, ready, and not at all elegant, but they work. The goal isn't to create a close approximation of the finished product or process; the goal is to elicit feedback that helps us work through the problem we're trying to solve. In a sense, we build to think.
>
> (Brown, 2007)

Note how prototyping at IDEO accelerates feedback, leading to faster and more effective PAK Loops.

More and more companies are focusing on their internal innovation processes to leverage the successful practices of design firms such as IDEO. Employees respond enthusiastically to opportunities to deliver new products and services that are truly meaningful to customers. Apple and Medtronic, reviewed in Chapter 4, are prime examples of companies that achieve competitive advantage through innovation.

### Knowledge Base

Our existing stock of knowledge affects how we perceive the world and recognize problems that interfere with achieving our purposes. We also confront anomalies that don't make sense based on our existing assumptions or theories about cause and effect. Taking actions (testing hypotheses) provides the feedback needed to complete a perceiving-acting-knowing loop.

To reiterate, the PAK Loop configuration and directional flow is a necessary construct for ease of explanation. To think of the process as a single transaction, a system with each aspect interacting simultaneously with all the others is more accurate. A market transaction may be a helpful analogy. A market transaction involves, at a point in time, a buyer, a seller, and a price, all within a constellation of potential buyers and sellers at various prices (demand and supply schedules that reflect past developments and future expectations) within an even more complex political and cultural universe. All of these aspects are captured and reflected in a single transaction. The PAK Loop captures these dynamics for building one's knowledge base, and therefore improves on the often-used (but vague) term *knowledge growth*.

Consider the enormous stock of built-up knowledge that a mechanical engineer brings to work each day. New problems without obvious answers are a way of life for engineers—as well as the rest of us. So, we experiment to try to understand cause and effect.

Given the difficulties in pinpointing cause and effect for complex systems, we *should* actively seek evidence that *disconfirms* the hypotheses we favor. But studies of how people analyze data and make conclusions strongly suggest that we tend to seek evidence that *confirms* our expectations (Heuer, 1999). Coupled with an oversimplification of cause and effect, we get stuck with bad habits that yield slow and ineffective cycles through the PAK Loop.

However, some people do especially well in overcoming this hurdle. For example, leaders of aircraft carrier crews treat their current expectations with constructive skepticism and are especially alert to potentially important new connections and alternative hypotheses.

## EXAMPLES OF SYSTEMS THINKING AND PROBLEM SOLVING

Let's dig deeper into how some people achieve fast and effective PAK Loops. For reference, Figure 1.2 shows the main points about the components of a PAK Loop. This is a useful reference for analyzing how systems thinking can contribute to improved knowing and better performance in a wide variety of situations. The following examples range from organizations where exceptional high performance is the norm to individuals with expertise in business theory and in the design of fighter aircraft.

### High-Reliability Organizations

In their book, *Managing the Unexpected: Assuring High Performance in an Age of Complexity,* Karl Weick and Kathleen Sutcliffe (2001) report on

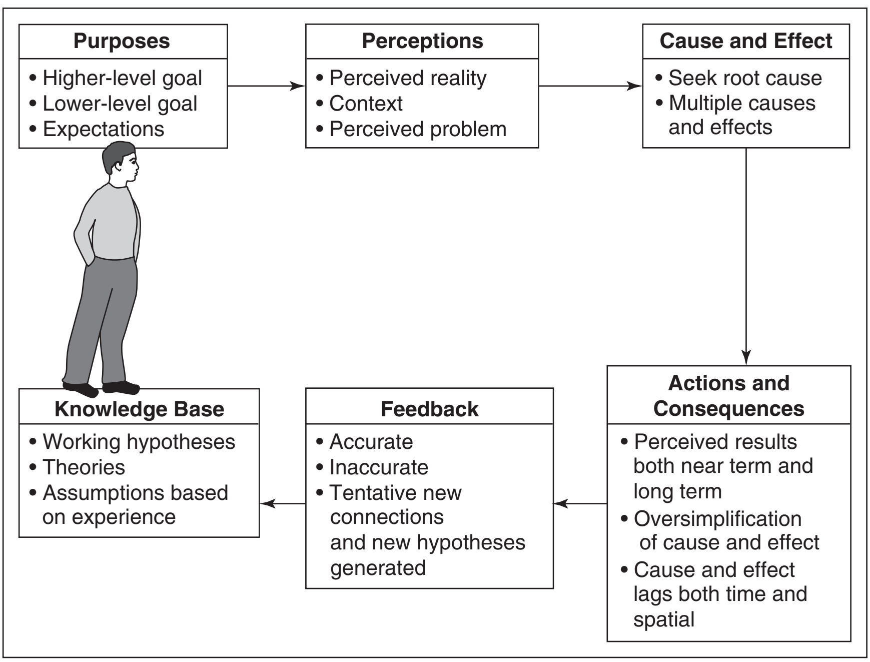


**FIGURE 1.2** PAK Loop Components
*Source*: Madden (2008b).

high-reliability organizations—aircraft carriers, nuclear power plants, firefighting crews, and the like. Weick and Sutcliffe use the term *mindfulness* to capture the five characteristics of organizations that excel in managing the unexpected:

1. Preoccupation with failure
2. Reluctance to simplify interpretations
3. Sensitivity to operations
4. Commitment to resilience
5. Deference to expertise

These characteristics are readily explainable within the PAK Loop framework. A *preoccupation with failure* can be viewed as a purpose in itself. That is, one makes a conscious attempt to override the comfortable assumption that all is fine if no significant problems are observed. By giving considerable attention to anomalies and minor issues, mindful people continually raise penetrating questions as to whether they are observing, not an insignificant oddity, but rather the beginning of a failure in the system. Their perceptions tend to raise questions rather than provide answers because their training and experience exposes very costly negative consequences of slow cycles through the PAK Loop.

An awareness that knowledge is always incomplete and the situation being faced is always complex naturally leads to a *reluctance to simplify interpretations*. In this regard, when studying the long-term histories of firms, I repeatedly encountered firms that got into trouble because top executives assumed that the future would be a replay of their past success. This simplistic extrapolation, typically coupled to a belief that bigger is always better, was at the heart of the declines for IBM and Digital Equipment, as illustrated in Chapter 4.

A nuclear plant operator, or a crew member on the flight deck of an aircraft carrier, is trained for fast cycles through PAK Loops. Of particular importance for evaluating working hypotheses is access to real-time data. This same *sensitivity to operations* is also evident in the highly efficient Toyota manufacturing plants described as part of lean enterprise management in Chapter 6.

A *commitment to resilience* is a characteristic of those who are cognizant of, and comfortable with, their incomplete knowledge and who also put a premium on early and insightful feedback. Feedback in an organization improves as more people with diverse viewpoints (skill sets) share the available data.

Diversity plays into *deference to expertise*. Expertise is crucial to the core objective of fast and effective cycles through PAK Loops. Those with expert knowledge in problem solving need to be in charge; otherwise, performance suffers, regardless of how fast the pace of decisions and feedback.

While species evolution may be summarized as "survival of the fittest," evolution of organizational systems may be summarized as "success goes to those with faster and more effective PAK Loops relative to competitors." Building up knowledge and dealing with problems in ways consistent with the PAK Loop framework results in mindful behavior as summarized by Weick and Sutcliffe:

> [M]indfulness is essentially a preoccupation with updating. It is grounded in an understanding that knowledge and ignorance grow together. When one increases so does the other. Mindful people accept the reality of ignorance and work hard to smoke it out, knowing full well that each new answer uncovers a host of new questions. The power of a mindful orientation is that it redirects attention from the expected to the [perceived to be] irrelevant, from the confirming to the disconfirming, from the pleasant to the unpleasant, from the more certain to the less certain, from the explicit to the implicit, from the factual to the probable, and from the consensual to the contested. Mindfulness and updating counteract many of the blind spots that occur when people rely too heavily on expectations. It is these very same blind spots that conceal the early stages of eventual disruptions. And it is the removal of these blind spots that is an important part of managing the unexpected. People on carriers work hard to minimize blind spots.
>
> (Weick and Sutcliffe, 2001, p. 44)

Systems thinking can be applied to basically any problem situation. Two impressive applications are described in the following.

### Eli Goldratt, Business Theorist

Eli Goldratt, a former physicist, has enormous expertise in applying systems thinking and cause-and-effect analysis to business firms in order to improve their performance. Goldratt communicates through conferences and videos (see www.eligoldratt.com) and popular novels such as *The Goal* (2004).

Goldratt's *Theory of Constraints* employs systems thinking to answer three core diagnostic and prescriptive questions:

1. What to change?
2. Change to what?
3. How to cause the change?

His thinking tools help to map complex systems, and track cause and effect attuned to pinpointing root sources of undesirable effects; identify constraints; uncover faulty assumptions; and develop, communicate, and implement solutions (Dettmer, 2007).

Goldratt begins with the goal of a system. A constraint is anything that interferes with achieving the goal. The key constraint, or bottleneck, is the largest impediment to improving system performance. Hence, the answer to the question of what to change is: Fix (elevate) the key constraint.

A key concept in Goldratt's mapping logic is the difference between local efficiency and overall system efficiency. Employees typically have expertise in one function or department within a larger organization. And their motivation is almost always to optimize productivity solely for their function or their department.

However, optimizing local efficiencies does not necessarily translate into optimizing overall system efficiency. Consider a manufacturing line where the key constraint is actually machine B. Although the installation of a more efficient and faster machine A upstream from and feeding into B will improve A's performance, this can easily make matters worse for B and degrade the overall system performance.

Another key idea is to apply constructive *skepticism to the oftentimes hidden assumptions that influence ways of thinking and doing things and that are the root causes of problems*. This is necessary to overcome misperceptions of problems. Important constraints often reside not in a physical process, but rather in the mindset of the managers (i.e., in how managers perceive reality).

Absent a systems mindset, managers can observe a resource sitting idle and reflexively conclude that this represents waste. Why? In terms of the PAK Loop, most likely their knowledge base reflects experience in improving local efficiencies as measured by accounting data.

The problem is not an idle machine, but how problems are perceived. Elimination of waste (activities that do not add value to the end customer) is critically important, as discussed in Chapter 6. Nevertheless, considerable care is needed to keep an eye on how a change in a process will impact the performance of the overall system. Goldratt provides valuable advice in terms of problem identification—look for the key constraint, which will not likely be an idle machine.

### Colonel John Boyd, Military Theorist

Widely recognized as the best pilot at the Fighter Weapons School at Nellis Air Force base in the1950s, John Boyd would defeat all opponents in engagements, and typically within 40 seconds. Throughout his career, he developed practical solutions to complex problems and improved his thinking process for making decisions. His energy maneuverability theory for jet fighters was, at bedrock, a dynamic systems approach for analyzing design tradeoffs. It was critically important to the development of the hugely successful F-16 aircraft (Hammond, 2001). Corcam (2002, p. 127) described it as "fundamental and as significant to aviation as Newton was to physics."

Boyd is most remembered for his *OODA Loop*, which he first used to explain his extraordinary success in aerial combat, and which he later generalized to maneuver warfare. He contended that success in conflict depended on operating inside the opponent's *observation-orientation-decision-action* time cycle, or OODA Loop. In operation, when one takes unexpected actions at a fast tempo, this can cause opponents to slow the orientation component of their OODA Loops and breed confusion as to what action they should take. Boyd noted that the German blitzkrieg strategy in World War II was successful because it allowed freedom at the platoon level to exploit opportunities via rapid OODA Loops.

The popularity of OODA Loop thinking has spread to business managers implementing time-based strategies to gain competitive advantage (Stalk and Hout, 1990). Boyd's detailed version of the OODA Loop (see Osinga, 2007, p. 231 and also www.d-n-i-net/dni/john-r-boyd/), while not explicitly dealing with the knowledge base and purposes components of the PAK Loop, nevertheless is similar in many respects to the PAK Loop. The OODA Loop corresponds to the PAK Loop as follows: observation (perceptions), orientation (cause and effect), decision/action (actions and consequences). Both the PAK Loop and the OODA Loop operate as a system. Boyd describes this as follows:

> Note how orientation shapes observation, shapes decision, shapes action, and in turn is shaped by the feedback and other phenomena coming into our sensing or observing window. Also note how the entire "loop" (not just orientation) is an on-going many-sided implicit cross-referencing process of projection, empathy, correlation, and rejection.
>
> (John Boyd, quoted in Corcam [2002, p. 344])

## CORRELATION, CAUSALITY, AND CONTROL SYSTEMS

In contrast to Boyd's OODA Loop, the PAK Loop makes explicit the importance of one's knowledge base and purposes that operate "behind the scenes" in the perception of problems. Consider steelworkers in two radically different environments. Chapter 4 contains the track records and company descriptions for both Bethlehem Steel and Nucor Corporation, another steel company. Bethlehem management was noted for an especially adversarial relationship with its unionized workforce and routinely fired large numbers of employees. Conversely, Nucor's nonunionized workforce, under its CEO Ken Iverson, was regularly paid substantial bonuses for productivity gains, participated in a culture of teamwork and respect for employees' problem-solving skills, and also benefited from a no-layoff policy.

Is it not plausible that a Bethlehem steelworker would either ignore, *or perhaps not even perceive,* a problem that would quickly gain the attention of a Nucor steelworker? In this case, their assumptions about their employer ("management exploits us" versus "management treats us fairly and respects our abilities") and employee purposes ("productivity gains are for management to worry about" versus "help those on my team to improve productivity") must certainly play an important role in how situations are perceived.

These different perceptions tie into a fundamental observation on improving the performance of organizations that was made by Steve Zaffron and Dave Logan (2009, p. 6): "How people perform correlates to how situations occur to them." In addition, assumptions about both the past and the future influence people's perception—that is, how a situation occurs to them.

Ignoring the heavy influence of assumptions in shaping employees' perceptions can easily lead management astray. That is, a faulty analysis of cause and effect leads to performance improvement initiatives that yield little, if any, sustained benefits.

An oversimplification of cause and effect is a major danger in problem solving. Note that oversimplification is a bullet point under the "Actions and Consequences" component (see Figure 1.2). Initially, it could be interpreted as the customary warning not to automatically conclude that *X causes Y* just because *X* is highly *correlated* with *Y*. While that is true, the key issue here is that individuals using systems thinking have the goal of gaining a more reliable knowledge base. And how one handles cause and effect is critical to achieving that goal.

Consider the situation of opening windows in a room (variable *X*) during a very cold winter and then observing (feeling) warm air (variable *Y*) beginning to flow through the vents into the room. In this case, the correlation of *X* with *Y* appears to imply that *X* causes *Y*. But, the key prerequisite to understanding this situation is to realize that a *control system* is involved. The thermostat in the room is adjusted to a desired temperature setting, or reference perception. If opening windows results in a temperature in the room significantly below the reference perception, the thermostat calls for the furnace to send warm air until the error term (actual versus reference perception) drops to zero. Room temperature is the control variable.

This shows that the degree of correlation between the independent and dependent variables depends on the environment, or context—in this case, the outside air temperature relative to the thermostat setting. The conclusion that opening windows "causes" warm air to flow through the vents ignores the purpose of the thermostat control system and yields an inaccurate understanding of the situation. The main message here is to be aware of situations that involve control systems, for such systems have a purpose and involve actions that can control perception.

A compelling case has been made that we humans have neural circuits wired as control systems.[3] As such, analyses of human behavior that ignore control variables and reference points can lead to illusions about cause and effect. Along these lines, have you not sometimes been initially puzzled by a person's observed behavior until later you learn what motivated that behavior, which is to say what his or her control variable was?

## Summary of Key Ideas

- People participate in shaping their perceived reality and are an integral part of the problems they seek to resolve. Being aware that we are unavoidably biased will help us to be open to observations and thoughts that go against our biases and could, perhaps, improve our lives.
- Difficulty in solving a problem varies in relation to the difficulty of understanding cause and effect for the system in which the problem resides. Systems involve causal loops in which cause and effect are intertwined.
- Excessive reliance on an analysis of variables in isolation misses the importance of system complexity, of the multiplicity of simultaneously interacting relationships, and thus often is not capable of revealing how a system, as a whole, functions. In such instances, problems are perceived within a silo, leading to actions that produce unintended, bad consequences.
- A systems mindset facilitates a transition from observing specific events, to realizing the patterns that connect events, and to a deeper appreciation of the interactive structure of a system. Understanding system structure is the key to discovering root causes of undesirable system effects. Often, a root cause is contained in a faulty assumption that has gone undetected because its connection to one or more undesirable effects is not obvious.
- One reason why organizations tend to encounter wickedly difficult problems is that their employees have myriad personal worldviews, purposes, and expectations. Systems involving people, who are purpose-driven, are ill-suited to simple, linear cause-and-effect analysis.
- Instead of treating perception, action, and knowledge as independent of one another, a better method is to emphasize the close relationships among perceiving, acting, and knowing. The PAK Loop is designed to do this.
- The benefit of a systems mindset is in developing faster and better solutions to problems. Whether problems are encountered in ecology, engineering, economics, or whatever the subject, a systems mindset helps to achieve better solutions. These are solutions that result in significant improvement to the performance of the overall system, in a cost-effective manner, while minimizing unintended adverse side effects.