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Process Analytic Models of Creative Capacities

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ABSTRACT: Although a number of factors condition the success of creative efforts, most investigators recognize the fundamental importance of novel problem solutions. As a result, a number of systems intending to describe the processes contributing to the generation of innovative problem solutions have been proposed. In the present article, earlier models describing the processes contributing to creative problem solutions are reviewed. The common themes appearing in these models are then considered in relation to the use of extant information structures. Certain implications of cognitive information processing for understanding the nature and ontogeny of the creative act are then discussed, along with their potential contributions to the identification and development of creative potential.

Mumford and Gustafson (1988) argued that creative behavior is reflected in the production of novel, socially-valued products. Although this conclusion is by no means unique (Briskman, 1980; Busse & Mansfield, 1980; Ghiselin, 1963; Hocevar, 1981), it does have an important, albeit often overlooked, implication. More specifically, creativity does not represent a unitary psychological attribute, but rather an outcome of a dynamic interplay of certain individual and situational variables (Amabile, 1983; Taylor, 1972). According to Mumford and Gustafson (1988), five basic kinds of variables are likely to condition a creative outcome: (a) the processes contributing to the individual's capacity for generating novel problem solutions, (b) the characteristics of the individual facilitating process operation, (c) the characteristics of the individual facilitating the translation of these solutions into action, (d) the attributes of the situation influencing the individual's willingness to engage in creative behavior, and (e) the attributes of the

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situation influencing evaluation of productive efforts.

In our view, without an initial problem solution, a creative product cannot be brought into existence. Numerous investigators have attempted to identify the processes contributing to the generation of new problem solutions. The intent of the present article is, broadly speaking, to summarize and extend understanding of the processes contributing to the generation of creative problem solutions by drawing upon recent work in cognition and prior work on creative thought.

Cognition and Creativity

Problem Solving

To understand the role of cognition in creative problem solving, one must first look at the creative act as a totality. When a person formulates a new idea that proves useful in addressing some social need, he or she has generated and implemented a novel course of action, one of many potential alternatives, that has brought about a valued end-state ranging from a new scientific theory (Kuhn, 1970; Zuckerman, 1974) to a joke facilitating group interaction (Firestein & McCowan, 1988) or a piece of artwork evoking a certain emotional state (Deschenes, 1989). Given Scandura's (1977) definition of problem solving as the generation and selection of discretionary actions to bring about a desired end state, it becomes apparent that creativity entails an important problem-solving component. In generating this problem solution or potentially useful action sequence, a series of mental operations referred to as cognition are required. These mental operations serve to guide individual behavior and may not be, in essence, different from those required in other problem-solving efforts (Bailin, 1984; Simonton, 1988; Sternberg, 1988a, 1988b; Weisberg, 1988).

Cognition and Problem Solving

At this juncture, the question arises as to the nature of the cognitive elements contributing to potential problem solutions and eventual production of novel, socially-valued products. Most discussions of problem solving focus on two basic kinds of cognitive elements. The first of these elements is knowledge or an organized set of facts and principles pertaining to the characteristics of objects lying in some domain (Chi, Glaser, & Rees, 1982; Fleishman & Mumford, 1989). The second element is reflected in those cognitive processes contributing to effective application of extant knowledge structures in solution generation (Sternberg, 1986a).

The availability of well-organized knowledge structures has been shown to have a marked impact on problem-solving capabilities. For instance, studies contrasting experts and novices indicate that more skilled problem solvers have more extensive and diverse knowledge structures, organize information into categorical systems based on underlying principles rather than on superficial content similarities, and have more efficient strategies for organizing information in memory via chunking (Chi et al., 1982; deGroot, 1966). Other work summarized by Siegler and Richards (1982) indicates that expertise in a given domain will influence the efficacy of problem solving, not only through the direct recall and application of available information, but also through more subtle effects on the efficacy of information acquisition and solution monitoring. Recently, Medin and Ross (in press) extended this argument with their proposition that reasoning is case-based and results from the accumulation and organization of domain-specific examples, rather than from the generation of abstract principles.

As might be expected, substantial evidence has also been accrued for the importance of domain-specific knowledge to creative undertakings. Historic, theoretically-driven efforts by Koestler (1964), Kuhn (1970), and Mumford and Gustafson (1988) indicate that the identification of discrepant facts and subsequent reorganization of extant knowledge structures to take these discrepancies into account may represent a key component of creativity. In a series of empirical studies, Weisberg and his colleagues (Weisberg, 1988; Weisberg, DiCammillo, & Phillips, 1978; Weisberg & Suls, 1973) found that experimental manipulations conditioning appropriate information search and application contributed to the solution of problems calling for novel or creative responses. Similarly, Langley, Simon, Bradshaw, and Zytkow (1987) and Langley and Jones (1988) developed models capable of replicating scientific discoveries using systematic information search and testing procedures. In a somewhat different vein, Simonton (1984, 1988) provided evidence indicating that knowledge is, up to some point, related to creative achievements, and that the number of previously uncombined knowledge configurations may condition creative capacity.

Ample evidence is available showing that some degree of knowledge or expertise is required for creative problem solving. It is, however, open to question whether knowledge per se provides a fully adequate basis for idea generation and problem solving. As Anderson (1985) noted, "If we had only domain-specific production rules, we would be incapable of solving problems in novel domains" (p. 220). Sternberg (1988b) has shown that unusually high degrees of domain-specific expertise may inhibit the creation of new knowledge through channeling and cueing effects. This point is also underscored in a study by Gentner and Block (1983). They found that domain-specific knowledge does not differentiate between experts' and novices' solutions to novel analogy problems intended to tap a given domain of expertise.

Observations of this sort have led many investigators to emphasize the role of cognitive processes in problem solving. Newell and Simon (1972), for instance, describe the role of various information search strategies in problem solving. Similarly, Anderson (1985) stressed the importance of various production rules. In an extensive series of studies, Sternberg (1986b) has shown how various cognitive processes, such as information encoding and stimulus transformation, contribute to the solution of analogy problems along with metacognitive processes, such as resource allocation and solution monitoring. The significance of these generalized rules for information application (Medin & Ross, in press) is illustrated in the work of Gick and Holyoak (1980, 1983). They found that general rule systems derived from training on several related tasks influenced performance on a creative problem-solving task.

Again, there is ample reason to suspect that these processes or general rule systems for information application play an important role in creative problem solving. For instance, studies by Getzels and Csikszentmihalyi (1976), Okuda, Runco, and Berger (1991), Runco and Okuda (1988), and Smilansky (1984) indicate that problem construction processes, or the general strategies used in initial problem definition, have a marked impact on long-term creative production. Other work by Cronbach (1968), Guilford (1950, 1967), and Mednick and Mednick (1967) has illustrated how solution monitoring, divergent thinking, and associational processes influence creative problem solving. Furthermore, if intelligence represents the ability to formulate abstract rules or principles (Humphreys, 1979; Tyler, 1965), the significance of these processes leads one to expect the kind of curvilinear, task-dependent relationship with creativity remarked upon by Guilford and Christensen (1973) and Mumford and Gustafson (1988).

Creative Problem Solving

We argued above that creativity begins with problem solving. Hence, both knowledge and rules for applying this knowledge should contribute to creative capacity. Because creativity requires the production of novel, socially-valued products, however, creative problem solving may make certain demands not found in other kinds of problem solving efforts. Broadly speaking, it appears that creative problem solving differs from standard problem solving in four ways.

First, unlike many problem-solving tasks, creativity typically occurs in ill-defined situations (Anderson, 1983). These ill-defined situations, characteristic of creative endeavors, do not clearly specify the goals, information, and resources to be used in problem solving. Thus, a greater burden is placed on the individual with respect to defining the nature of the problem and identifying the information and rules used to solve the problem. As a result, problem construction, or alternatively, problem finding, is likely to be emphasized in creative efforts, although it is not given much weight in other kinds of problem-solving tasks (Baer, 1988; Getzels & Csikszentmihalyi, 1975; Okuda et al. 1991).

In most problem-solving efforts, people search for, and typically apply, available previously acquired solutions (Nutt, 1984). Further, as Cyert and March (1963) pointed out, people often satifice applying the first available solution identified. Creativity, however, requires the production of novel problem solutions. Because creativity requires people to generate new solutions that will, hopefully, solve the problem at hand, this satificing strategy is unlikely to contribute much to creativity. Rather, creativity requires the generation and exploration of novel, alternative problem solutions or divergent thinking (Guilford, 1950). Creativity, however, is not solely a matter of divergent thought. Because selected alternatives must yield viable solutions, they need to be evaluated with respect to their potential utility. This evaluation component implies a need for convergent thinking. Of course, convergent and divergent thinking must be applied in an integrative fashion so that evaluation does not preclude the generation and application of potentially viable alternatives (Isaksen & Parnes, 1985). This need for both divergent and convergent thought is a second characteristic of creative problem solving.

The need to balance convergent and

divergent thinking points to a third characteristic of creative problem-solving efforts. In traditional problem-solving tasks, there is often no real need to generate and evaluate alternative solutions. Thus, problem solving can proceed in an additive fashion, using simple activation, generation, and application mechanisms (Langley & Jones, 1988). In generating new alternatives, however, initial approaches may prove attractive, but need substantial refinement. Thus, individuals are likely to cycle through multiple stages of divergent and convergent thought as they refine and extend plausible initial solutions. As a result, creative problem solving will make stronger attentional or resource demands and require more active and flexible controlled processing efforts (Ackerman, 1986).

The fourth characteristic of creative problem solving is related to the application of existing knowledge. Current theory holds that information is stored, recalled, and understood through the application of categorical structures or schema (Barsalou, 1982, 1983). Because these categories are a result of prior learning, except under conditions where existing categories are applied in a new situation, they are unlikely to give rise to new, alternative problem solutions. Rather, it appears that new solutions are derived from the systematic combination and reorganization of existing categories (Hausman, 1988; Hodder, 1988; Mumford & Gustafson, 1988; Mumford & Mobley, 1989; Rothenberg, 1988). Research by Rothenberg and his colleagues (Rothenberg, 1986; Rothenberg & Sobel, 1980; Sobel & Rothenberg, 1980) indicates that experimental manipulations intended to facilitate category combination did in fact contribute to creativity. Historic studies of creative achievement by Kuhn (1970) and Koestler (1964) have also provided evidence indicative of the importance of category combination and reorganization for creative problem solving.

Aside from providing an information base for generating new problem solutions from earlier learning, the combination and reorganization of existing categories leads to a number of other features of creative thought worthy of mention. To begin, category combination and reorganization can be accomplished in a number of ways ranging from the creation of totally new information categories for use in problem solving to a relatively simple rearrangement of the linkages among existing categories and category elements or exemplars (Barsalou, 1983). Additionally, the information contained in these new categories or category linkages will be dependent on both the characteristics of the individual at hand, the categories available to them, and the history of the problem-solving effort. Thus, the content and implications of these restructurings may be somewhat idiosyncratic and only loosely linked to consensual, culturally-defined knowledge structures (Mumford & Mobley, 1989). Finally, the nature of these categories and category combination operations implies some degree of domain specificity in the nature of creative thought, just as dependence on these categories and basic operating processes allow for some generality.

Process Models

Many efforts in the creativity arena have explicitly focused on general processes. One reason for this focus is that creativity entails confronting problems or generating problem solutions that go beyond extant knowledge. This substantive reason aside, a pragmatic concern also contributes to this focus on general processes. Creativity researchers are often concerned with the identification and development of creative potential under conditions where specific problem content is diverse, ill-defined, and quite variable across individuals. Under these conditions, effective interventions require a focus on general, cross-domain factors contributing to the generation of new problem solutions (Covington, 1987). Because these processes play a crucial role in solution generation by providing a framework guiding information application, they provide a general structure for the identification and development of creative potential. The ensuing discussion examines prior attempts to define the major processes involved in creative problem solving.

Prior Process Models

One of the first process models bearing on creative problem solving was proposed by Dewey (1910). He was interested in how the mind identifies problems and in the development of problem-solving capacities. As part of his effort to train thought, he attempted to break problem solving into a series of elementary steps which, in effect, yielded an initial process model of the creative act. In Dewey's (1910) system, these basic stages included: (a) a difficulty is perceived or felt, (b) the problem is located and defined, (c) possible solutions are suggested, (d) implications of the suggested solutions are elaborated, and (e) testing of the solution leads to its acceptance or rejection. Although somewhat archaic in language, Dewey's (1910) system contains the antecedents of current concerns with problem construction and idea evaluation, while specifying an intriguing element of emotion or affect. This emotional feeling is held to serve as a trigger or guide for problem generation representing a somewhat unique process worthy of renewed investigation.

Like Dewey's (1910) conceptualization, our next major model is also concerned with general problem solving. Wallas's (1926) model, however, was the first which explicitly focused on invention as a topic in its own right. Wallas (1926) proposed four stages: (a) preparation, or problem investigation knowledge acquisition, (b) incubation, or a period of rest accompanied by unconscious work, (c) illumination, or the sudden appearance of a solution, and (d) verification, where the validity of an idea is tested. The significance of this model lies in the two middle stages which laid a groundwork for later efforts by Patrick (1941), Poincare (1952), Gordon (1973), Vinacke (1974), Landau (1978), Rubenzer (1979), and Moriarty and Vandenberg (1984), among others, which stress the role of uncontrolled, unconscious processing in idea generation.

Osborn (1953) proposed a model of the creative process that incorporated elements of Wallas's conceptualization. Starting from the proposition that creative problem solutions derive from the association of ideas, he proposed a model specifying processes of (a) orientation, (b) preparation, (c) analysis, (d) hypothesis generation, (e) incubation, (f) synthesis, and (g) verification. The major point of departure from Wallas (1926) lay in the addition of an orientation process involving active construction of the problem. The addition of the analysis, hypothesis, and synthesis stages is also important. The addition of these three latter processes can be viewed as an attempt to refine the concept of illumination by breaking up relevant material, picking up significant alternatives by way of ideas, and linking these parts through associational mechanisms. Thus, Osborn's (1953) work took us away from the view of creative problem solving as a mystic, inarticulate event driven by illumination. He replaced this concept with the generation and associational linkage of alternative ideas.

The next significant advance in the development of process analytic models came with Merrifield, Guilford, Christensen, and Frick's (1962) attempt to apply Guilford's (1967) structure of intellect model to the generation of novel problem solutions. This model explicitly recognized the significance of both convergent and divergent thinking, as well as the cyclical nature of creative problem solving. They proposed a five-process model involving (a) preparation, or problem recognition, (b) analysis, or developing familiarity with situational potentialities and goal requirements, (c) production, or generating a tentative solution bridging the gap to goal states, (d) verification, or solution evaluation, and (e) reapplication, which permits a return to earlier stages to select another tentative solution. The addition of convergent and divergent elements in a cyclical system represented an important advance. This model, however, also had substantial impact by tying creativity to explicit problem-solving capacities and by indicating the directed, goal-oriented nature of creative thought.

This practical, goal-oriented view of creative problem solving had a marked impact on later process-analytic models. Kepner and Tregoe (1965), for instance, proposed a 14-step model, which deemphasized the cyclical nature of creative thought. This model, however, did emphasize the significance of goals and controlled solution implementation, as well as the need to take practical constraints into account during process operation.

Parnes' (1967) model displays a similar orientation. He proposed a five-step model which consisted of fact finding, problem finding, idea finding, solution finding, and acceptance finding. The substantive character and implication of these processes was then used to formulate interventions intended to facilitate creative problem solving, such as overcoming habits or deferring judgment. This conceptualization has been successfully applied in attempts to improve creative problem solving over the last 20 years (Baer, 1988; Covington, 1987; Reese, Parnes, Treffinger, & Kaltsounis, 1976). Recent versions of this model (Isaksen & Parnes, 1985) have, however, added (a) an objective-finding process as a first step where "messes" are selected, along with (b) substages of divergent and convergent thought within each major process. This notion of subordinate processes, adding to the richness and texture of process models, has since been incorporated in the work of other investigators (e.g., Basadur, Graen, & Green, 1982).

Cognitive Models

In recent years, processing models flowing from the creative thought tradition have been influenced by the theoretical approach employed in cognitive psychology. Of signal import in this regard is Newell and Simon's (1972; Simon & Newell, 1971) work on the role of cognition in problem solving. Within Newell and Simon's (1972) system, the proposed processes include (a) translation of the input, or generation of a problem statement, (b) internal representation, or the encoding of stimuli in memory, (c) selection of a problem-solving method, and (d) application of the problem-solving method. Perhaps the most significant aspect of Newell and Simon's (1972) work is that it goes on to specify specific problem-solving strategies, such as means-ends analysis, heuristic search, and difference reduction, by which information is employed in an attempt to generate viable problem solutions. By explicitly acknowledging the role of information acquisition and utilization in their work, they provided a groundwork for process-analytic models recognizing the importance of domain-specific expertise in process application.

A recent extension of Newell and Simon's (1972) approach can be found in Silverman (1985). In Silverman's (1985) model, one finds the same emphasis on information use and representation. However, analogical reasoning is viewed as the key mechanism underlying idea generation. This principle led to specification of the following processes: (a) problem identification, (b) acquisition of information concerning similar problem structures, (c) acquisition of information concerning similar problem solutions, (d) analog knowledge transfer, where the solution is mapped onto the previously generated solution structure, (e) analog knowledge transformation, where critical revisions in the solution structure are made, and (f) application of the problem solution. Although this model finds some support in Gick and Holyoak (1980, 1983), its reliance on a specific strategy for information linkage (e.g., analogical reasoning) may set undue limits on generality, while ignoring significant aspects of creative problem solving that do not involve this mechanism.

Facet Models

Newell and Simon's (1972) work also had a marked impact on the process models proposed by Busse and Mansfield (1980) and Mansfield and Busse (1981). This later work, however, provides a better illustration of the promise of this approach when multiple problem-solving strategies are taken into account. In Busse and Mansfield's (1980) model, five basic processes for the application of information in creative problem solving are proposed: (a) *selection of* the problem, (b) expending effort to solve the problem, (c) setting constraints or using conscious and unconscious mental sets to put bounds on the nature of the problem, (d) changing constraints or altering original constraints that later prove incorrect, and (e) verification and elaboration of the problem solution. Although Busse and Mansfield (1980) did not retain Newell and Simon's (1972) problem representation notion, they did add a significant motivational or attentional component, noting that these processes are applied in a dynamic, selective fashion bound by real-world constraints. Their work, however, illustrated an important characteristic of facet models, pointing out that the efficiency of process application is likely to be influenced by a host of personality, developmental, and social influences conditioning available information, skill utilization, and problem definition (Mumford & Gustafson, 1988).

This same trend is manifest in recent work by Amabile (1983), who noted that solution generation is likely to be conditioned by three categories of variables: (a) domain-relevant skills, or the response possibilities, factual knowledge, and technical skills available to the individual, (b) creativity-relevant skills, including cognitive style, working style, and heuristic cognitive processes, and (c) task motivation. Within this framework, five basic cognitive processes are thought to have an impact on the generation of creative problem solutions: (a) problem or task presentation, including both presented and discovered problems, (b) preparation, where the person gathers or recalls relevant procedural and declarative knowledge, (c) response generation, (d) response validation, and (e) outcome assessment, permitting the individual to stop processing or to return to the first stage.

A similar approach can be seen in Sternberg's (1986a, 1986b, 1988a) three-facet model of creativity which is comprised of personality, stylistic, and intellectual constructs. All three of these facets are held to interact in a dynamic fashion to condition the nature and content of creative problem solutions. Of special interest is the intellectual function or intellective style component, where intelligence is viewed as a form of mental self-government serving adaptation through application of internal and external components. The internal component is of significance because it underscores the role of metacognitive components, such as problem recognition, problem definition, and strategy formulation, in aiding process application to external, experiential information. Sternberg (1986a, 1986b, 1988a) proposed three basic information processes contributing to solution generation: (a) selective encoding, in which relevant information is stored in working memory, (b) selective comparison, where information from long-term memory, potentially relevant to the problem solution, is recalled and where mechanisms, such as analogical or associative thought, are applied, and (c) selective combination, where information in working memory is put together to generate a problem solution.

Conclusions Concerning Existing Models

This review of process-analytic models indicates a progressive maturation in our conception of the mechanisms underlying idea generation. Initially, models viewed creativity as a mysterious, inherently inarticulate phenomenon. Over the years, however, the core components of this mysterious entity have been specified in greater detail. Researchers have also begun to display greater sensitivity to the dynamic, perhaps cyclical nature of process application, the goal-oriented nature of creative problem-solving efforts, the significance of real-world constraints, and the impact of motivational, developmental, and personality attributes which can condition the efficiency of process application.

It should also be recognized that these models display some marked similarities in the nature and sequencing of the proposed processes. For instance, a number of the models reviewed above propose some kind of problem-definition or problem-construction process, as well as an information-encoding mechanism (Amabile, 1983; Busse & Mansfield, 1980; Sternberg, 1988a). Other common elements appear in information-evaluation, information-linkage, and solution-generation processes.

It is also true, however, that the models reviewed above differ from each other in terms of the number and nature of the proposed processes. Some models, for instance, emphasize unconscious processes, and others do not. Nonetheless, the existence of these commonalities suggests that it might be possible to organize this literature and identify a general set of core processes by attending to both the essential characteristics of creative problem solving and the information-processing demands common to all forms of problem solving. Of particular import is the fact that creativity does not arise in a vacuum: Instead, it requires the generation of new understandings derived from already available understandings. Thus, the proposed processing mechanisms must contribute to the generation of new understandings based on knowledge already available to the individual. The ensuing discussion will examine how this cognitive information-processing approach might be used to specify the core processes contributing to creative problem solving through the systematic restructuring of available information.

Core Processes

Background Principles

We will take as our point of departure the fact that any successful problem-solving effort requires information. This observation leads to our definition of a process as an organized set of operations performed on some information set resulting in one or more outcomes required for eventual solution generation. It is assumed that multiple operations are likely to be required in most complex problem-solving efforts, and that individuals may differ in the efficiency and appropriateness with which they apply these operations (Sternberg, 1986a, 1988a).

It is also assumed that the information to which these operations are applied reflects knowledge. Knowledge, however, should not be automatically equated with information. Rather, in accordance with current views of human cognition, we postulate that information is stored and interpreted in categorical structures (Chi et al., 1982; Siegler & Richards, 1982). These categorical structures or schema represent an organized interrelated set of discrete pieces of information, where organization is derived from the central features of the category (Barsalou, 1982, 1983). Further, these categories may be either procedural or declarative in nature. Declarative categories refer to the objects and object properties in some domain, and procedural categories refer to principles for applying or acquiring declarative information. It is further assumed that these procedural and declarative categories are created from past experience and are systematically related to each other in associative networks (Langley & Jones, 1988).

If it is granted that extant information is organized and understood through the application of categorical structures, then the question arises as to how these categories might be used to generate new understandings. Based on our earlier comments, and the observations of Koestler (1964), Kuhn (1970), Mumford and Gustafson (1988), Sobel and Rothenberg (1980), Rothenberg (1986, 1988), and Rothenberg and Sobel (1980), it appears that the new understandings providing a basis for novel problem solutions are derived from either the combination or reorganization of these categorical knowledge structures. More specifically, individuals might generate a novel approach to a problem by applying extant categories to a new type of problem or applying these categories in a different sequence. Alternatively, a new ad-hoc category might be created by combining certain elements of existing procedural and declarative categories. By providing new sets of information for use in problem solving, these alternative combinations and reorganizations will yield the new understandings that permit the generation and implementation of novel problem solutions.

Processes

Any problem-solving effort in ill-defined domains requires definition of the problem to be solved. Thus, in accordance with many prior models (e.g., Osborn, 1953; Parnes, 1967), the first core process we wish to propose is *problem construction*. Although the impact of problem construction activities may vary with the degree of a priori structuring (Dillion, 1982), studies by Getzels and Csikszentmihalyi (1975), Runco and Okuda (1988), and Smilansky (1984) indicate that differences in the efficiency of problem-construction efforts will have a marked impact on creative problem solving. This process is especially likely to prove important in real-world settings, where the degree of a priori structure is minimized (Okuda et al., 1991).

At this juncture, the rules and operations employed in problem construction are difficult to specify with complete conviction (Csikszentmihalyi, 1988). Based on the findings of Barsalou (1983) and Gick and Holyoak (1980, 1983), however, it seems reasonable to hypothesize that, using the outcomes of prior problem-solving efforts, individuals will form ad-hoc categories reflecting crucial elements in the problem, including goals, constraints, outcomes, key steps in problem solution, and essential declarative information. Contextual stimuli will, of course, trigger certain problem schema. It is anticipated that individuals will screen these activated schema to identify commonalities in the significant elements. At this juncture, clear-cut evidence is not available as to the rules and operations employed in screening or how these elements are synthesized, or combined, to provide cohesive problem definitions. Regardless of the specific operations that are applied, similarities in the most highly activated schema seem to provide a plausible basis for problem definition and will result in a tentative set of new problem schema, each reflecting an integrated set of initial goals, key procedures, salient information, and significant constraints.

These tentative schema derived from the problem-construction process may be quite idiosyncratic in ill-defined domains. For instance, the individual's values may influence the salience of various goals just as the individual's knowledge, skills, and abilities will condition the available repertoire of available problem schema (Howe, 1982). To complicate matters further, a variety of contextual factors may influence this process, including the time and attentional resources available to the individual, the salience of cues indicating the desirability of certain goals or the importance of certain restrictions, the degree of acceptable risk, and the nature of other currently activated categorical structures.

Initial understandings of the problem provided by the problem-construction process will not provide a fully sufficient basis for problem solving. Rather, problem constructions serve to specify the kinds of knowledge applicable to the problem. Thus, problem constructions will be used to guide the retrieval of pertinent information from long-term memory or the search for new, apparently necessary information (Amabile, 1983). Thus, *information encoding* represents a second, potential core process.

Sternberg (1986a) illustrated the impact of effective encoding on both problem solving and creativity. Although a number of studies have examined the mechanisms by which information is retrieved from long-term memory (Siegler & Richards, 1982), less attention has been devoted to procedures underlying the acquisition of new information. It can, however, be expected that information acquisition will be strongly influenced by extant activated procedural and declarative knowledge structures guiding information search and retrieval, where activation is engendered by prior problem construction, associative networks, and stimulus cues (Norman, 1980; Reif & Heller, 1982). Furthermore, under conditions where new information or knowledge structures must be acquired, it can be expected that this process will be prolonged and will involve intense, active processing drawing out elaborations and implications of this knowledge (Schmeck & Grove, 1979; Snow & Lohman, 1984; Thompson, 1985).

Once information has been obtained or retrieved, it must be placed in a context where it can be understood. Thus, the next core process contributing to creative problem solving will be a *category search* intended to specify relevant schema or knowledge systems for understanding factual information pertinent to the problem, as well as rules for applying this information. Based on the findings of Alissa (1972), Gough (1976), Harrington (1981), Kogan, Connor, Gross, and Fava (1980), Mednick and Mednick (1967), Poze (1983), and Runco (1986, in press-a), it appears that the breadth and efficiency of this search process may have a marked impact on creativity. Although a variety of mechanisms, such as associational and analogical thought, may serve to guide category search, the intent of this effort is to define a set of categories that will allow pertinent procedural and declarative information to be organized and interpreted. In essence, then, this category search will define a problem space specifying relevant categories of procedural and declarative knowledge.

Although the preceding paragraphs have distinguished between information encoding and category search, in many complex problem-solving efforts these processes are likely to operate in tandem. Thus, initial information will activate certain categories. These categories will then influence further encoding, while serving to activate still other categories through new information and category relationships. In other cases, however, especially those where there is no real need to acquire new information, these processes may operate as relatively discrete entities. Aside from problem complexity, operation of the encoding and search processes might be influenced by a number of other individual and situational influences. Expertise is, of course, likely to condition the amount and nature of the information encoded, along with other differential variables, such as energy levels, problem sensitivity, tolerance for ambiguity, interests, and mastery motives (Barron & Harrington, 1981; Dweck, 1986). Further, situational variables influencing attentional resources or information access will play a role in this process, along with instructional sets conditioning information search procedures (Dinnel & Glover, 1985).

As illustrated in the work of Langley, Simon, Bradshaw, and Zytkow (1987), this search process will lead a number of categorical structures to be included in the resulting problem space. Thus, some constraints must be placed on the number and nature of the categories used. This observation leads to specification of our next major process: *specification of the best fitting categories.* The category specification process may involve many operations. For instance, Barsalou's (1983) work suggests that categories having the best fit in terms of ideal, frequent, or typical exemplars with encoded information are likely to be retained. It might also be argued, however, that categories associated with significant constraints will be eliminated, along with goal-inappropriate categories. Similarly, categories closely linked to each other through prior association and effective use, especially associated procedural and declarative categories (Krietler & Krietler, 1987a, 1987b), are likely to be retained as an integrated set.

Our foregoing observations indicate that category specification represents a systematic evaluative process. Thus, one might expect expertise and intelligence to influence the efficiency of process operation. However, a number of other variables, such as cognitive complexity, flexibility, and openness, might influence the nature of evaluation criteria and, therefore, the outcomes of process operation. In addition to these differential constructs, performance pressures and environmental stressors might influence the operation of this process (Fiedler & Garcia, 1987), along with environmental conditions, such as social pressure, influencing perceptions of category appropriateness.

Once a set of categories has been identified, these categories must be used to generate new problem solutions. As noted earlier, generation of the new understandings from extant knowledge requires that relevant categories be *combined and reorganized* in such a way as to generate an integrated sequence of actions likely to bring about the goals inherent in this problem-solving effort. The importance of this combination and reorganization process was discussed earlier, and its relevance to creative thought has been underscored in the work of Mumford and Gustafson (1988), Owens (1969), and Rothenberg (1986).

The exact mechanisms by which individuals attempt to combine and reorganize categories represents one of the important remaining mysteries of creative thought (Barsalou, 1989). It seems likely, however, that overlap in organizing principles and category exemplars, commonalities in elemental or procedural steps, and available analogical models and divergent thinking skills all play an important role here (Holyoak, 1984; Medin & Ross, in press; Mumford & Gustafson, 1988; Owens, 1969; Runco & Albert, 1985). It can also be expected that this linking of procedural and declarative categories within themselves and with each other to generate an action plan (Krietler & Krietler, 1987a, 1987b) will involve substantial reasoning capacity and concerted active processing. Further, differential variables, such as self-esteem, organization, independence, flexibility, and openness, conditioning the individual's willingness and capability for working with multiple categories might influence the efficiency of process operation (Feldhusen & Hobson, 1972; Houtz, Jambor, Cifone, & Lewis, 1989; McCrae, 1987), along with climatic influences, such as communication, peer support, and norms stressing the value of alternative ways of looking at things (Abbey & Dickson, 1983; Knapp, 1963).

Having generated a potential problem solution through the structuring, combination, and organization of existing categories, the potential utility of this problem solution must be evaluated. This process of *idea evaluation* has been discussed by a few theorists (e.g., Dewey, 1910; Wallas, 1926; Osborn, 1953). This core process has not received a great deal of attention (Runco, in press-a). Nonetheless, the evidence provided by Runco and Albert (1985) and Harrington, Block, and Block (1983) pertaining to the predictive value of frequency-controlled, high-quality divergent thinking scores is considered, along with Cronbach's (1968) comments regarding the importance of idea evaluation indicates that there is reason to suspect that this evaluative step may constitute an important determinant of "real-world" creativity. It can be expected that the ability of a proposed solution to satisfy the goals at hand in an efficient manner within the constraints set as part of the initial problem construction will play an important role in evaluation, as will projected contingencies and expected payoffs from solution implementation (Hogarth, 1980; Rubenson & Runco, in press; Torrance, 1965). Thus, idea evaluation will be influenced by climatic, motivational, and environmental contingencies, such as role models and reinforcement contingencies, as well as by concrete intellectual functions, especially variables conditioning decision biases and decision-making operations (Einhorn & Hogarth, 1981; Hogarth, 1980; Kahneman, 1972). This latter point has been illustrated in recent studies by Runco (in press-a) and Runco and Vega (1990), who noted that the locus of evaluation, either intra- or interpersonal, may be related to creativity. Similarly, differential constructs, such as risk-taking, curiosity, and self-esteem, influencing the individual's willingness to pursue untried, new ideas, may also influence process operation.

After a decision has been made to implement a proposed problem solution, the next necessary step is actual *implementation*. Although this process may be of little import in laboratory problem-solving tasks, in actual creative undertakings it will represent a crucial execution process involving the marshalling of many task-relevant knowledges, skills, and abilities, as well as personality characteristics ranging from energy level to persuasion (Barron & Harrington, 1981; Simonton, 1988). Further, attentional allocation and controlled processing coupled with opportunistically-driven extension or revision of an initial plan may constitute a significant and necessary component of this process and account for changing environmental contingencies (Carroll & Gillen, 1987, Hayes-Roth & Hayes-Roth, 1979). These conclusions are by no means unique. Similar observations have been made by Newell and Simon (1972) and Silverman (1985) in their work on process analytic models of "real-world" problem solving.

The complex nature of "real-world" creativity underscores the need for a final core process: *monitoring.* In essence, this process entails the systematic search for information about the conditions and success of problem solutions. This monitoring process is of substantial import in complex situations, where feedback is often ambiguous and subject to certain biases in interpretation (Hogarth, 1980). Further, recent work by Hayes and Flower (1986) and Brown and Campione (1986) indicates that monitoring may provide a groundwork for learning and for new problem-solving efforts by denoting key elements in problem solutions and by suggesting necessary revisions in categorical structures. Given these observations, it is hardly surprising that some time ago Kepner and Tregoe (1965) and Parnes (1967) also argued for the potential significance of this process. In fact, the significance of this process suggests that evaluative skills and self-awareness may prove of some import to understanding creative thought, along with the nature and accuracy of environmental feedback (Morgan, 1985).

Relationships Among Core Processes

In considering the nature of these core processes and their anticipated interdependencies, it becomes apparent that creative thought is likely to represent a complex, integrated phenomenon. Figure 1 presents the model derived from the hypothesized process relationships. However, it also reflects the dynamic cyclical interrelationships likely to be observed as these core processes are applied in complex, creative, problem-solving efforts. More specifically, it is assumed that if a satisfactory outcome cannot be obtained, individuals may cycle back to any one of the earlier stages. The particular stage chosen will, to some extent, depend on the nature of the deficiency at hand. However, the principle of cognitive efficiency suggests a tendency in people to cycle back to the immediately preceding process. Not only does this cyclical processing seem consistent with many descriptions of creative thought (Howe, 1982; Koestler, 1964; Rothenberg, 1986), it also suggests how integration occurs and why phenomena arise, such as the impact of available categorical structures and prior life history on information search (Gruber, 1983; Siegler & Richards, 1982).

A second noteworthy characteristic of the relationships specified in Figure 1 may be found in the sequential arrangement of processes. One implication of this structure is that successful process application in the later phases of problem solving is contingent on adequate "up front" work. Not only does this serial dependency explain why creative efforts are often difficult and time consuming, it also indicates that relationships among processes may prove difficult to ferret out, because of the operation of intervening steps or mediating mechanisms. These sequential dependencies should not, however, be taken to imply that these processes are of equal import in all settings. For instance, if a problem is fully defined, relatively little effort may be devoted to problem construction, or if category search and specification yields adequate declarative and procedural categories, little effort may be expended on category combination and reorganization. These observations in turn imply that the relative import of these processes will vary across problem domains, with creative thought being least difficult when the problem domain emphasizes application of the latter process.

A third, perhaps less obvious, characteristic of the relationships presented in Figure 1 may be found in its implications for divergent and convergent phases of thought (Chambers, 1969; Isaksen & Parnes, 1985). The relationship between category search and specification of best-fitting categories provides one illustration of this principle, as does the relationship between category combination and idea evaluation. Thus this model underscores the importance of both convergent and divergent processes.

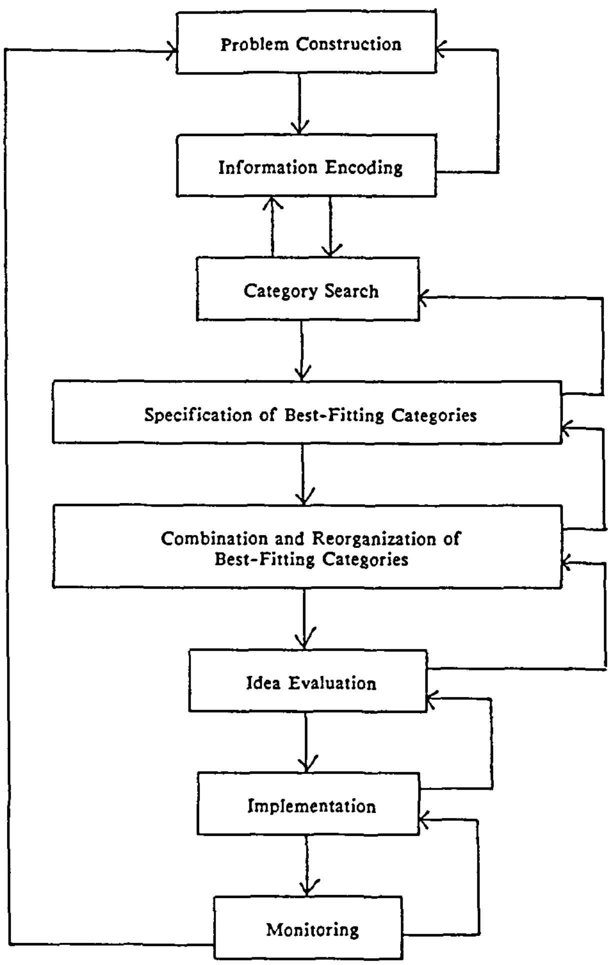

Figure 1. *Hypothesized relationship among core processes*

Based on Isaksen and Parnes' (1985) comments, this observation might argue for a "mess-finding" process to be coupled with the problem construction process. Although further evidence is required prior to incorporating a core process of this sort, some support for this proposition may be found in discussions pertaining to the role of discrepancy identification (Kuhn, 1970; Reitman, 1964), issue awareness (Zuckerman, 1974), and political fragmentation (Simonton, 1984) in creative thought.

Implications of Core Processes

Of course, the processes and model sketched out above have a number of antecedents in the literature. Thus, one might ask what the present effort has contributed to our understanding of creative problem solving. Our observations indicate that creative problem solving involves a number of processes, some of which might not be observed in more routine problem-solving tasks. More specifically, this model suggests that problem construction, category search, and category combination and reorganization play a crucial role in generating new problem solutions. This observation, in turn, suggests that work, such as Baer's (1988), attempting to break these processes down into discrete steps and elucidate the rules underlying their application in various domains, may contribute much to our understanding of creativity.

Unlike other efforts for which the same claim might be made, the present effort has explicitly tied the operation of these processes to the categorical knowledge structures or schema. This extension of the traditional process analytic framework was most directly manifested in the hypothesized role of the combination and reorganization process. One implication of this principle is that the nature and quality of creative problem solutions may vary with the kind of information considered in combination and reorganization. For instance, it is possible that the use of procedural, as opposed to declarative, structures may involve different types of rules and lead to very different kinds of creative products. Alternatively, problem constructions based on goals may have different implications than constructions derived from content similarities.

This explicit linkage of information to process operation has three other noteworthy implications. First, the quality and organization of categorical structures may have a marked impact on creativity. Poorly defined or inarticulate categories may well prohibit effective application of these processes, just as highly articulated, well-differentiated structures can, thereby giving rise to a curvilinear relationship between expertise and creativity (Simonton, 1984). Second, information encoding and search heuristics probably warrant more attention in discussions of creative thought than has hithertofore been the case. Third, the nature of this model and its emphasis on categorical information structures suggests that some strategies for organizing information are more likely to facilitate operation of the search, construction, and combination processes. Thus, there is a need for research intended to explicate the interactions between information organization and process operation. This observation points to a somewhat broader substantive implication of the present effort. More specifically, domain-specific, knowledge-based approaches to creative problem solving are not necessarily incompatible with process-based models. Rather, they should be viewed as interactive systems such that divergent thinking may represent both a domain-specific capacity and a generalizable characteristic of individuals.

The importance of this approach might be illustrated by considering some of the ways an understanding of information structures might be used to facilitate the application of these core processes. In the case of the combination and reorganization process, novel combinations might be facilitated by (a) restrictions prohibiting the application of simple hierarchical combination strategies (Mobley, 1990); (b) an explicit emphasis on the need to incorporate discrepant observations or diverse categories (Kuhn, 1970); and (c) activation of atypical category exemplars or exemplars of associated multiple categories (Doares, 1990). By encouraging individuals to consider similarities in the goals, constraints, and strategies used in prior problem-solving efforts, as well as content similarities, it might be possible to facilitate novel problem constructs and potentially viable new solutions (Reiter-Palmon, 1990). Similarly, events contributing to the application of multiple extended search strategies might also contribute to the generation of novel problem solutions through more effective application of the category search process.

Although the foregoing discussion has focused on the role of problem construction, category search, and category combination process as crucial to the generation of new problem solutions, this model also indicates the potential importance of processes, such as information encoding, specification of best-fitting categories, and idea evaluation. For the most part, processes of this sort, focusing on the convergent elements of creative thought, have not received a great deal of attention in the literature, although there is reason to expect that they contribute to creative thought (Runco, in press-b). In a recent series of investigations, Runco (in press-b) and Runco and Vega (1990) have expressly examined the role of idea evaluation. Their findings indicate that evaluative skill is related to creativity, as measured by divergent thinking tests and captures something beyond intelligence. It also appears that the locus of evaluation, either intra- or interpersonal, may play a role in the operation of evaluative processes. Further studies along these lines are needed to elucidate the import of encoding and category specification in creative problem solving. In the specification of best-fitting categories, for instance, one might expect that creativity would be restricted by retention to too large or too small a number of categories. Similarly, Alissa's (1972) work on overinclusion suggests that encoding diverse, apparently relevant information may also contribute to creativity, up to a point.

In considering the relationships among these processes, another important conclusion comes to fore. This model does not assume rote process application. Rather, it is held that individuals will apply these processes selectively, as called for by the demands of the problem-solving situation, cycling back through these or earlier processes, wherever criteria for movement to the next process have not been met. Thus, this model indicates the need to attend to decision heuristics in studies of creative problem solving. Although decision rules guiding process application have not received a great deal of attention in the literature, illustrations of the potential utility of this approach may be found in the influence of satisficing strategies or creative problem solving (Cyert & March, 1963; Nutt, 1984), the influence of instructions to be creative (Harrington, 1981), and the potential impact of premature convergence (Basadur, Wakabyashi, & Graen, 1990). It seems likely that analysis of the decision rules guiding process application will not only enhance our understanding of creativity in general, but also our understanding of cross-domain differences.

These observations concerning the controlled nature of process application point to two other implications of these core processes. First, analysis of the errors made in creative problem solving, along with the location of these errors, may prove useful in elucidating processing rules and the potential impact on effective process operation in various domains. Second, people's resources are inherently limited, and controlled processing may make strong resource demands (Ackerman, 1986). Thus, task motivation may constitute a crucial determinant of effective process application. Although this conclusion is not especially novel, it should be recognized that the goals and values leading resources to be devoted to one process may not be the same for all other processes. For instance, performance goals may encourage solution evaluation, and learning goals might contribute to category search. It is of note that effects of this sort will be attenuated by aggregation over processes, thereby indicating the risks involved in drawing simple conclusions about general relationships holding for all phases of creative problem-solving efforts.

The hierarchical nature of this model indicates that errors made early on in creative problem solving will carry through the system. This characteristic of the model implies that creative thought will often be a difficult and chancy undertaking, especially in the ill-defined problem-solving situations posed by real-world tasks. Thus, time spent in the application of initial processes may make a disproportionate contribution to creative problem solving (Getzels & Csikszentmihalyi (1975). In accordance with this hypothesis, Okuda et al. (1990) found that problem finding or problem construction is more strongly related to creative activities than divergent thinking.

This observation brings us to a few, final comments bearing on the implications of this model. Divergent-thinking tests have frequently been criticized for their weak validity coefficients (Runco, 1986). This result, however, might be attributed to the tendency of these tests to focus on a limited number of processes ignoring interactions with other processes and available information structures. Similarly, the overlap observed between certain processes involved in creativity and those underlying intelligence (Sternberg, 1986b) might, in part, account for the observed correlation between these measures. Because of the hypothesized interdependencies among these processes, it might also provide an alternative explanation for the triangular relationship described by Guilford and Christensen (1973). Finally, given the nature of these processes and the importance of viable categorical structures to effective process application, certain characteristics of the individual, such as mastery motives (Dweck, 1986), problem sensitivity (Fleishman & Quaintance, 1984), openness (McCrae, 1987), and interest coherence (Terman & Ogden, 1959), probably deserve more attention as predictors of creative capacity than they have received to date. The significance of these characteristics, of course, lies in their potential contributions to knowledge structure development and application.

Taken as a whole, it appears that the present effort has contributed something to our understanding of creative problem solving. This is not to say that the proposed processes are completely unique. Rather, by explicitly linking process operation to categorical knowledge structures, it becomes possible to extend our understanding of the nature and implications of the role of cognitive processes in creative problem solving. Further efforts intended to extend this approach to the analysis of specific processes will, hopefully, yield similar gains in description, prediction, and understanding.

Alternative Conceptions of Creative Problem Solving

Having considered the processes contributing to creative problem solving, it would now seem germane to examine the relation of process analytic models to other conceptions of creative capacity. Perhaps the most common view of creative problem solving may be found in Guilford's (1950) divergent-thinking construct, which reflects a trait approach to creative capacity. Trait models define capacity in terms of individual differences in performance on some set of tasks (Fleishman & Quaintance, 1984).

Process-analytic models, on the other hand, do not specifically focus on performance differences, but instead search for common elements that shape the performance of all individuals. Although these two approaches are quite different, studies by Keating and Babbitt (1978), Keating, List, and Merriman (1985), and Lansman, Donaldson, Hunt, and Yantis (1982) indicate that individual differences in the speed or efficiency of process operation can account for the performance differences observed on trait measures of intelligence and spatial ability.

Although research is needed indicating how differential process execution is related to performance on standard trait measures of creativity, one might expect demonstrated relationships of this sort to contribute much to description, prediction, and understanding. For instance, the limited predictive power of divergent-thinking measures (Runco, in press-a) might be traced to their tendency to focus on certain processes, such as category search and combination, to the exclusion of evaluative and encoding processes. By examining shifts in the significance of these processes across subpopulations, such as younger and older adults, or trait measures, using items drawn from different domains, much might be revealed about the nature of creative problem solving. As Snow and Lohman (1989) pointed out, this enhanced understanding should in turn allow for the design of more sophisticated trait measures explicitly designed to tap the application of certain processes in certain problem-solving domains.

Not only do processing models have some important implications for understanding traditional trait measures, they also have some bearing on associational models for understanding creative problem solving. For many years, the capacity to generate new associational linkages has been used to account for creative problem solutions (Mednick & Mednick, 1967). These associational models range from Mednick and Mednick's (1967) concept of remote associations to more recent discussions of node linkages (Lumsden & Findlay, 1988; Simonton, 1988). Typically, these models attribute creative problem solutions to useful, new element linkages emphasizing stimulus activation, association of activated elements, and subsequent trial-and-error evaluation.

Although evidence is available arguing for the potential utility of these models (Langley & Jones, 1988), Mumford and Mobley (1989) noted that they suffer from certain deficiencies as a general framework for understanding creative problem solving. More specifically, simple associationalistic models fail to account for a number of phenomena, including (a) the active, effortful nature of creative problem solving (Howe, 1982); (b) the internal direction that occurs in creative problem solving (Getzels & Csikszentmihalyi, 1975); (c) the restrictions prior categorization places on possible linkages (Perkins, 1983); and (d) the apparent importance of discrepancies (Kuhn, 1970). On the other hand, Redmond (1990) and Reiter-Palmon (1990) argued that associational mechanisms, when combined with the selection, generation, and application of rules for applying these linkages, may play an important role in the operation of certain processes, such as problem construction and category combination. Thus, the integration of process and associational models may provide a more comprehensive basis for understanding creative thought through research elucidating the kind of associations and rules applied in different processes operating in various domains.

A third major alternative to process analytic models may be found in the various theories emphasizing the role of unconscious or primal thought in creative problem solving (Arieti, 1976; Dudek & Verreault, 1989; Kris, 1952; Suler, 1980). Although we agree with Guilford's (1982) position that unconscious, inarticulate thought processes are unlikely to play a direct role in creative problem solving, they may play a significant supporting role. For instance, unconscious process might provide new kinds of category combinations or bring to awareness new kinds of relationships among categories (Mumford & Gustafson, 1988). Alternatively, they might reflect the outcomes of ongoing, albeit unconscious, process operation. In either case, however, there is a need for research examining how this material is subsequently employed in more directed, conscious processing efforts.

Our foregoing comments bring us to our final, alternative conception of creative problem solving. Here, we refer to the stylistic view of creativity reflected in MacKinnon's (1962) work, where creativity is held to flow from certain temperamental or personality characteristics. Process analytic models do not typically view temperamental attributes as central to the production of novel problem solutions. It should, however, be recognized that individual differences in these temperamental constructs may contribute to the relative efficiency of process operation under different conditions. Tolerance for stress and energy level, for instance, are often related to creative performance, perhaps because they permit individuals to devote more resources to process execution. Similarly, tolerance for ambiguity, openness to experiences, and cognitive complexity might contribute to the individual's willingness to seek out and apply multiple categories (McCrae, 1987). Processing models do not preclude temperamental constructs, and in fact might do much to elucidate how these attributes act to condition creative problem solving in different situations.

Practical Implications

Earlier, it was noted that our interest in creative processes is often driven by practical concerns. We invest time in the analysis of these processes hoping that they will lead to useful conclusions concerning the identification, development, and facilitation of creative thought. In the ensuing discussion, we will examine some practical implications of the core processes with regard to these objectives.

Facilitating Creative Thought

Because creative problem solving involves the cyclical application of a number of processes, creative thought takes time. Thus, interventions encouraging people to devote adequate time to effective process application may do much to facilitate creative performance (Gettinger & White, 1979). One way this use of time might be accomplished is by establishing creative performance goals (Harrington, 1981; Rubenson & Runco, in press; Torrance, 1965) and by ensuring some intrinsic task motivation (Amabile, 1983; Amabile, Hennessey, & Grossman, 1986). Similarly, attempts to call forth mastery motives might prove useful by encouraging people to extend search and combination processes, while cycling through these processes a number of times in their search for a viable problem solution (Dweck, 1986). Another way one might encourage people to devote time to process application is by removing blocking or inhibitory factors. One might, for instance, attempt to minimize competing time commitments, reduce stress, and minimize pressure for immediate production (Feldhusen & Hobson, 1972; Fiedler & Garcia, 1987; Wallach & Kogan, 1965).

Another significant implication of these processes may be found in their implications for convergent and divergent thinking. In the divergent stages of thought, one might facilitate creativity through interventions encouraging people to suspend judgment and to explore diverse alternatives. This principle has been illustrated in Parnes' (1981) work on brainstorming techniques. In addition, it seems likely that the role of dreams and unconscious processes is that they permit a more extensive, unconstrained category search. When convergent stages of thought are being applied, actions which encourage people to seek feedback from others and to identify action constraints might prove useful when applied by appropriate times so as not to inhibit divergent thought.

Although these structural characteristics of the core processes have some important implications, the specific nature of the proposed process also suggests certain strategies for facilitating creativity. To begin, consider the nature of problem construction. The nature of this process suggests that creativity might be enhanced by avoiding specific problem statements and by presenting broad objectives which allow people to construe the problem in different ways. Alternatively, one might incorporate multiple, diverse elements in problem definitions. Problem construction, of course, provides a basis for information encoding. Thus, conditions that permit the generation of richer, more diverse knowledge structures might also contribute to creativity. Here, tacit knowledge and technology, such as computer literature searches, might prove useful by facilitating information gathering, as well as by providing bibliographies and literature summaries pointing to new information and viable mechanisms for organizing the information. Alternatively, openness of communication, interpersonal trust, and cooperative group organizations might serve to encourage information gathering (Andrews, 1975; Pelz, 1956) as may situational influences emphasizing exploration and openness to new experiences. People's openness in information search may, moreover, be influenced by self-esteem and emotional support, especially when unfamiliar information must be obtained and mastered (Knapp, 1963).

The category search, specification, and combination processes also make crucial contributions to idea generation. Again, the nature of these processes suggests certain interventions that might prove useful in enhancing creativity. Because extended category search should contribute to creativity, actions taken to encourage overinclusion should prove useful. Many actions, of course, fall under this rubric, such as providing incubation time, calling for multiple category listings, and encouraging acknowledgment of alternative perspectives (Torrance, 1981; Whitting, 1958). In category specification, creativity is likely to be enhanced by blocking an overly restrictive definition of applicable categories. Thus, interventions, such as instructions to be creative (Harrington, 1981), that inhibit satisficing by calling for unique, high-quality problem solutions may prove useful, as may interventions encouraging discrepancy recognition and sensitivity to multiple alternative features of the categories through intellectual values, independence, and task involvement (Kuhn, 1970; Mumford & Gustafson, 1988; Ross, 1976; Wolf & Larson, 1981.)

In category combination, however, these elements must be reorganized into a potential problem solution. Here, one might expect that by calling for alternative arrangements of elements and for application of different linkage strategies, creativity might be enhanced (Allen, 1962). Given the need for unique combinations, however, interventions encouraging independence, playfulness, and exploration should also contribute to creative thought.

Idea evaluation, implementation, and monitoring represent the last three processes proposed in this model. In the case of idea evaluation, which represents a decision-making component, one might expect that the many techniques proposed by Hogarth (1980), such as consequences analysis, might prove useful. Additionally, attempts to encourage risk taking, supportive feedback, and recognizing accomplishment might also prove useful (Abbey & Dickson, 1983). Relatively little work is available that is pertinent to implementation and monitoring. However, interventions focusing on the social support, independence, self-confidence, resources, and motivation required to implement new problem solutions may prove useful, as well as interventions contributing to careful monitoring and opportunistic adjustments (Andrews, 1975; Hayes-Roth & Hayes-Roth, 1979; Mumford & Gustafson, 1988).

Assessing Creative Potential

Friedricksen (1984) and Snow and Lohman (1984, 1989) noted that a particularly important application of process-analytic models is in the specification of measures for assessing problem-solving capacities. The core processes outlined above might be used to develop measures intended to capture individual differences in the effectiveness with which individuals apply certain processes within the across-problem domains. Alternatively, they may be used to specify the kind of differential characteristics likely to contribute to creative potential.

In fact, the process-analytic model outlined above provides some important guidelines for application of traditional differential measures in assessing creative capacity. Intelligence represents a case in point. If it is granted that intelligence reflects that capacity to generate abstract rules and organizing principles (Humphreys, 1979; Tyler, 1965), then to the extent that effective process application in some domains requires generation of these rules and organizing principles, one would expect some relationship between intelligence and creativity (Guilford & Christensen, 1973). Similarly, category search might require some ability to apply associational and analogical skills. Thus, it is not surprising that measures of this sort have been shown to be related to creative capacity across a number of domains (Mednick & Mednick, 1967; Poze, 1983). Divergent thinking, or the individual's capacity to generate multiple potential-problem solutions (Guilford, 1950), has also been shown to be related to creative performance across a number of domains (Runco, 1986, in press-b;Runco & Albert, 1985). Although divergent-thinking measures have many facets, Mumford and Gustafson (1988) argued that it may reflect the capacity to identify and reorganize categories. Given the crucial import of the search and category combination and reorganization processes to creative thought, it is not surprising that such measures have evidenced some general value in assessment of creative potential.

Beyond its value in explaining the substantive utility of available measures of creative capacity, we believe this model may prove useful in guiding the development of new measures. For instance, as might be expected based on this model, Smilansky (1984) and Runco and Vega (1990) developed measures of problem construction and evaluation skills evidencing some validity in performance prediction. The nature of the processes specified in this model, however, indicates the need for a number of other measures. More specifically, measures of information acquisition or encoding skills are not commonly employed in assessments of creative potential, nor are measures of category specification and monitoring skills. Thus, development of measures intended to assess effective application of these processes might do much to enhance our ability to understand and predict creative potential.

Not only does this model underscore the need to extend current measurement systems to capture multiple processes in a systematic multivariate framework (Mumford & Gustafson, 1988), the general structure of this model also suggests some potential refinements in our strategies for assessing creative potential. First, in addition to general process measures, it might prove useful to formulate measures focusing on process application in specific problem domains. The potential value of this approach has been illustrated in a study by Owens (1969), where a measure of category combination processes as applied to mechanical problems was found to be an unusually effective predictor of creative performance as measured by patent awards and rating criteria. Second, because these processes must be applied to domain-specific knowledge structures, it would seem desirable to extend assessments of creative potential to domain-specific knowledge, as well as to relevant skills and abilities involved in solution implementation and motivational or interest variables conditioning their development. Finally, the cyclical, controlled nature of process application suggests that measures of pertinent metacognitive capacities might also prove useful. This point is illustrated in Friedricksen and Ward's (1978) work, where assessment of creative potential explicitly included a cyclical, controlled processing element.

Developing Creative Capacities

Siegler and Richards (1982), Snow and Lohman (1984, 1989), and Wagner and Sternberg (1984) argued that the efficacy of educational programs might be enhanced by the application of interventions intended to facilitate the efficiency of process operation. In fact, recent research by Davey and McBride (1986), Day (1986), and Hayes and Flower (1986) indicates that educational interventions explicitly designed to illustrate and provide practice in the application of underlying processes may do much to facilitate learning and problem solving. Thus, the nature of these core processes might provide some useful guidelines for the design of educational interventions.

In a recent review of the literature bearing on the development of human capacities, Fleishman and Mumford (1989) concluded that successful programs for developing these processes, or the cognitive abilities which subsume them, share certain characteristics. Initially, the nature of the component sequence and its utility is described, along with the role these processes play in problem solving. Subsequently, application of these processes is demonstrated, and individuals receive structured practice and feedback in process application on a variety of problems designed to illustrate and enhance process application. Support for this general paradigm may be found in the work of Alexander, White, Hanesly, and Jeaner (1986), Brown, Campione, and Day (1981), Day (1986), and White and Alexander (1986). Snow and Lohman's (1984) work, however, indicates that application of this paradigm needs to be tailored to the prior developmental experiences of the target population.

In the context of creative problem solving, application of this paradigm is relatively straightforward. For instance, with respect to category search, individuals might be shown the reasons for and the principles underlying the identification of viable categories. They might subsequently be provided with feedback and practice on the problems intended to illustrate these principles and to eliminate common errors. Similarly, the nature of more and less effective strategies for interrelating categories might be described along with the principles underlying their construction. Then, practice could be provided in combining and reorganizing categories. After such process-specific training has been provided, later efforts might be targeting on controlled application of these processes by providing practice in determining when more extensive encoding is required or when the problem situation needs to be redefined.

Of course, this process-analytic model presupposes that these processes will be applied to knowledge structures. Thus, educational interventions intended to provide individuals with well-developed procedural and declarative knowledge structures might also act to enhance creative potential. The development of these knowledge structures appears to be facilitated by providing and illustrating key diagnostic facts and principles (Bromage & Mayer, 1986), along with expert principles for organizing these discrete elements (Halff, Hollan, & Hutchins, 1986). Subsequently, training material might be formulated calling for the active application and elaboration of these knowledge structures (Dinnel & Glover, 1985; Snow & Lohman, 1984). The availability of these well-organized knowledge structures is an important requirement for effective process application. In the case of creative problem solving, however, multiple categories must be identified, combined, and reorganized. Thus, optimal educational interventions should also attempt to provide multiple, relatively diverse categories, delineate category relationships, and illustrate principles for organizing and interrelating these categories (Friedricksen, 1984).

In keeping with the facet-model principles employed throughout this article, it should also be noted that effective educational interventions are likely to consider a number of other potential influences on creative potential. For instance, interventions might be designed to ensure possession of those skills and abilities required for solution implementation and acceptance. Alternatively, educational interventions might be designed to enhance mastery motives, tolerance for ambiguity, and independence by assigning practical, independent projects requiring multiple issues and points of view to be considered (Torrance & Myers, 1970; Treffinger, Isaksen, & Firestein, 1983). When interventions of this sort are formulated with respect to basic processes and knowledge structure requirements, it seems likely that they may do much to enhance creative capacity.

Conclusions

Over the course of this century, substantial progress has been made in elucidating the essential processes contributing to creative problem solving. Not only have these models become progressively more precise concerning the exact nature and role of proposed processes, they have become more sensitive to the fact that many individual and situational variables act to condition the efficiency of process operation. This trend is of some import because it allows process models to be integrated with the broader literature on creative performance, and because it facilitates development of the hypotheses concerning the kind of actions one might take to improve creativity.

Process-analytic models have become substantially more valuable as a tool for enhancing creative potential with progress in our understanding of human cognition. One result of these gains is that it has become possible to draw from the cognitive and educational literatures in formulating strategies for developing creative capacities. This progress has also made it possible to specify core processes with greater confidence than hithertofore has been the case. In part, this progress arises from the fact that there is no longer a need to maintain an artificial distinction between general processes and domain-specific knowledge. By recognizing that processes operate on categorical knowledge structures, it becomes possible to formulate more powerful developmental interventions while specifying process operations in relation to the nature of knowledge and its role in problem solving. The other important outcome of this growing sophistication is that we have become more sensitive to the organized, highly interdependent nature of effective process application, as well as to the need for multiple sequential processing operations.

Of course, the core processes specified herein should not be viewed as providing a set of absolute entities. As with any other theoretical effort, we expect that future research will dictate adjustments in the nature and relationships among the hypothesized processes. Nevertheless, we hope that this effort will serve not only to provide some useful guidelines for practical developmental efforts, but also to suggest some promising new avenues for research intended to extend and refine our understanding of these core processes. When efforts of this sort are coupled with ongoing research into other major domains of innovation, they may do much to paint a picture of the creative act that captures both its dynamism and power in conditioning the course of human life.

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