Applying Multiple Knowledge Structures in Creative Thought: Effects on Idea Generation and Problem-Solving

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Prior studies have indicated that multiple knowledge structures, schema, associations, and cases, are involved in creative thought. Few studies, however, have examined how these different knowledge structures operate together in idea generation and creative problem-solving. Accordingly, in the present study 247 undergraduates were asked to generate ideas relevant to a social innovation problem and then provide a potential solution to the problem. A training manipulation was used to encourage application of schematic, associational, or case-based knowledge either alone or in combination. It was found that prompting use of a single knowledge structure, specifically schema or associational knowledge, resulted in the production of more high quality ideas. However, prompting use of multiple knowledge structures, specifically combining either schema or associations with cases, resulted in the production of higher quality and more original problem-solutions. The implications of these findings for understanding the role of different knowledge structures in creative thought are discussed.

Current models of creative thought stress the importance of two critical cognitive capacities. Most models hold that creative thought depends, in part, on knowledge or expertise (e.g., Amabile, 1988; Ericsson & Charness, 1994; Howe, Davidson & Sloboda, 1998; Rich & Weisberg, 2004; Weisberg, 1999) and, in part, on effective application of requisite processing operations to relevant knowledge (e.g., Brophy, 1998; Estes & Ward, 2002; Finke, Ward, & Smith, 1992; Scott, Lonergan, & Mumford, 2005; Sternberg, 1989). Although few scholars would dispute the need for knowledge in idea generation and creative problem-solving, little attention has been given to the nature of the knowledge applied and how different forms of knowledge might operate together to make creative thought possible (Mumford, Blair, & Marcy, in press; Radvansky, 1994). The potential importance of this issue becomes apparent when it is recognized that at least three distinct forms of knowledge have been identified that might be applied in creative thought: 1) schematic knowledge (e.g., Ward, Patterson, & Sifonis, 2004), 2) associational knowledge (e.g., Gruszka & Necka, 2002) and 3) case-based knowledge (e.g., Scott, Lonergan, & Mumford, 2005).

The involvement of multiple knowledge structures in creative thought, however, poses a host of questions (Clement, 1988). For example, do some forms of knowledge provide a particularly useful basis for the generation of ideas and the formation of creative problem solutions? Is creative problem-solving more likely to occur if multiple knowledge structures are applied? And, does the use of one type of knowledge structure
facilitate or inhibit application of other knowledge structures? Accordingly, the intent of the present study was to examine how different types of knowledge structures, specifically schematic, associational, and case-based knowledge, act both alone, and in combination, to influence idea generation and creative problem-solving.

Knowledge Structures

Schematic knowledge. Schematic knowledge is based on concepts and principles abstracted from past experience (Phye, 1990; Sakamoto & Love, 2004; Wisniewski, 1996). These concepts may be viewed as a set of categories where each category serves to organize a set of objects, or exemplars, based on a set of underlying principles or features (Bansalou, 1993; Estes & Ward, 2002)—for example, birds fly and have feathers. Schematic knowledge, however, not only entails principles for organizing, or establishing relationships, within a category or concept, it also involves the construction of relationships linking different categories or concepts.

Schematic knowledge provides a basis of analogical problem-solving with the application of feature search and mapping mechanisms (Gentner, 1989; Hummel & Holyoak, 1997; Reeves & Weisberg, 1994). Baughman and Mumford (1995), in a study of conceptual combination, showed that feature search and mapping operations contributed to the generation of new concepts and creative problem solutions. Some support for this conclusion may be found in a more recent study by Ward, Patterson, and Sifonis (2004). In this study, people were asked to draw aliens under conditions where they were, or were not, asked to think about abstract principles before starting work. It was found that more creative drawings were obtained when people were asked to apply abstract principles—the kind of abstract principles held to be embedded in schematic knowledge. A real-world illustration of schematic knowledge structures in creative thought may be found in Edison’s inventions (Hughes, 1989).

Associational knowledge. In contrast to schematic knowledge which is acquired rather slowly and with some difficulty (Halford, Smith, Dickson, Mayberry, Kelly, Bain, & Stewart, 1995), associational knowledge appears to be acquired relatively effortlessly with little conscious processing (Reber, 1989, 1992). Associational knowledge reflects regularities in experience based or probabilistic linkages among stimuli and response event nodes (Estes, 1991)—for example, attending a party is associated with having fun. These event nodes are organized in a network structure such that activation of one node serves to activate other related nodes (Boucher & Dienes, 2003). Traditionally, associational knowledge has been held to give rise to creative thought through network activation resulting in the production of remote or unusual associations (Mednick, Mednick, & Jung, 1964). More recent work by Gruzaka and Necka (2002), however, suggests that the use of associational knowledge in creative thought may depend on the network structure. In a study contrasting more and less creative people, they found that while creative people were more likely to act on remote associations they also evidenced longer response times indicating use of a more extensive and diffuse network.

Case-based knowledge. In addition to schematic and associational knowledge, people may also apply case-based, or episodic, knowledge in creative thought. Case-based knowledge entails formation of a mental model describing critical aspects of past performance events (Hammond, 1990; Kolodner, 1997)—for example, planning a shopping trip. Thus case-based knowledge can be viewed as a form of contextual knowledge that provides a model for action when people encounter similar situations (Hershey, Walsh, Read, & Chulef, 1990). These cases, as a form of mental model, represent a complex entity including information about goals, key actions, outcomes, contingencies, restrictions, and potential opportunities (Hammond, 1990). These cases are held to be stored in a library, which includes both prototypic cases and noteworthy deviations from this prototype—with cases being indexed against situational attributes indicating relevance to the situation at hand (Siefert, Hammond, Johnson, Converse, McDougall, & Vanderstoep, 1994). The manipulation and rearrangement of the components of activated cases in this library is, in turn, held to give rise to novel problem solutions (Spalazzi, 2001; Xiao, Milgram, & Doyle, 1997).

In one study examining the use of case-based knowledge in creative problem-solving, Scott, Lonergan, and Mumford (2005) asked people to solve a social innovation problem involving the development of a curriculum plan for a new experimental school. They found that the systematic analysis and transformation of case components could result in the production of creative problem solutions. In another study along these lines, Rich and Weisberg (2004) found that the transformation of case elements derived from British situational comedies provided a basis for American situational comedies. Weisberg (2004) has provided evidence indicating that similar phenomena may also play a role in scientific and artistic creativity.

Knowledge Structure Interactions

Although there is evidence available indicating that schematic, associational, and case-based knowledge may all provide a basis for creative thought (Clement, 1988), it is possible that these different knowledge
structures might be applied in different ways in different phases of creative effort. For example, in idea generation, the availability of a dense associational network with extensive connections among diverse nodes may promote the rapid generation of multiple ideas (Gruszka & Necka, 2002). Similarly, schematic knowledge structures, by virtue of access to multiple features and multiple exemplars of relevant concepts, should promote generation of multiple ideas. In contrast, due to the situational bounding of case-based knowledge structures, cases may provide a less effective framework for idea generation. Accordingly, the following hypothesis seemed indicated.

Hypothesis One: Prompting use of associational and schematic knowledge structures should result in the production of more ideas, and potentially higher quality ideas, than prompting the use of case-based knowledge structures.

By the same token, however, it should be recognized that the ideas per se do not ensure a viable solution to problems calling for creative thought. Instead, creative problem solutions require ideas that are likely to prove workable within the context in which ideas will be evaluated, refined, and implemented (Csikszentmihalyi, 1999). This point is of some importance because it suggests that the ideas resulting from application of case-based knowledge may prove to be particularly useful in generating high quality, context sensitive, solutions. Moreover, because cases provide a basis for the elaboration and contextual exploration of ideas, and elaborative exploration has been found to contribute to the generation of original solutions (Finke, Ward, & Smith, 1992), it is possible that the use of case-based knowledge may also contribute to generation of original as well as high quality problem solutions. These observations, led to a second hypothesis.

Hypothesis Two: Prompting the use of case-based knowledge will result in the production of higher quality and more original solutions to problems calling for creative thought than prompting the use of associational and schematic knowledge.

These differences in the effects of different knowledge structures on idea generation and creative problem-solving, however, bring to fore a new question. How will the use of different combinations of knowledge structures affect creative thought? Generally speaking, the increased complexity and higher processing demands associated with the activation of multiple knowledge structures can be expected to make idea generation more difficult resulting in the production of fewer high quality ideas especially when generation time is limited. With regard to problem-solving, as opposed to idea generation, however, Mumford, Blair, and Marcy’s (2007) observations suggest that a somewhat more complex pattern of inhibitory and facilitory effects will be observed that depend on the particular combination of knowledge structures under consideration.

For example, one can argue that joint activation of schematic and associational knowledge structures will tend to inhibit creative problem-solving. One line of evidence supporting this conclusion may be found in Reber, Kassin, Lewis, and Cantor (1980). In a study of artificial grammar learning, they found that induction of formal rules inhibits associational learning. Another line of evidence supporting this argument may be found in Kubose, Holyoak, and Hummell (2002) who found that schema coherence facilitates the feature search and mapping needed to apply schematic knowledge in creative problem-solving (Baughman & Mumford, 1995). Because associations, especially remote associations, will reduce coherence, it seems likely that joint activation of schematic and associational knowledge will inhibit creative problem-solving. Taken together these observations suggest the following hypothesis.

Hypothesis Three: Interventions prompting the use of both associational and schematic knowledge structures will diminish the quality and originality of solutions obtained on creative problem solving tasks.

In contrast to the inhibitory effects resulting from the joint activation of schematic and associational knowledge structures, there is reason to suspect that joint activation of case-based and associational knowledge structures will facilitate the production of creative problem solutions. Mumford, Blair, and Marcy (2007) noted that associational linkages can activate multiple alternative cases that might be applied in problem-solving. The activation of multiple cases, in turn, may prompt the analytic comparison of case elements needed to generalize case-based knowledge and insure the transfer of case knowledge to novel problems (Didierjean & Nogry, 2004). Moreover, activation of multiple cases will provide additional, potentially unique, material (e.g., goal and action alternatives) needed to facilitate the transformation of extant cases in the generation of novel solutions. Hence, the following hypothesis:

Hypothesis Four: Interventions prompting the use of both associational and case-based knowledge structures will enhance the quality and originality of solutions obtained on creative problem-solving tasks.

With regard to the joint activation of schematic and case-based knowledge, it is possible that either facilitory or inhibitory effects might be observed. Inhibition might arise because case-based knowledge will lead people to focus on concrete operations and discount principles needed to transfer knowledge to novel problem-solving tasks. In contrast to this inhibitory proposition, Kolodner and Simpson (1989) have argued that activation of case-based knowledge may improve schema-based problem solving by encouraging contextual elaboration—contextual elaboration known to contribute to creative
thought (Finke, Ward, & Smith, 1992). Given this observation, and the findings of Heydenbluth and Hesse (1996) indicating that contextual similarities improve analogical problem-solving through elaborative mechanisms, a fifth, and final, hypothesis seemed indicated.

Hypothesis Five: Interventions prompting the use of both schematic and case-based knowledge structures will enhance the quality and originality of solutions obtained on creative problem-solving tasks.

METHOD

Sample

The 247 members of the sample used to test these hypotheses were recruited from a large southwestern university. The 100 men and 147 women who agreed to participate in the study were recruited from undergraduate psychology courses providing extra-credit for participation in research studies. Participants selected the study as a basis for extra-credit after reviewing a posting of the options available. Most of the undergraduates who agreed to participate in the study were in their sophomore year and were 19 years old. Their average scores on the scholastic aptitude test were half of a standard deviation above national norms for freshmen entering a four year college but were typical of the university as a whole.

General Procedure

These undergraduates were recruited to participate in what was purported to be a study of problem-solving skills. During the first hour-and-a-half of the three hour experimental study, participants were asked to complete a background information form and a battery of individual differences measures. These individual difference measures were intended to provide a set of covariate controls taking in account general abilities, dispositional characteristics, and prior experience that might influence performance on creative problem-solving tasks—both schematic and case-based intelligence and divergent thinking (Vincent, Decker, & Mumford, 2002). Accordingly, the first covariate control measure applied in the present study was the Wonderlic Personnel Test. The Wonderlic is a 50-item multiple choice test intended to provide an omnibus measure of intelligence. The test typically yields split-half reliability coefficients above .80. Evidence for the criterion related validity of this test, and its construct validity as a measure of general intelligence, may be obtained by consulting Bell, Mattews, Lassister, and Leverett (2002), Dodrill and Warner (1988), McKelvie (1989), and Wonderlic (1992).

Participants were also asked to complete three measures of divergent thinking skills. All three divergent thinking measures were drawn from prior studies by Guilford and his colleagues (e.g., Berger, Guilford, & Christensen, 1957; Merrifield, Guilford, Christensen, & Frick, 1962). The three tests selected were chosen to capture differential skill in applying each of the three
knowledge structures under consideration (schematic, associational, and case-based) in creative problem-solving: 1) alternative uses (schematic), 2) associations III (associational) and 2) seeing deficiencies (case-based). All three of these tests produced internal consistency coefficients above .90. Evidence for the construct validity of this scale may be obtained by consulting Scott, Lonergan, and Mumford (1962).

The alternative uses test is a two item test where people are asked to generate alternative uses for 1) a brick and 2) a wooden pencil. In accordance with the test administration manual, people are given 5 minutes to generate these alternatives for a given problem. Because identification and extrapolation of features is a crucial aspect of performance on this test, it was held that the alternative uses test called for application of schematic knowledge. The associations III test is a 30 item, 12 minute, test where people are asked to think of a single word (e.g., bunk) that would have a meaning similar to two other words (e.g., nonsense and bed). Because these items are constructed to capture remote connections among word pairs, it was held this test would reflect skill in applying associational knowledge. The seeing deficiencies test is a 20 item, 20 minute, test where people are presented with a one paragraph description of a “real-world” plan and asked to indicate, in writing, the major error in this plan. Because planning is held to rely on case-based knowledge (Berger & Jordan, 1992), it was expected this test would reflect divergent thinking based on case material. The alternative uses test was scored for fluency, flexibility, and originality, while the associations III and seeing deficiencies tests were scored through application of test manual scoring keys.

To take into account prior exposure to the kind of material presented on the criterion task, a social innovation problem involving curriculum design, participants were asked to complete a background data measure developed by Scott, Lonergan, and Mumford (2005). This 10 item background data scale measures interest in, and prior involvement with, educational issues through self-report questions such as “I am interested in teaching some day” and “I have family members who teach in schools.” Reponses to these questions are scored on a five point continuum with item responses producing internal consistency coefficients above .90. Evidence for the construct validity of this measure may be obtained by consulting Scott (2002).

The final control measures participants were asked to complete was Cacioppo and Petty’s (1982) need for cognition scale. This 15 item self-report inventory asks people to indicate the extent to which their behavior can be described by statements such as “I prefer complex to simple problems.” This scale produces internal consistency coefficients in the .80s. Evidence for the construct validity of this scale, as a measure of a dispositional characteristic held to influence performance on complex problem-solving tasks, has been provided by Butler, Scherer, and Reiter-Palmon (2003).

Experimental Manipulations

Knowledge structure activation. The first experimental manipulation occurred as participants worked through the self-paced instructional program. This manipulation, based on the material presented during training, was intended to prompt the application of different knowledge structures. In all, seven different training packets were devised to encourage application of 1) only schematic knowledge, 2) only associational knowledge, 3) only case-based knowledge, 4) both schematic and associational knowledge, 5) both associational and case-based knowledge, 6) both case-based and schematic knowledge or 7) all three forms of knowledge–schematic, associational, and case-based.

The instructional material that provided the basis for this manipulation was divided into three segments. In the first segment the nature of the relevant knowledge structures, and the way in which they are applied in problem-solving, was described. In the second segment, participants were asked to provide a solution to a, day-to-day real-world, problem (Reiter-Palmon, Mumford, & Threlfall, 1998) after answering a series of prompt questions intended to encourage application of the knowledge structures applying in a given condition. In the third segment, participants were presented with prototype answers to these prompt questions and were asked to compare their answers to the illustrative answers provided. The three real-world problems providing the basis for the second and third training segments examined 1) developing a plan for a championship soccer match, 2) obtaining the money needed to hold a class prom, and 3) attaining election as a club president. These three training problems were selected to ensure realism and relevance while minimizing content overlap with the social innovation problem to be used in assessing creative problem-solving.

Activation of the knowledge structures applying in a given condition occurred as participants worked through this instructional material—material they were led to believe would help them solve the social innovation problem. Activation of the knowledge structures relevant to a given condition occurred at three points as participants worked through the self-paced instructional program. The first activation event occurred when the overview of the relevant knowledge structures was presented. Here only those knowledge structures relevant to a given condition were described. The second
activation event, intended to encourage application of select knowledge structures, occurred as participants began working on the training problems. Here only those prompt questions intended to encourage application of the relevant knowledge structures were presented. The third activation event occurred as participants reviewed illustrative answers to these questions with illustrative answer material being devised to reinforce use of relevant knowledge structures.

Figure 1 illustrates the nature of the prompt questions used to encourage application of the relevant knowledge structures while Figure 2 illustrates the model answers to be reviewed after participants had provided their own answers to these questions. In the conditions intended to encourage application of associational knowledge, participants were asked to list things they thought were relevant to the problem and then list another thing related to the thing they had just listed. In the conditions intended to encourage application of case-based knowledge, participants were asked to list and briefly describe their experiences in similar performance situations they had encountered in their past lives. In the conditions intended to encourage application of schematic knowledge, participants were asked to list

![Soccer Coach Problem](image)

**Figure 1** Example of questions asked on practice problems to activate knowledge structures.
general principles, or concepts, applicable to this type of problem.

With regard to this knowledge structure manipulation three further points are of note. First, answers to these prompt questions were to be provided prior to formulating a problem solution. Second, multiple answers were to be provided for each prompt question. Third, in conditions where multiple knowledge structures were to be activated, the order of presentation of the knowledge structure description, the associated prompt questions, and the illustrative question answers was rotated to control for potential carryover effects.

**Activation strength.** Activation strength was manipulated to be either extended or truncated by providing participants with more or less space, and thus time, to prepare answers to the prompt questions. This second manipulation occurred after participants had completed instructional material as they began work on the social innovation problem. After participants had read through the background material describing the problem, they were asked to answer those prompt questions presented in the training problems, again, but as they pertained to the social innovation problem. These questions appeared in the same order as the training problem to maintain the rotational control. However, no illustrative answers were provided. In the extended idea activation condition, participants were given a full page and five minutes to list their answers to each of the relevant prompt questions. In the truncated activation condition, participants were given only half of a page and three minutes to list their answers to each of the relevant prompt questions.

**Creative Problem Solving Task**
The creative problem-solving task participants were asked to work on during the final 45 minutes of this
study was a social innovation problem. On this problem, a variation on Scott, Lonergan, and Mumford’s (2005) curriculum design task, participants were asked to assume the role of a recently hired high school teacher who had been asked to design a new course. This course was intended to reduce the college dropout rate of students graduating from the high school. The problem statement presented to participants explicitly noted the need for a novel solution due to the failure of prior attempts to solve this problem. Figure 3 presents the problem statement presented to participants. After reading through the problem statement, participants were asked to answer prompt questions intended to encourage application of the knowledge structures relevant to the knowledge structure manipulation applying in the condition at hand. Not only did answers to these questions provide a basis for the idea generation manipulation, they served to reinforce relevance of these knowledge structures in solving the transfer (social innovation) problem. In answering these questions, however, you have recently been hired as a new faculty member in a town called Imlay City. You were hired directly out of college and have the summer to prepare your courses. The high school is in a very nice area of Oklahoma and pays better than nearly all other high schools in the state. The high school contains about 600 students or about 150 per grade. The school is made up of roughly 55% females, 45% males. The demographics are predominately white (89%) with some blacks (5%) and Hispanics (6%).

As with most high schools, a large proportion of Imlay City’s graduates are attending college (70%), though this number is slightly below the national average (77%). Because of this slight discrepancy, the principal of your new school examined the statistics of Imlay City graduates attending college. In the midst of her search, the principal found that Imlay City graduates were dropping out of college at a rate much greater than the national average. Specifically, the national percentage of college freshman dropouts is 30%. In comparison, Imlay City’s freshman dropout rate is a staggering 50%. Moreover, a survey of five other local schools revealed dropout percentages of 10%, 11%, 9%, 6% and 12%, respectively.

This alarming trend led the principal to search for an explanation of these numbers. She quickly sent out a survey to past high school graduates, asking them for feedback on how difficult college was for them. The responses to the survey indicated that those students that did not drop out of school their freshman year reported a great deal of difficulty that first year. Moreover, they indicated that the only way they survived the first semester was by adopting new patterns of behavior—substantially differing from those learned in Imlay City. Even more startling was that those individuals who did drop out their freshman year indicated very clearly that they were overwhelmed by college life and simply not ready for it. The results of the survey led the principal to a single solitary conclusion: Imlay City graduates were not prepared for college.

A week after being hired, the principal has called you into her office for a very important meeting. She informs you that because you are a recent college graduate and that because you come so highly recommended, you have been selected to teach a very important new course at Imlay City—the senior college prep course. The new class will be mandatory for all seniors and they must pass the course with a “C” or better in order to graduate. This will be the only course you teach and each class will contain about 30 students. In her description of the requirements for the course, the principal makes one point very clear: what Imlay City has done in the past has not worked. Simply put, the new course must be different. In addition, she demands to see some improvement in the next year’s dropout rates. Moreover, she demands to see a new dropout rate in four years that is at or under the national dropout rate.

You have three months to develop a new course to better prepare Imlay City’s seniors for college. How will you go about solving this problem?

FIGURE 3 Description of social innovation problem.
participants were not provided with illustrative potential answers. Once they had generated ideas in response to the relevant prompt questions (e.g., list relevant concepts and principles, describe relevant prior experiences, list related things), participants were asked to propose a solution to this course design problem. More specifically, participants were asked to provide a half page to one page description of the course they would propose to address the dropout rate problem.

Dependent Variables

The first two dependent variables examined idea generation in response to the prompt questions presented on the course design problem. One dependent variable was a count of the number of ideas produced for each of the initial prompt questions—standardized to take into account cross-condition differences in the opportunity for idea generation. The second dependent variable was a 5-point rating of the average quality of the ideas generated in response to each question. These ratings were made by four judges, all doctoral candidates in psychology, after a review of all responses to a given question based on the recommendations of Runco and Mraz (1992). These overall quality judgments produced an intraclass agreement coefficient (ICC) of .73. The average originality rating across questions and the average number of responses across questions provided operational measures of the dependent variables. It is of note that originality scores were also obtained for participants, answers to the tutorial questions to provide a control for effort and initial learning on the training task.

In addition to the number and quality of ideas generated in response to prompt questions, four judges, again all doctoral candidates in psychology, were asked to read through the written descriptions of the final solutions to the course design problem provided by participants. They were then asked to evaluate the quality and originality of these solutions by applying a set of benchmark rating scales developed using the procedures recommended by Redmond, Mumford, and Teach (1993). In accordance with Redmond, Mumford, and Teach (1993), quality was defined as a logical, complete, coherent solution while originality was defined as a novel, unexpected, solution where the solution was potentially viable. Based on these definitions, solutions provided by participants were reviewed, and sample solutions reflecting high, moderate, and low levels of quality, and originality, were identified. These benchmark solutions were then summarized and used to construct the scale anchors for evaluating the quality and originality of relevant problem solutions. Figures 4 and 5 illustrate the nature of these benchmark rating scales. Prior to making their ratings of solution quality and originality these judges were asked to complete a 20 hour training program. In this training, judges were familiarized with the task and the nature of the benchmark rating scales. Subsequently, they were asked to apply these ratings scales to a set of sample problem solutions. After making their ratings, judges convened as a panel to discuss their ratings and resolve any observed discrepancies. Following training, these judges produced intraclass agreement coefficients (ICCs) of .82 and .77 for solution quality and originality—using the procedures suggested by Shrout and Fleiss (1979).

Analyses

A series of analysis of covariance tests were conducted where scores on the individual differences measures, the background information form, and the indices of training performance were treated as covariate controls and knowledge structure activation and strength of activation were treated as independent variables. In the first set of analysis of covariance tests, the average number of ideas generated and the average quality of these ideas were treated as the dependent variables of interest. In the second set of analyses, the dependent variables examined were the quality and originality of solutions to the course design problem. In this set of analyses, however, the number and quality of ideas generated were treated as covariates to control for the effects of initial idea generation on the resulting problem solutions. In all these analyses a potential covariate was retained only if it produced a relationship significant beyond the .05 level.

RESULTS

Idea Generation

Table 1 presents the results obtained for the effects of the knowledge structure activation and activation strength on the number of ideas generated in response to questions intended to prepare people for work on the social innovation problem. Table 2 presents the means and standard errors for each condition. The quality of the material generated in the initial tutorials proved to be a significant \( F(1, 226) = 18.96, p < .001 \) covariate. As expected, quality of the tutorial performance proved to be positively related to the number of responses generated to the prompt questions presented as people began work on the course design problem. The alternative uses test, when scored for flexibility, also produced a significant \( F(1, 226) = 13.34, p < .001 \) positive relationship with the number of ideas generated. The activation strength manipulation produced a significant \( F(1, 226) = 37.36, p < .001 \) main effect with
respect to the number of ideas provided in response to
the relevant prompt questions. As might be expected,
more ideas were obtained in the extended activation
\((M = .27, \ SE = .056)\) than the truncated activation
\((M = .21, \ SE = .056)\) condition. Apparently, when
people are given more time and opportunity they, in
fact, generate more ideas in relation to prompt ques-
tions intended to activate application of select knowl-
edge structures.

A more noteworthy finding emerged in examining the
effects obtained for the type of knowledge structures
activated by these questions. A significant \(F (6, 226) = 2.69, p \leq .05\) main effect was obtained for the knowl-
edge structure activation. Inspection of the relevant cell
means indicated that more ideas were provided to
prompts when associational knowledge structures
\((M = .44, \ SE = .119)\) were activated than all other con-
ditions \((M = .03, \ SE = .101)\) including conditions
where multiple knowledge structures were activated.
Apparently, activation of associational knowledge per-
mits the rapid production of ideas but not necessarily
if other types of knowledge structures are activated.

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Scale and Benchmarks

1) Poor rating: The solution is illogical and incomplete. It does not make sense and fails to provide an
answer to the problem in a sound, rational, manner.

Ex: Stress importance of work ethic and the like but explain that a portion of the grade will be
on creativity task for a “creative process sheet.” Creativity through presentations — everyone
must participate. Treat all students equally and make no special exceptions. Make students
responsible for themselves.

2) Poor to average rating

3) Average rating: The solution has logical elements to it. Though missing some key elements, most
ideas are complete. The solution may contain one or two confusing elements, but makes general
sense, overall.

Ex: The course will be a lecture course and will attempt to duplicate the difficulty of a college
level course. The material will consist of strategies for effective study and test taking. Tests will
be on a mid-term and a final system, with 2 midterms and one comprehensive final. The tests
will be intended to be extremely difficult, and will require sufficient studying at the material.
Study time sheets will be used, in which students will record the amount of time they spend
studying for all of their courses, not just the college prep class. Extra credit will be given to
those with the most study hours. The 4 months before the start at the school year will be spend
organizing, defining and revising the curriculum. Which should ideally mimic a college class by
revolving around some kind of textbook.

4) Average to excellent rating

5) Excellent rating: The solution is exceptionally logical. The solution includes all necessary elements
for developing a new classroom, and is soundly complete. The solution is clear and exceptionally
coherent.

Ex: First, for a general layout of the course, I will build a list of key components based on my
experiences as well as other college freshman so there will be a basis of what to focus on and
what not to focus on. Using each of these key elements in scenarios is necessary; as well as
finding a way to present the information in a way that can not only be understood, but intriguing
at the same time. I will also take the time in class to focus on each one of the students
strengths and weaknesses individually to help them on a more personal level. Keeping the
course from being terribly difficult will also be a huge factor in whether or not the students will
retain the information. Also, if the structure of the class is based on learning instead of
achieving a high grade, this will boost the students confidence level in dealing with such issues
when they become college freshmen. Another element that will be focused on in the class is the
importance of higher education. If these students are aware of the risks and benefits of
choosing whether or not to achieve higher education, they will be more apt to stick with
something that is very challenging to them. Finally, it cannot go without recognition that this
class will focus on the main aspect of confidence and self-esteem. Preparing these students
academically will help to a certain degree, but it is within the confidence of the students that lies
the true potential for success.

FIGURE 4 Benchmark rating scale for quality.
Scale and Benchmarks

1) **Poor rating:** The solution is very predictable and fails to provide any new or unique ideas. The solution completely lacks richness and descriptiveness. It is almost impossible to visualize the proposed course.

   Ex: I think I will have new teaching to help the students study well and pass the grade C such that includes a tutor outside the classroom and help the students do homework. If they don’t understand, I can explain until they got it. Also, take attendance to students because it encourages students to work harder. Beyond those, I think the students will have progress during studying.

2) **Poor to average rating**

3) **Average rating:** The solution has a few original and unique elements. The solution, however, still contains many predictable concepts. The solution is somewhat descriptive.

   Ex: The first day of the course will be introducing different careers to students, and inform them that they will need to know what their potential career would be before the end of the semester. Basically, this will try to introduce a college atmosphere into the classroom, combing the amount of work and research that are required for college freshman. There will be guest speakers, who will discuss what they found to be difficult during their freshman year and their solution to them. Other guest speakers will include college counselors and college professors.

4) **Average to excellent rating**

5) **Excellent rating:** The solution is clearly unique. It has core elements that appear wholly original—particularly to the participant. It is clear what the classroom would look like as well as operate. The solution is exceptionally rich and descriptive.

   Ex: I would hand out a survey about “how far, how big, things it should offer,” referring to colleges. Tell them they all must be considering college. If they aren’t, I would like to offer a separate class for those kids considering vo-tech or other things. Help them decide on 3 colleges to apply to. Make applications due and then I will review them for errors. One of those applications must require an essay or they must find a scholarship with an essay. We would then look for scholarships. The must complete 3 applications for that too. We would then take personality tests to help then identify a career of choice. They would then write a research paper. I would teach MLA and citing for this. We would also learn about research in a library. We would then have visitors from college come and talk about different things most colleges offer. We would talk about dorm life, etc. At the end of the course, I would give them college survival guides about everything including, packing for dorms, writing papers, etc.

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**FIGURE 5** Benchmark rating scales for originality.

---

**TABLE 1**

<table>
<thead>
<tr>
<th></th>
<th>Number</th>
<th></th>
<th></th>
<th>Quality</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
<td>df</td>
<td>p</td>
<td>d</td>
<td>F</td>
<td>df</td>
</tr>
<tr>
<td>Covariates</td>
<td></td>
<td></td>
<td>-----</td>
<td></td>
<td></td>
<td>-----</td>
</tr>
<tr>
<td>Alternative uses flexibility</td>
<td>13.34</td>
<td>1, 226</td>
<td>.001</td>
<td>.49</td>
<td>5.01</td>
<td>1, 226</td>
</tr>
<tr>
<td>Tutorial quality</td>
<td>18.96</td>
<td>1, 226</td>
<td>.001</td>
<td>.58</td>
<td>66.63</td>
<td>1, 226</td>
</tr>
<tr>
<td>Main effects</td>
<td></td>
<td></td>
<td>-----</td>
<td></td>
<td></td>
<td>-----</td>
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<tr>
<td>Knowledge structures activated</td>
<td>2.69</td>
<td>6, 226</td>
<td>.015</td>
<td>.22</td>
<td>2.26</td>
<td>6, 226</td>
</tr>
<tr>
<td>Activation strength</td>
<td>37.36</td>
<td>1, 226</td>
<td>.001</td>
<td>.82</td>
<td>6.20</td>
<td>1, 226</td>
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<tr>
<td>Interactions</td>
<td></td>
<td></td>
<td>-----</td>
<td></td>
<td></td>
<td>-----</td>
</tr>
<tr>
<td>Knowledge structures by activation strength</td>
<td>2.25</td>
<td>6, 226</td>
<td>.039</td>
<td>.09</td>
<td>1.18</td>
<td>6, 226</td>
</tr>
</tbody>
</table>

*Note. F = F-ratio; df = degrees of freedom; p = significance level; d = effect size.*
along with associational knowledge. In contrast, activation of case-based knowledge resulted in the production of relatively few ideas ($M = -.16, SE = .134$ vs. $M = .061, SE = .094$).

A significant ($F(6, 226) = 2.25, p \leq .05$) interaction was also obtained between knowledge structure activation and activation strength. This effect appeared attributable to two types of knowledge structures. In contrast to other conditions where time and opportunity led to the production of more ideas, activation of case-based knowledge per se resulted in the production of a similar number of ideas in the truncated ($M = -.15, SE = .133$) and extended ($M = -.16, SE = .190$) activation conditions. Thus, the limited value of case-based knowledge for idea generation does not appear to be solely a matter of time or the demands of response production. In addition, it was found that activation of schematic knowledge resulted in relatively few ideas in the truncated activation condition ($M = .40, SE = .188$ vs. $M = .18, SE = .133$) but a relatively large number of ideas ($M = .53, SE = .15$, vs. $M = .31, SE = .131$) in the extended activation condition. Apparently, schematic knowledge may provide a useful basis for generating a number of ideas if sufficient time is provided for feature search and elaboration.

Table 1 also presents the results obtained when the quality of the ideas produced in response to the idea generation prompt questions was examined. Again, alternative uses flexibility ($F(1, 226) = 5.01, p \leq .05$) and tutorial quality ($F(1, 226) = 66.63, p \leq .001$) proved to be significant covariates producing positive relationships with the quality of the ideas generated in response to the relevant knowledge structure activation questions. Activation strength, again, produced a significant ($F(1, 226) = 6.20, p \leq .01$) main effect with, as expected, higher quality ideas emerging in the extended ($M = 3.19, SE = .040$), as opposed to the truncated ($M = 3.05, SE = .041$), activation conditions.

More centrally, a significant ($F(6, 226) = 2.26, p \leq .05$) main effect was obtained for the type of knowledge structures activated. In keeping with our earlier observations, the cell means indicated that activation of associational ($M = 3.36, SE = .086$) and schematic ($M = 3.18, SE = .086$) structures resulted in the production of higher quality ideas in response to the relevant prompts than all other conditions ($M = 3.05, SE = .071$). Taken as a whole, these findings suggest that applying associational and schematic knowledge, as opposed to multiple different knowledge structures, or case-based knowledge per se, results in the production of the largest number of viable ideas.

**Solution Production**

Table 3 presents the results obtained in the analysis of covariance examining effects of knowledge structure

---

**Table 2**

<table>
<thead>
<tr>
<th>Knowledge Structure</th>
<th>Num</th>
<th>Qual</th>
<th>Num</th>
<th>Qual</th>
<th>Num</th>
<th>Qual</th>
<th>Num</th>
<th>Qual</th>
<th>Num</th>
<th>Qual</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3.36</td>
<td>.086</td>
<td>3.38</td>
<td>.086</td>
<td>3.38</td>
<td>.086</td>
<td>3.36</td>
<td>.086</td>
<td>3.36</td>
<td>.086</td>
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<tr>
<td>S</td>
<td>3.18</td>
<td>.086</td>
<td>3.19</td>
<td>.086</td>
<td>3.19</td>
<td>.086</td>
<td>3.18</td>
<td>.086</td>
<td>3.18</td>
<td>.086</td>
</tr>
<tr>
<td>C</td>
<td>3.05</td>
<td>.041</td>
<td>3.09</td>
<td>.040</td>
<td>3.09</td>
<td>.040</td>
<td>3.05</td>
<td>.041</td>
<td>3.05</td>
<td>.041</td>
</tr>
</tbody>
</table>

Note. Standard errors are presented in parentheses; Num = number of ideas generated in standardized score format; Qual = quality of ideas generated; Orig = originality of solution generated.

**Table 3**

<table>
<thead>
<tr>
<th>Knowledge Structure</th>
<th>Num</th>
<th>Qual</th>
<th>Num</th>
<th>Qual</th>
<th>Num</th>
<th>Qual</th>
<th>Num</th>
<th>Qual</th>
<th>Num</th>
<th>Qual</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3.36</td>
<td>.086</td>
<td>3.38</td>
<td>.086</td>
<td>3.38</td>
<td>.086</td>
<td>3.36</td>
<td>.086</td>
<td>3.36</td>
<td>.086</td>
</tr>
<tr>
<td>S</td>
<td>3.18</td>
<td>.086</td>
<td>3.19</td>
<td>.086</td>
<td>3.19</td>
<td>.086</td>
<td>3.18</td>
<td>.086</td>
<td>3.18</td>
<td>.086</td>
</tr>
<tr>
<td>C</td>
<td>3.05</td>
<td>.041</td>
<td>3.09</td>
<td>.040</td>
<td>3.09</td>
<td>.040</td>
<td>3.05</td>
<td>.041</td>
<td>3.05</td>
<td>.041</td>
</tr>
</tbody>
</table>
activation and strength of activation on the quality and originality of the solutions obtained for the course design problem. Table 3

The associated means and standard errors are presented in Table 4. As may be seen, a number of covariates produced significant positive relationships with ratings of solution quality including alternative uses flexibility ($F(1, 224) = 5.79, p \leq .05$), seeing deficiencies ($F(1, 224) = 6.32, p \leq .01$), need for cognition ($F(1, 224) = 4.42, p \leq .05$), English as first language ($F(1, 224) = 6.40, p \leq .01$), and tutorial quality ($F(1, 224) = 4.27, p \leq .05$). In addition, the quality of the ideas generated in response to the prompts ($F(1, 224) = 12.58, p \leq .001$) was found, as expected, to be positively related to the quality of the problem solutions people eventually proposed.

Even taking into account the effects of prior idea generation activities, a significant ($F(6, 224) = 3.48, p \leq .01$) main effect was obtained for the type of knowledge structures activated and the quality of the solutions provided to the course design problem. Inspection of the cell means indicated that activation cases ($M = 2.74, SE = .122$), schema and cases ($M = 2.81, SE = .080$) and associations and cases ($M = 2.96, SE = .083$) resulted in the production of higher quality solutions than activation of schema ($M = 2.58, SE = .108$), associations ($M = 2.59, SE = .111$), associations and schema ($M = 2.54, SE = .080$), and schema, associations and cases ($M = 2.52, SE = .086$). Apparently, cases provide a stronger basis for solution generation than idea generation with case-based knowledge proving particularly valuable when it is combined with associational or schematic knowledge. However, the value of applying multiple knowledge structures did not hold if knowledge structures subject to interference (e.g., associations and schema) were simultaneously activated.

The activation manipulation also produced a marginally significant ($F(1, 224) = 3.40, p \leq .10$) main effect. Inspection of the relevant cell means indicated that higher quality solutions were obtained when generation of responses to the knowledge structure activation questions was truncated ($M = 2.75, SE = .05$) rather than extended ($M = 2.60, SE = .050$). Although this finding may, at first glance, appear surprising, it may reflect the greater difficulty of crafting coherent, logical, solutions when a large number of ideas are available.

As may be seen in Table 2, only two covariates produced significant ($p \leq .05$) relationships with solution originality. Again, significant positive relationships were produced by alternative uses flexibility ($F(1, 224) = 7.81, p \leq .01$) and seeing deficiencies ($F(1, 224) = 4.92, p \leq .05$). More centrally, however, knowledge structure activation produced a marginally significant ($F(6, 224) = 1.93, p \leq .10$) main effect in accounting for the originality of solutions to the course design problem. In accordance with the results obtained for solution quality, the most original solutions were obtained when cases and associations ($M = 2.55, SE = .081$), cases and schema ($M = 2.44, SE = .078$), and cases ($M = 2.36, SE = .119$) were activated. Less original solutions were obtained when associations ($M = 2.18, SE = .109$), schema ($M = 2.21, SE = .106$), schema and associations ($M = 2.30, SE = .078$), and schema, associations, and cases ($M = 2.32, SE = .089$) were activated. Thus, case-based knowledge, particularly when combined with associational or schematic knowledge, appears to contribute to the production of original solutions as well as high quality solutions on social innovation problems.

In this regard, however, it is important to bear in mind the significant ($F(6, 229) = 2.76, p \leq .05$) interaction obtained between knowledge structure activation

<table>
<thead>
<tr>
<th>Covariates</th>
<th>Quality</th>
<th>Originality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$F$</td>
<td>$df$</td>
</tr>
<tr>
<td>Alternative uses flexibility</td>
<td>5.79</td>
<td>1, 224</td>
</tr>
<tr>
<td>Tutorial quality</td>
<td>6.32</td>
<td>1, 224</td>
</tr>
<tr>
<td>Need for cognition</td>
<td>4.42</td>
<td>1, 224</td>
</tr>
<tr>
<td>English first language</td>
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<td>1, 224</td>
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<tr>
<td>Tutorial quality</td>
<td>4.27</td>
<td>1, 224</td>
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<tr>
<td>Quality of generation</td>
<td>12.58</td>
<td>1, 224</td>
</tr>
<tr>
<td>Interactions</td>
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<tr>
<td>Knowledge structures activated</td>
<td>3.48</td>
<td>6, 224</td>
</tr>
<tr>
<td>Activation strength</td>
<td>3.40</td>
<td>1, 224</td>
</tr>
<tr>
<td>Knowledge structures by activation strength</td>
<td>.99</td>
<td>6, 224</td>
</tr>
</tbody>
</table>

Note. $F$ = F-ratio; $df$ = degrees of freedom; $p$ = significance level; $d$ = effect size.
and activation strength. Examination of the cell means indicated that the effect could be traced to schematic knowledge. Activation of schematic knowledge, just schematic knowledge, resulted in especially original solutions in the truncated activation condition ($M = 2.60, SE = .169$) and especially unoriginal solutions in the extended activation condition ($M = 1.81, SE = .137$) in comparison to all other conditions ($M = 2.36, SE = .129$). This finding, however, may simply reflect the induction of a relatively inflexible mental set with extended activation of relevant schema—an inflexibility that, in turn, may undermine the production of original solutions on creative problem solving tasks (Finke, Ward, & Smith, 1992; Mumford, Blair, Dailey, Leritz, & Osburn, in press).

**DISCUSSION**

Perhaps the most straightforward conclusion that can be drawn from the present study involves the role of multiple knowledge structures in creative thought. Apparently, people can think about social innovation problems, such as the course design problem examined in this study, using a number of different knowledge structures. In fact, schema, associations, and cases, either alone, or in combination, were related to the generation of ideas about the problem and the development of original, high quality, problem solutions. In keeping with the earlier observations of Mumford, Blair, and Marcy (in press), however, a rather complex set of effects were observed as a result of knowledge structure activation with the effects of knowledge structure activation depending on the particular aspect of creative thought, idea generation or solution generation, under consideration, the particular knowledge structures or combination of knowledge structures activated, and the strength of knowledge structure activation.

Traditionally, experimental studies of creative thought have examined one of two criteria—idea generation or problem-solving (Runco & Sakamoto, 1999). Often it is assumed that because idea generation is a necessary (although perhaps not sufficient basis) for creative problem-solving, one can assume the effects observed for idea generation will apply in understanding how people go about solving problems calling for creative thought. The results obtained in the present study, however, indicate that different knowledge structures appear to contribute to creative thought in different ways depending on whether idea generation or solution formation are under consideration. More specifically, when the criterion of concern was idea generation per se, associational or schematic knowledge appeared more useful than case-based knowledge or various combinations of knowledge structures. Apparently, people
generate ideas most easily when they can work with a single knowledge structure that provides a variety of connections or relationships that are not bound to a particular performance setting.

When one considers the quality and originality of solutions to social innovation problems, however, a rather different pattern of findings emerged. Although activation of case-based knowledge did not promote idea generation, it was found to contribute to the production of original, high quality problem solutions. Solution generation, moreover, in contrast to idea generation, appeared to benefit from the application of multiple knowledge structures—specifically joint activation of associational and case-based knowledge and joint activation of schematic and case-based knowledge. One implication of this pattern of findings is that creative problem-solving should be viewed as a distinct phenomena involving different knowledge structures and potentially different processing operations (Scott, Lonergan, & Mumford, 2005), than idea generation.

More centrally, however, these findings indicate that creative problem-solving may involve different knowledge structures or combinations of knowledge structures than idea generation. Weisberg and his colleagues (Rich & Weisberg, 2004; Weisberg, 2003) have argued that creative problem solutions often arise from transformations. This point is of some importance because it suggests that people, by reorganizing and rearranging the elements of prior problem solutions can formulate creative problem solutions, both original and high quality solutions, without necessarily generating a large number of ideas. This kind of experiential, or case-based, analysis may provide especially valuable in creative problem-solving both because it will result in solutions that are contextually appropriate or field relevant (Csikszentmihalyi, 1999), and because it allows people to take into account the many complex considerations (e.g., goals, resources, restrictions, contingencies) needed to craft viable creative problem-solutions in real-world settings (Mumford, Bedell, & Hunter, in press). In fact, the results obtained in the present study, pointing to the unique value of case-based knowledge in creative problem-solving, provide some support for these observations.

One reason we tend to discount the importance of case-based knowledge in creative problem-solving, is that it is difficult to see how prior solutions can result in the truly novel solutions that are the hallmark of creative thought. One way experiential knowledge can give rise to novel problem solutions is through a sequence of progressive transformations. The results obtained in the present study, however, suggest that the effective use of experiential knowledge in creative problem-solving, may also occur by linking experiential, or case-based knowledge, to other forms of knowledge that would promote the production of novel solutions. Thus it was not the activation of case-based knowledge per se that resulted in the highest quality and most original problem solutions but rather 1) activation of case-based knowledge along with associational knowledge, and 2) activation of case-based knowledge along with schematic knowledge. Apparently creative problem-solving is most likely to occur when people incorporate new elements into cases through associational connections or apply schematic principles in extending and reorganizing cases with respect to prior experience bearing on the problem at hand (Kolodner & Simpson, 1989).

Although the associational or schematic extension of case-based knowledge represents one way to generate creative problem-solutions, it is not necessarily the only way (Clement, 1988). In fact, in the present study it was found that schematic knowledge could be applied in generating original problem solutions provided that extended activation of these schema did not induce set effects. This finding is, of course, consistent with the earlier observations of Baughman and Mumford (1995) concerning the application of analogical mechanisms in creative problem-solving. However, the fact that effective application of schematic knowledge could be inhibited by extended activation, and induction of potential set effects (Finke, Ward, & Smith, 1992; Mumford, Blair, Dailey, Leritz, & Obsborn, in press), suggests that the use of schematic knowledge in creative problem-solving may depend on the flexible application of principles or features abstracted from these schema (Ward, Patterson, & Sifonis, 2004).

The use of analogical mechanisms when schema are applied in creative problem-solving suggests a potential explanation for the inhibitory effects observed when both associational and schematic knowledge were activated and when associational, schematic and case-based knowledge structures were all activated. Associations reduce schematic coherence, and, this reduction of schematic coherence will inhibit analogical transfer (Kubose, Holyoak, & Hummel, 2002). Although the inhibitory effects can be explained in a relatively straightforward fashion, it is possible other explanations might be applied based on activation patterns or cognitive load. Regardless of the explanation applied, however, these inhibitory effects remind us that it is not simply activating multiple knowledge structures that contributes to creative thought but rather the particular combination of knowledge structures activated.

These observations about the kind of inhibitory and facilitory effects observed with the activation of multiple knowledge structures are of interest for practical as well as theoretical reasons. Many programs intended to develop creative thinking skills explicitly include interventions intended to encourage people to apply certain
types of knowledge in idea generation or creative problem-solving (Scott, Leritz, & Mumford, 2004). For example, Davis (1999) describes instructional techniques such as brainstorming (associational knowledge), morphological synthesis (schematic knowledge) and direct analogical thinking (case-based knowledge). Clearly, these interventions are most likely to prove effective if they focus on requirements for creative problem-solving rather than idea generation per se. Moreover, interventions along these lines are most likely to prove effective if they focus on the application of knowledge structures evidencing facilitory rather than inhibitory effects—proving most useful when principles or associational connections are used to help people think about the application of experiential knowledge in new ways.

In considering these conclusions, however, it is important to bear in mind certain limitations of the present study. To begin, the present study was based on a “classic” experimental design. As a result, some caution is called for in generalizing these findings to other populations especially populations evidencing the very high levels of expertise that might promote the joint application of even incongruent knowledge structures. Along similar lines it should also be noted that all these effects were observed on one type of creative problem-solving task—specifically a social innovation problem. Although use of a social innovation problem was attractive in an initial study because there was reason to believe that solved social innovation problems can be solved using a variety of different knowledge structures (Scott, Lonergan, & Mumford, 2005), the question remains as to whether these findings can be extended to other domains (Baer, 2003).

It should be also borne in mind that the design applied in the present study was expressly intended to separate the effects of knowledge structure activation and activation strength. This was accomplished through a series of prompt questions presented in training and as people began work on the creative problem-solving task. Although this design is attractive with regard to control, and isolation of the unique effects of different combinations of knowledge structures, it is possible that knowledge structures might be applied in a somewhat different fashion in more naturalistic settings. In fact, future research intended to “tease-out” sequential and recursive interactions among different knowledge structures in real-world creative problem-solving efforts might prove of substantial value.

Finally, it should be recognized that we have, in the present study, examined the effects of only three types of knowledge structures on creative thought—schematic knowledge, associational knowledge, and case-based knowledge. Although schematic, associational, and case-based knowledge are all commonly considered integral to creative thought, it is also true that other forms of knowledge, for example visio-spatial knowledge (Radvansky, 1994), have been identified that might play a role in creative thought. Thus the question remains as to how these knowledge structures might act to influence idea generation and creative problem-solving in conjunction with schematic, associational, and case-based knowledge.

Even bearing these limitations in mind, however, we believe that the findings obtained in the present study have an important cautionary implication. Not only is caution called for in assuming that idea generation leads to creative problem-solving, caution is called for in the assumptions we make about how knowledge contributes to creative problem-solving. In fact, no one form of knowledge may prove sufficient for creative problem-solving. Instead, what creative thought may require is the use of multiple knowledge structures that allow people to apply their experience and expertise in new ways. Hopefully, the present study will provide an impetus for further research examining how people apply different forms of knowledge in creative problem-solving.

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