The Psychology of Problem Solving

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Recognizing, Defining, and Representing Problems

Jean E. Pretz, Adam J. Naples, and
Robert J. Sternberg

What are the problems that you are currently trying to solve in your life? Most of us have problems that have been posed to us (e.g., assignments from our supervisors). But we also recognize problems on our own (e.g., you might have noticed the need for additional parking space in the city where you work). After identifying the existence of a problem, we must define its scope and goals. The problem of parking space is often seen as a need for more parking lots or parking garages. However, in order to solve this problem creatively, it may be useful to turn it around and redefine it as a problem of too many vehicles requiring a space in which to sit during the workday. In that case, you may be prompted to redefine the problem: You decide to organize a carpool among people who use downtown parking lots and institute a daytime local taxi service using these privately owned vehicles. Thus, you solve the problem not as you originally posed it but as you later reconceived it.

Problem solving does not usually begin with a clear statement of the problem; rather, most problems must be identified in the environment; then they must be defined and represented mentally. The focus of this chapter is on these early stages of problem solving: problem recognition, problem definition, and problem representation.

THE PROBLEM-SOLVING CYCLE

Psychologists have described the problem-solving process in terms of a cycle (Bransford & Stein, 1993; Hayes, 1989; Sternberg, 1986). The cycle consists of the following stages in which the problem solver must:

1. Recognize or identify the problem.
2. Define and represent the problem mentally.
3. Develop a solution strategy.
4. Organize his or her knowledge about the problem.

5. Allocate mental and physical resources for solving the problem.
6. Monitor his or her progress toward the goal.
7. Evaluate the solution for accuracy.

The cycle is descriptive, and does not imply that all problem solving proceeds sequentially through all stages in this order. Rather, successful problem solvers are those who are flexible. The steps are referred to as forming a cycle because, once they are completed, they usually give rise to a new problem, and then the steps need to be repeated. For example, if you solve the parking-space problem by carpooling, then you may find that you are facing the problem of a work schedule that diverges from that of the person or people with whom you carpool. In other words, the solution to one problem gave rise to another problem, which then again needs to be solved through the problem-solving cycle.

CLASSES OF PROBLEMS

There are two classes of problems: those that are considered well defined and others that are considered ill defined. Well-defined problems are those problems whose goals, path to solution, and obstacles to solution are clear based on the information given. For example, the problem of how to calculate the price of a sale item is well defined. You see the original price on the tag, calculate the discount percentage, and subtract this amount from the original price. The solution is a straightforward calculation. In contrast, ill-defined problems are characterized by their lack of a clear path to solution. Such problems often lack a clear problem statement as well, making the task of problem definition and problem representation quite challenging. For example, the problem of how to find a life partner is an ill-defined problem. How do you define "life partner"? What traits should that individual have? Where do you look to find such a person? Only after considerable work has been done to formulate the problem can an ill-defined problem become tractable. Even at this stage, however, the path to solution may remain fuzzy. Multiple revisions of the problem representation may be necessary in order to find a path to a solution. In contrast to well-defined problems, ill-defined problems can lead to more than one "correct" solution.

The solution process for well-defined problems has been studied extensively, often using algorithms to describe how each step of a problem is solved (e.g., Newell & Simon, 1972). A well-defined problem can be broken down into a series of smaller problems. The problem may then be solved using a set of recursive operations or algorithms. In contrast, algorithms cannot be used to solve ill-defined problems precisely because the problem cannot be easily defined as a set of smaller components. Before a path to solution is found, ill-defined problems often require a radical change in representation. For example, consider the following problem:

> You have a jug full of lemonade and a jug full of iced tea. You simultaneously empty both jugs into one large vat, yet the lemonade remains separate from the iced tea. How could this happen?

At first, this puzzle is difficult. You imagine two pitchers of refreshing drinks being poured into a common vessel and wonder how they could not mix. (It is safe to assume that the lemonade and iced tea have similar densities). However, if you change your mental representation of the lemonade and iced tea, you see that *frozen* drinks could be easily poured into the same vat without mixing. Though the problem itself does not specify the state of the drinks, most people assume that they are liquid, as is usually the case. But this constraint is simply an assumption. Of course, this puzzle is a fairly trivial one. But in life, we often make unwarranted assumptions in our everyday problem solving. Such assumptions can interfere with our ability to discover a novel solution to an ordinary problem.

PROBLEM RECOGNITION, DEFINITION, AND REPRESENTATION

Problem recognition, definition, and representation are metalevel executive processes, called metacomponents in Sternberg's (1985) triarchic theory of human intelligence. This theory proposes that metacomponents guide problem solving by planning, monitoring, and evaluating the problem-solving process. The metacomponents include such processes as (1) recognizing the existence of a problem, (2) defining the nature of the problem, (3) allocating mental and physical resources to solving the problem, (4) deciding how to represent information about the problem, (5) generating the set of steps needed to solve the problem, (6) combining these steps into a workable strategy for problem solution, (7) monitoring the problem-solving process while it is ongoing, and (8) evaluating the solution to the problem after problem solving is completed. In this theoretical context, the processes of problem recognition, definition, and representation correspond to the first, second, and fourth metacomponents, which are used in the planning phase of problem solving.

Problem recognition, also referred to as problem finding, is one of the earliest stages of problem solving. Getzels (1982) classified problems based on how they were "found." According to Getzels, there are three kinds of problems: those that are presented, those that are discovered, and those that are created. A presented problem is one that is given to the solver directly. In this case, there is no need to recognize or find the problem; it is stated clearly and awaits solution. A discovered problem, however, is one that must be recognized. Such a problem already exists, but it has not been clearly stated to the problem solver. In this case, the problem solver must put together the pieces of the puzzle that currently exist and seek out a gap in current understanding in order to "discover" what the problem is. In contrast to presented and discovered problems, the third class of problems comprises those that are created. Created problems are those in which the problem solver invents a problem that does not already exist in the field. For this reason, one can argue that a created problem will, in some sense, always produce a creative solution, simply because its problem statement deviated from the usual way of thinking about the problem. Getzels and Csikszentmihalyi (1976) found that artists who spent more time in the problem-finding stage while creating an artwork were judged to have more creative products than did artists who spent less time in problem finding. In fact, the artists who spent more time also remained highly creative seven years later. For the purposes of this chapter, problem recognition refers to both discovered and created problems.

Problem definition is the aspect of problem solving in which the scope and goals of the problem are clearly stated. For example, a presented problem may be easy to define if the problem statement has been prepared for the solver. However, some presented problems are not clearly stated, requiring the problem solver to clarify the precise definition of the problem. Discovered problems usually require definition because the problem solver has identified the problem in his or her field. Defining a created problem is likely to be a challenge, given that the problem solver has gone beyond the current field in inventing the need for a solution in the first place.

Problem representation refers to the manner in which the information known about a problem is mentally organized. Mental representations are composed of four parts: a description of the initial state of the problem, a description of the goal state, a set of allowable operators, and a set of constraints. By holding this information in memory in the form of a mental representation, the problem solver is able to remember more of the problem by chunking the information, in order to organize the conditions and rules of a problem to determine which strategies are useful, and to assess progress toward the goal state (Ellis & Siegler, 1994; Kotovsky, Hayes, & Simon, 1985; Newell & Simon, 1972). A problem may be represented in a variety of ways, for example, verbally or visually. Even a presented problem may require the generation of a new representation in order to be solved. For example, given the problem of finding your way to a new location, you may find it much easier to follow a map than to read a set of directions. If you have trouble following the map, then it may be worthwhile to write out a description of the route in words, re-representing the information in a way that makes it easier to get to your destination.

It is important to note that these three aspects of problem solving are not discrete, sequential stages in the solution process, but rather are interactive and often difficult to tease apart in a real problem-solving situation. When a problem is represented in a new way, the problem solver may decide to redefine the goal accordingly. Similarly, a redefinition may lead to a new representation.

It is useful to consider the roles of problem recognition, definition, and representation in the solution of well-defined versus ill-defined problems. Recall that a well-defined problem is one whose path to solution is straightforward, whereas an ill-defined problem is one that does not lend itself to a readily apparent solution strategy. Consider the following well-defined problem, referred to as the Tower of Hanoi problem:

> There are three discs of unequal sizes, positioned on the leftmost of three pegs, such that the largest disc is at the bottom, the middle-sized disc is in the middle, and the smallest disc is on the top. Your task is to transfer all three discs to the rightmost peg, using the middle peg as a stationing area, as needed. You may move only one disc at a time, and you may never move a larger disc on top of a smaller disc. (Sternberg, 1999)

The problem here is easy to recognize: One needs to move the discs onto the rightmost peg. The problem is also defined clearly; the relative sizes of the discs as well as their locations are easy to distinguish. Also, the solution path is straightforward based on this representation. Working backward, one realizes that the largest disc must be placed onto the rightmost peg, and in order to do so, the other two discs must be removed. So that the medium-sized disc does not end up on the rightmost peg, the smallest disc must first be moved to the far right. Then the medium disc is placed on the middle peg; the small disc is placed on top of the medium disc. The large disc is then free to be placed on the rightmost peg. Finally, the small disc is moved to the left so that the medium disc is free to move to the rightmost peg. The last step is then to move the small disc atop the other two and the problem is solved. Note that this well-defined problem can be expanded to include many pegs and many discs of varying sizes, but its solution will always proceed according to the algorithm described in this, the simplest case.

For the most part, well-defined problems are relatively easy to recognize, define, and represent. However, a well-defined problem may entail some degree of "problem finding," in the sense that a problem exists but must first be discovered. For example, a scientist may struggle to identify a gap in the existing literature on a problem, but the actual process of filling that gap may come easily once the problem itself has been identified. The solution to the discovered problem may follow a path similar to that of other problems in the field (e.g., experimental methods). For example, much early psychological research was conducted using male participants. When a researcher questioned the validity of the results for females, a new problem had been discovered. Given this new problem, the path to solution was well defined: Simply use the same experimental method but include female participants in the study. In this sense, this well-defined problem was somewhat difficult to recognize, yet once identified, it was easily defined and represented in familiar terms.

The representation of well-defined problems is not necessarily easy, however. Consider another problem:

> Three five-handed extraterrestrial monsters were holding three crystal globes. Because of the quantum-mechanical peculiarities of their neighborhood, both monsters and globes come in exactly three sizes, with no others permitted: small, medium, and large. The small monster was holding the large globe; the medium-sized monster was holding the small globe; and the large monster was holding the medium-sized globe. Since this situation offended their keenly developed sense of symmetry, they proceeded to transfer globes from one monster to another so that each monster would have a globe proportionate to its own size. Monster etiquette complicated the solution of the problem since it requires that: 1. only one globe may be transferred at a time; 2. if a monster is holding two globes, only the larger of the two may be transferred; and, 3. a globe may not be transferred to a monster who is holding a larger globe. By what sequence of transfers could the monsters have solved this problem? (See Kotovsky et al., 1985)

Most people find this problem to be more difficult than the Tower of Hanoi problem (Newell & Simon, 1972). However, it is actually directly isomorphic to (i.e., its structure is exactly the same as that of) the Tower of Hanoi problem. In this case, it is the difficulty of representing the problem correctly that increases the level of difficulty of the problem as a whole. After you are told of the isomorphism between the two problems, the solution is simply a matter of mapping relationships from one problem to the other. In summary, problem definition is usually easy for the class of well-defined problems; however, accurate problem recognition and representation are not necessarily straightforward, even when the scope and goals of the problem are clear.

In the case of ill-defined problems, however, it is often the case that all aspects of problem formulation are relatively challenging. Perhaps the easiest stage in attempting to solve an ill-defined problem is that of problem recognition. It is often relatively simple to identify a fuzzy problem. For example, it is easy to identify the problem of developing a test of creativity. It is hard, however, to define the exact contents of such a measure.

The real difficulty in solving an ill-defined problem is in clarifying the nature of the problem: how broad it is, what the goal is, and so on. Although well-defined problems have a clear path to solution, the solution strategy for an ill-defined problem must be determined by the problem solver. To develop a problem-solving strategy, it is first necessary to specify the goals of the task. For example, if we take on the task of designing a creativity test, we must decide whether the goal is (a) to estimate the creativity of undergraduate psychology majors or (b) to measure creative potential among people of all ages and educational and cultural backgrounds. Before the path to solution can be constructed, the goal must be clear.

Representing information about the problem is also difficult in the formulation of an ill-defined problem. Consider again the problem of parking mentioned at the beginning of the chapter. The representation of the problem affects the solution. If we think of the parking problem in terms of parking spaces, we are likely to seek additional spaces when there are too many cars to park. However, if we think of parking in terms of too many idle vehicles, we are more likely to consider new ways of making use of the cars that have remained idle during the workday (e.g., driving other people who need transportation around the city). This latter perspective will guide us to seek solutions that maximize efficiency rather than maximizing the amount of concrete and asphalt in the downtown area. To solve a problem, it often is necessary or, at least, desirable to try out several representations of the problem in order to hit upon one that leads to an acceptable solution.

Problem-solving research has not revealed a great deal about the processes involved in problem recognition, problem definition, and problem representation. Indeed, the emphasis in research has been on the latter rather than the earlier phases of problem solving. Yet these earlier phases are critical to accurate and efficient problem solving, especially in the solution of ill-defined problems. The study of ill-defined problems generally has been less fruitful than the study of well-defined problems. Well-defined problems are well described by current theories of problem solving; however, ill-defined problems are ill understood by psychologists. Yet arguably most of the problems in the real world are not well defined. Most are fuzzy problems, often difficult to delineate and sometimes even harder to represent in a way that makes them solvable. Our current educational system better prepares children to answer questions that are well defined and presented to them in the classroom than it does to formulate the nature of problems in the first place. Often the skills involved in solving well-defined problems are not the same as those involved in recognizing a nonobvious problem or creating a problem. The skills needed clearly to state a problem and to represent information about it in a way that permits solution are also often not emphasized in current classrooms. In this chapter we consider what factors influence the metacognitive processes involved in recognizing, defining, and representing problems.

Research on problem solving has identified several variables that influence problem-solving performance. Among these are knowledge, cognitive processes and strategies, individual differences in ability and dispositions, as well as external factors such as social context. Those variables known to influence general problem solving will be examined with respect to the three particular aspects of problem solving that are the focus of this chapter: problem recognition, problem definition, and problem representation.

KNOWLEDGE

Everyone approaches a problem situation with a unique knowledge base. That knowledge base is essentially a set of expectations about the way the world works. As you began to read this chapter, your experience with reading chapters in similar books led you to expect a certain structure and content. Similarly, when you identify, define, and represent a problem, it is in terms of what you already know. For example, consider how the parking problem mentioned in the beginning of the chapter would be approached differently by individuals with different knowledge bases. An urban planner is more likely to identify or notice that problem as one of primary importance than is a person who does not live in an urban area. The urban planner is also more likely to consider different variables in defining the problem than someone from a small town. For example, the urban planner defines the problem in terms of how it may affect the city's income (e.g., parking meters or garages) and use the city's resources (e.g., administrative factors associated with employees and regulation of parking). In contrast, the small town resident may define the problem in terms of the esthetics of housing many vehicles (e.g., parking garages are often not welcome sights in small towns) because the solution of this problem is less likely to generate funds for the town than it would in an urban setting. According to the definition of the problem, the problem would be represented differently depending on the knowledge of the problem solver, be it an urban planner or small town parking supervisor. Problem-solving research has accumulated a tremendous amount of information regarding the relationship between knowledge and problem definition and representation and, to a lesser extent, regarding problem recognition.

It is important to keep in mind that knowledge may help or hinder problem solving. For example, knowledge plays an important role in the solution of analogies. In such problems, your task is to map the relationship between two items onto two other items. For example, *apple* is to *apple tree* as *pear* is to *pear tree*. The relationship here should be clear: You are pairing fruits with their respective trees of origin. Consider the following analogy problem.

Nefarious is to Dromedary as Eggs are to:
A: Chapel
B: Yellow
C: Bees
D: Friend (Concept Mastery Test; Terman, 1950)

The correct answer to this problem is bees. The mapping rule here is that the number of letters in each part of the analogy must match. The typical approach to analogy problems is to look for a semantic connection between the constituents rather than a surface similarity such as the number of letters. In this example, knowledge is actually an impediment to problem-solving success.

Everyday Knowledge and Problem Definition and Problem Representation

Research has demonstrated the effects of knowledge in general on problem solving, as well as its effect on domain-specific expertise. Most of this research has focused on problem representation and can also be applied to our understanding of problem definition. One source of evidence of the effect of knowledge on problem definition and representation stems from early research on the solution of well-defined problems.

Early problem-solving research sought to describe the problem-solving process as a set of steps in higher order, isomorphic problem spaces (e.g., Newell & Simon, 1972). Such research on problem solving and the concept of "problem space" grew from Newell and Simon's (1972) work on the General Problem Solver, or GPS, a model of human problem-solving processes. This model defined a problem as composed of a problem space, a starting state, a goal state, rules of transition, and heuristics. The problem space refers to all the possible states a problem could be in, such as during a bridge or checkers game. The starting state refers to the initial state of the problem. The goal state is the state to be reached by the system. Rules of transition refer to those functions that move the system from one state to another. Finally, heuristics are defined as rules that determine which moves are to be made in the problem space, as opposed to a random walk. Essentially, the GPS employs means-end analysis, a process that compares the starting state of a problem with the goal state and attempts to minimize the differences between the two. These components are well suited for solving well-defined problems where the space and transitions between states are unambiguous. However, the model offers no solution whatsoever for dealing with ill-defined problems. Nevertheless, the idea of a problem space has become a widely used and effective way of formalizing well-defined problems.

Recall the Tower of Hanoi and Monsters and Globes problems mentioned previously. According to the GPS, isomorphic problems should theoretically be solved similarly regardless of the way the information in the problem is represented. However, this model has been called into question by further studies of problem-solving performance on problems identified to be isomorphic to the Tower of Hanoi problem. Although these problems share with the Tower of Hanoi problem an identical problem space and solution structure, it is clear that the constituents chosen to represent the surface structure of each problem do have an effect (sometimes negative) on the mental representation of the problem space. One source of such evidence comes from a study that used isomorphs of the Tower of Hanoi problem involving acrobats of differing sizes (Kotovsky et al., 1985). Consider one such isomorph:

> Three circus acrobats developed an amazing routine in which they jumped to and from each other's shoulders to form human towers. The routine was quite spectacular because it was performed atop three very tall flagpoles. It was made even more impressive because the acrobats were very different in size: The large acrobat weighed 700 pounds; the medium acrobat 200 pounds; and the small acrobat, a mere 40 pounds. These differences forced them to follow these safety rules.
>
> 1. Only one acrobat may jump at a time.
> 2. Whenever two acrobats are standing on the same flagpole one must be standing on the shoulders of the other.
> 3. An acrobat may not jump if someone is standing on his shoulders.
> 4. A bigger acrobat may not stand on the shoulders of a smaller acrobat.*
>
> At the beginning of their act, the medium acrobat was on the left, the large acrobat in the middle, and the small acrobat was on the right. At the end of the act they were arranged small, medium, and large from left to right. How did they manage to do this while obeying the safety rules?
>
> *For the Reverse Acrobat problem this rule was reversed so that the smaller acrobat could not stand on the larger one; thus, the large ones had freedom of movement in that version. (Kotovsky et al., 1985, p. 262)

In the reversal of the situation where the large acrobats were standing on the smaller acrobats, participants took significantly more time to solve the problems. When an individual's expectations about a problem are violated (i.e., smaller acrobats should stand on top of larger acrobats), it requires more time successfully to build and navigate a solution to the problem. Alternatively, performance was facilitated when the information presented was in synchrony with the individual's knowledge, or in a form that did not lead to inadequate representations. Clement and Richard (1997) again used the Tower of Hanoi framework to examine problem solving, coming to the conclusion that the most difficult versions of the problem were those that required an individual to abandon their initial point of view in favor of a new, more appropriate one.

These findings pose a challenge to the idea that an individual's representation of a problem is based solely on structure, as implied by the GPS model. Even when the structure of two problem spaces is identical, the solution of those problems will depend on dissimilarities in surface elements and modalities of thought (Kotovsky et al., 1985; Simon & Newell, 1971). Simply put, these results show that one does not enter a problem as a blank slate. Prior knowledge provides a tool to structure the information in the problem, allowing the individual to apply a familiar scaffold to the information, regardless of how helpful or harmful it might be. Prior knowledge mediates an individual's ability to represent the problem in the most efficient fashion.

There is also evidence to suggest a developmental trend in the ability to use knowledge, a skill that affects problem definition. Siegler (1978) found that older children outperform younger children on a balance-scale task because of their attention to all the relevant information about the problem. Older children realize that it is necessary to encode information about multiple dimensions of the task, but younger children do not without prompts to do so. Thus, to the extent that problem definition relies on the knowledge that multiple sources of information need to be attended to and encoded, the skill of defining problems will also increase with age.

Expert Knowledge and Problem Definition and Problem Representation

Prior knowledge has been discussed in terms of everyday knowledge about the world; however, research in cognitive psychology has found a qualitative distinction between the knowledge of individuals who have more or less experience with a particular domain. Specifically, studies show that individuals who have accumulated considerable knowledge in a domain represent information about problems differently from the ways these problems are represented by individuals without extensive knowledge bases (see Chi, Glaser, & Farr, 1988). Often experts have more efficient representations of their domain than do novices. These representations have stripped away irrelevant details and get at the deeper structure of the problem, in part by chunking information. These differences in knowledge structure affect the way an expert identifies, defines, and represents problems. For example, experts and novices typically differ in how they define problems, as illustrated in the following example.

Two groups of students were given physics problems and asked to sort them into several groups, based on their similarity (Chi, Feltovich, & Glaser, 1981). The students were either graduate students in physics (experts) or undergraduates with some physics knowledge (novices). Level of expertise determined how the students defined the problems. The novice students organized their problems based on the surface features of the problem, such as whether the problem contained a spinning object, a falling object, or some other similar surface feature. The graduate students, in contrast, organized problems based on deeper, structural similarities, such as what principles of physics were required to solve the problems. This sort of deep-level process is exactly what is needed to sift through most of the unimportant information contained in the texts of many well-defined problems. It also is most likely what impairs people when they are confronted with problems that present the information in a fashion that causes them to frame the problems in an inappropriate manner.

The expert-novice differences in problem representation are well illustrated by the famous studies of chess expertise. Chase and Simon (1973) studied the reconstructive memory of individuals for arrangements of chess pieces on boards. The chess experts performed better than the novices in reconstructing the board when the pieces were placed as they would be in the middle of a chess game. However, when the pieces were arranged randomly, the experts performed no better than the novices, suggesting that the violation of these deep-level rules about the structures of chess lessened the usefulness of the expert knowledge. Experts' mental representations of chess pieces on a chessboard are more sophisticated than those of novices in that they contain more chunked information. When chess pieces are arranged on the board randomly, expert mental representations based on familiar board configurations are of no help. Randomly placed pieces cannot be chunked together according to patterns that naturally occur in chess play, rendering expert players as naive as novices when it comes to remembering random arrangements of pieces.

Empirical studies of problem solving have demonstrated a distinction between expert and novice problem representation in terms of the time spent on various stages of the problem-solving process (Lesgold, 1988). Specifically, Lesgold found that experts spent more time determining an appropriate representation of the problem than did novices. Novices were found to represent the problem relatively quickly and spend their time working on a solution. In contrast, experts spent more time comparing their current knowledge to the information they needed to discover in order to best represent the problem. After the problem was set up in the expert problem solver's mind, the process of solving it proceeded quickly relative to the novices. Thus, the effect of expertise provides the problem solver with skills that aid problem solving from the very early stages. Because novices may not notice the flaws in their representations of the problem, they will often be forced to start over, forfeiting a lot of hard work on a poorly represented problem. An expert's well-organized knowledge base is better equipped to assess the appropriateness of a problem representation even before further work is done on the problem.

While expertise is often hailed as a key to problem-solving success, it seems that the development of a highly specialized body of knowledge can lead to an impairment in the ability of experts to incorporate new rules into their thinking or to modify older ones. For example, Frensch and Sternberg (1989) have studied expert and novice bridge players. In games of bridge, the expert players performed much better than the novice players when a surface rule was changed. However, when a deeper rule was changed (for example, the rules that specified who played the lead card on the next trick), the experts' performance deteriorated more, in the short run, than did that of the novices. Frensch and Sternberg concluded that experts' entrenched strategies interfered with, rather than facilitated, their performance. The preceding examples highlight the fact that even though experts often both define and represent problems differently than do novices, the experts can suffer when the fundamentals of their representations are altered, resulting in significantly different performance profiles.

Problem Recognition

Problem recognition occurs with respect to the knowledge a person has about a domain. The fact that an expert's knowledge about a domain is organized differently from that of a novice will affect the nature of the problems that are recognized in a domain. Studies of creativity have found that it requires a considerable amount of expertise in a domain before an individual begins to recognize and create valuable new problems (Csikszentmihalyi, 1996; Simonton, 1999). Only after a person knows a field well can that person recognize gaps in the field's body of knowledge; novices are more susceptible to recognizing problems that have already been addressed by the field in the past. Not only do experts need to be thoroughly familiar with their domain; Csikszentmihalyi and Sawyer (1995) found that problem recognition often also involves the synthesis of knowledge from more than one domain. It is unfortunate that so few researchers have directly examined the effect of knowledge on problem recognition.

Both everyday knowledge and expert knowledge of a particular domain play an important role in the recognition of a problem, as well as the nature of a problem's definition and representation. However, more research has focused on the latter than the former aspects of problem solving. The next section considers the *process* of using knowledge in the course of problem solving.

COGNITIVE PROCESSES AND STRATEGIES

How do cognitive processes and strategies play a role in problem recognition, definition, and representation? Mumford, Reiter-Palmon, and

Redmond (1994) have developed one of the few models that attempts to describe the cognitive processes involved in the early stages of problem solving. Their model of problem construction proposes a set of processes that are implemented in finding, defining, and representing problems. First, problem solvers must be aware of cues, patterns, and anomalies in the environment (attention and perception). Second, analogous problem representations must be accessed from memory (activation of representations). Third, these representations must be evaluated (screening strategy selection). Fourth, the goals and constraints of the problem must be defined (element selection strategy). Fifth, these elements of the problem must be represented mentally (element reorganization).

Consider again the example of finding a life partner in the context of this model. First, the problem is recognized through attention to cues in the environment, such as noting who you are, what your needs are, and what type of person might possess the qualities you are seeking. Second, as you think of where to find such an individual, you consider analogous problems, such as how you went about selecting a suitable career or how you found friends when you moved to a new area. Third, you screen these possible analogous representations for importance. Whereas the strategy of choosing friends may have been governed by proximity and common interests, you may find that the strategy of choosing a career is more appropriate to finding a life partner if your career is one that you are passionate about, that takes into account your values and interests, and that is something that you are committed to for the long term (as opposed to a superficial friendship, which may last only as long as you remain in the same city or neighborhood). Fourth, you examine the goals and constraints of the problems. For example, it may be more important to consider the compatibility of lifestyles (e.g., career, values) with a life partner than it is with a friend. That is, you may maintain friendships with individuals whose political or religious ideals are very different from your own, but you would be less likely to choose to initiate a romantic relationship with someone with incompatible values. Fifth and finally, all of the considerations you have identified as relevant to finding a life partner are represented in a way that makes it possible to conceptualize who that person might be.

Processes in Problem Recognition

Another model of problem solving has focused more specifically on problem recognition. Brophy (1998) described a series of processes that artists and scientists report engaging in prior to defining a problem. These presymbolic processes set out the goals and obstacles in a problem situation. Brophy described these processes as "unconscious, intuitive thought that combines perceptual pattern recognition, abstract analogy creation,