

# Effect of Problem Solving Support and Cognitive Styles on Idea Generation: Implications for Technology-Enhanced Learning

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## Abstract

*This study investigated the effect of two problem-solving techniques: (a) free-association with a direct reference to the problem, called shortly direct, and (b) free-association with a remote and postponed reference to the problem, called remote, on fluency and originality of ideas in solving ill-structured problems. The research design controlled for possible effects of cognitive style for problem-solving—adaptor versus innovator. The results showed that both groups significantly outscored a control group on fluency and originality. The remote group outperformed the direct and control groups on originality, but not on fluency. Innovators scored significantly better than adaptors in the control group on fluency, but not on originality. No significant difference was found between innovators and adaptors in both direct and remote groups. There was no statistical indication for an interaction effect between treatment and cognitive style. Based upon the results of this study, four implications for learning and instruction have been formulated for designing and developing technological arrangements for learning to solve ill-structured problems. These guidelines will support designers in developing instructional design solutions in educational technology applications. (Keywords: learning to solve problems, problem solving support, paradox of knowledge structure, cognitive styles, conceptual design.)*

Contemporary software design methodology and practice stress that problems in technological design are principally due to problems in the original conceptual design (Constantine, 2001; Holtzblatt, Wendell, & Wood, 2005; Kuniavsky, 2003). If something goes wrong in the conceptual design its negative effects on the next phases of the software development are multiplied. In business applications, this can result in lost capital. If it happens in educational applications, learners will lose interest and leave. The effectiveness of technological solutions that support learning depends heavily on the instructional design strategy implemented in the educational software applications used (Clark, 1994; Russell, 2001; Stoyanov & Kommers, 2006).

This article reports on research exploring the impact of different types of problem solving support and their interaction with learner cognitive style on idea generation in ill-structured problem situations. It is intended to generate basic instructional design guidelines for technology-enhanced learning.

Solving problems is considered an important competence of students in higher education (Ge & Land, 2004; Jonassen, 2004; Merrill, 2002; Van Merriënboer & Kirschner, 2007). It is a crucial task of higher education to help students to develop the knowledge, skills, and attitudes needed to deal with the challenges arising from rapid societal and technological changes. Instructional design, in recognition of this situation, is shifting from emphasis on well-struct-

tured learning tasks to ill-structured, real-world, authentic problems. According to Merrill (2002), involving learners in solving real-world problems is the first principle of instructional design.

The issue, however, is not only to engage higher education students in solving ill-structured problems but also to provide them with relevant support for learning how to solve ill-structured problems. Instructional design should determine the most effective and efficient conditions of providing both process and operational support to solving ill-structured problems. Most of the research on problem solving has been focused on process-support identifying the phases of problem solving process, the sequence of which a problem solver should follow (see Jonassen, 2004, for an overview). Less attention has been paid to operational and instrumental problem solving support, in terms of specific techniques and tools that facilitate problem-solving activities within these phases (Ge & Land, 2004; Stoyanov & Kommers, 2006). The knowledge that one should analyze the problem situation, generate ideas, select the most appropriate, and then implement and evaluate is necessary, but not sufficient. Skills of similar importance are needed for *how* to proceed in these problem-solving phases, such as what to do when analyzing the problem situation, how to generate ideas, how to select a solution and implement it in practice. The selection and application of these procedures, techniques, and tools depends to a large extent on the desired outcomes of problem-solving determined by the nature of ill-structured problems and the cognitive structures and processes involved in solving them. The first issue to address, therefore, is what the characteristics of ill-structured problems are and what cognitive mechanisms are activated in such problem situations.

### **Characteristics of Ill-Structured Problems**

Ill-structured problems are characterized by incomplete data or insufficient access to information, existence of alternative and often conflicting approaches, lack of clear-cut problem-solving procedure and no agreement upon what can be accepted as an appropriate solution (Jonassen, 2004; Schön, 1996; Wagner, 1992). Some researchers have challenged the position that ill-structured problems can, in principle, be represented as a set of well-defined problems (Cho & Jonassen, 2002; Hong, Jonassen, & McGee, 2003; Jonassen, 2004; Pretz, Naples, & Sternberg, 2003). These authors argue that different intellectual skills are needed for solving well-defined and ill-structured problems. In our view, ill-structured problems activate specific cognitive processes which may either enable or restrict problem solving.

### **Cognitive Conditions of Ill-Structured Problem Solving**

Most of the research on problem solving has referred to the limited capacity of short-term memory as the most important cognitive factor to deal with (Hambrick & Engle, 2003; Kirschner, 2002; Paas, Renkl, & Sweller, 2004). However, some classical and contemporary cognitive theories have emphasized the crucial role of long-term memory as well (Davidson, 2003; De Bono, 1990; Ericsson & Kintsch, 1995; Gick & Holyoak, 1983; Lubart & Mouchiroud,

2003; Wenke & Frensch, 2003). Long-term memory may be unlimited in terms of storing information, but in a situation of ill-structured problem solving it is the retrieval of relevant information that is critical. Most of the issues with long-term memory in ill-structured problem situations can be explained by a phenomenon we called it the *paradox of knowledge structure*.<sup>1</sup> This paradox states that the structure of knowledge both enables and restricts ill-structured problem solving. Knowledge organizes itself into knowledge structures (patterns, schemas), which are necessary for successful problem solving. These structures are easily recognizable, repeatable and give rise to expectancy. Knowledge structures provide a platform for interpreting incoming information and communicating new solutions. It is natural for an individual in a problem situation to bring his or her own experience to bear. Knowledge structures are familiar scaffolds that individuals tend to apply in problem situations. Often knowledge structures provide useful short cuts to the solutions.

Knowledge structures, however, have some characteristics that may hinder problem solving. A knowledge structure can establish a dominance, which forces the problem solver to see and follow only one path and not be aware of other possibilities (Anderson, 1983; De Bono, 1990; Qullian, 1988). Other spreading activation paths can be completely ignored, no matter how closely they are positioned to the dominant one. Once a knowledge structure presents itself, the tendency is for it to get larger and more firmly established. This makes it very difficult to break off and jump into an alternative line of reasoning. A well-established knowledge structure may inadequately represent a novel problem situation, thus reducing the problem situation to one that fits that knowledge structure. It is no longer the richness of situation that matters, but the presence or absence of a well-established structure (De Bono, 1990). Management of the restricting part of the paradox of knowledge structure requires a specific type of problem solving support that can cope with the negative effects of knowledge structure.

### **Problem Solving Support in Ill-Structured Situations**

Research on the role of the external instructional stimuli (e.g., cues, clues, hints, or prompts) in dealing with the negative effects of the paradox of knowledge structure returned inconsistent conclusions. Some authors have noticed the positive role of external cues on memory searching in problem-solving situations (Bower & Mann, 1992; Gick & Holyoak, 1983; Halpern, Hanson & Riefer, 1990; Jones, 1982; Paivio, 1986; Runco & Sakamoto, 2003), while others scholars have found that external cues disrupt people's normal search processes through long-term memory and inhibits the access to relevant knowledge structures (Raaijmakers & Shiffrin, 1981).

A number of studies have investigated the effect of different types of instructional cues and prompts on memory production (Ge & Land, 2004; Halpern, Hanson, & Riefer, 1990; Jones, 1982; Paivio, 1986). Paivio found that concrete

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<sup>1</sup> We adopted the term 'paradox of structure' from M. Kirton (2003).

cues lead to better memory performance than abstract cues. Jones's multiple-route approach promotes the idea that the existence of cues can support either a direct access to information or an indirect generation of possible answers. Ge and Land referred to the positive role of question prompts for scaffolding ill-structured problem solving. Giora (1993), studying analogical problem solving, argued that distance analogies impair the recall of facts and understanding of a text. Different results were reported in the study of Halpern, Hanson, and Riefer (1990) that showed that far-domain analogies are more effective than near-domain analogies for studying text. Holyoak (1991) found that when people are directed to relate two analogies, they often succeed in effectively using remote analogies.

Most of the studies on the role of instructional stimuli referred to were conducted in laboratory settings with artificial problem solving tasks. The current study applies problem solving techniques that follow the research tradition of the effect of direct vs. remote, abstract vs. concrete, and far-domain vs. near-domain stimuli on problem solving outcomes. It also makes use of problem-solving techniques that contain a set of actions for approaching real problems in a natural setting. The idea for using these techniques comes from historiometric, psychohistorical and psychobiographical types of inquiry, which analyze the rich creative problem solving experience of eminent personalities (Michalko, 1998; Simonton, 2003). This type of research derived principles, when properly applied, support the successful management of the paradox of knowledge structure. For the purposes of this study we developed two types of techniques: a free-association with a direct reference to the problem, and free-association with a remote and postponed reference to the problem. The free association supported by the *direct* technique is supposed to stimulate the flow of ideas and bypass the dominant knowledge patterns activated by the original problem definition. The *remote* technique is supposed to provoke divine inspiration, an activation of unusual avenues in the knowledge structure as the attention is initially directed to something not related to the problem. At a later stage, a forced relationship between the remote domain and the original problem definition is required. The first research question that this study investigates is this: What is the effect of *direct* and *remote* problem solving techniques on idea generation in an ill-structured problem-solving situation?

### **Cognitive Style as Moderating Variable for Problem Solving**

Research on problem solving has shown that there may be some sources of individual variation that moderate the effect of problem solving techniques on problem solving achievements. While some of these more *level* oriented types of cognitive constructs, such as knowledge and intelligence, have been studied extensively (see Sternberg & O'Hara, 2003; Weisberg, 2003; Wenke & Frensch, 2003, for an overview); others, such as cognitive *style*, which is a cognitive predisposition characteristic, has attracted less interest. It might be expected that cognitive style is an important individual dimension of knowledge structure as some people are assumed to be more committed to a particular knowledge structure than others. Some individuals more easily see the enabling part of a

knowledge structure, while others more easily notice the restricting part of a particular structure.

Research on problem-solving cognitive style has produced inconsistent findings. Cognitive styles have been found to moderate reactions to explicit problem solving support. Martinsen and Kaufmann (1991) studied the effect of four problem solving strategies (i.e. analyze and think verbally, analyze and think visually, explore and think verbally, and explore and think visually) and cognitive style assimilator vs. explorer on insight problems. They found that the exploratory strategy, either verbal or visual, was the most effective problem-solving approach. Some of their later studies confirmed that certain styles facilitate creative problem solving more than others (Martinsen, 1995; Martinsen & Kaufmann, 1999). The data also revealed an interaction effect as assimilators benefited from instruction to explore and visualize, while explorers benefited from the instruction to analyze and verbalize. Similar results were reported in another study where the intuitive style measured by Myers-Briggs Type Indicator (1962) and by a set of scenarios, was correlated positively with a range of creative tasks, while the sensing or logical style was not (Lubart & Sternberg, 1995; Raidl & Lubart, 2001). As a separate line of research, some scholars have made the conclusion that people without a strong preference to a particular style are the most creative performers (Guastello, Shisler, Driscoll, & Hide 1998; Meneely & Portillo, 2005; Noppe, 1996; Sternberg, 1994). The inconsistency of the data related to cognitive style can be attributed to the difference in definition of cognitive style: (a) either as a level-type construct (some styles are better than others), or (b) as a preference to approaching problems in a particular way.

An increasing number of research findings have empirically confirmed that cognitive style is conceptually independent from the level types of cognitive constructs such as knowledge and intelligence (see Kirton, 2003). Level and style measures, if pure, do not correlate at all. People performing on the same level can approach problems in different ways. Style preferences are value-neutral as each style can produce creative solutions. The research conducted by Kirton (2003) suggests that the problem-solving cognitive style should be distinguished from the problem solving process as at each stage; people can operate on different levels and can apply different styles. A distinction should also be made between preferred behaviour and observed behaviour. Sometimes, in order to cope with the requirements of a problem situation, people operate outside their preferred way, but it is always at the expense of more effort and time. The cognitive style theory of Kirton (2003) predicts that people can be positioned on a continuum from a more adaptive to a more innovative cognitive style. A more adaptive style tends to adhere to a particular structure—a theory, a rule, or a reference point—while a more innovative style tends to solve problems outside of a particular structure. A more adaptive style produces fewer solutions, but the solutions produced are more feasible, while a more innovative style tends to propose more and unusual, but more risky and often non-practical solutions. The fact that the Adaptor-Innovator cognitive style (Kirton, 1999) is defined according to the extent of adherence to a particular structure suggests

that it can be used in investigating the role of cognitive style in managing the paradox of knowledge structure.

To test the assumptions that emerged from the analysis of the problem-solving cognitive style, this study will explore two more research questions, namely:

What is the effect of problem-solving cognitive style on problem solving outcomes?

Is there an interaction effect between type of problem-solving support (direct vs. remote techniques) and cognitive style (innovator vs. adaptor)?

In order to answer the research questions related to assumed effects of problem-solving support and cognitive style on problem-solving achievements, an experimental situation is arranged. It includes two types of treatments—direct technique, and remote technique—and two cognitive styles—innovator and adaptor. Further details are provided in the following section.

## **METHOD**

### **Research Design**

The research design of the study consists of two experimental and one control group with a post-test measurement. The three groups have to provide solutions to a change-management problem in higher education. The independent variable is problem solving techniques with two levels—direct and remote. The direct technique involves specific instruction that supports idea generation by applying the following brainstorming rules: criticism is postponed; free-wheeling is encouraged; quantity is preferred; and combination and improvement are required. The remote technique is an instruction that supports idea generation by applying forced relationships between the problem to be solved and unrelated to the problem personal experience. The experimental design controls for a possible effect of problem solving cognitive style. The cognitive style variable is operationalised through the scores on Adaptor-Innovator Inventory—KAI (Kirton, 1999). The dependent variable is idea generation production, which is analysed in terms of creative fluency and originality. Fluency, following the tradition established by research on creativity, is defined as the number of ideas produced (Runco & Sakamoto, 2003). Originality is an experts' judgment of the extent on a five-point scale to which an idea has a potential to contribute to changing the current situations of higher education significantly.

### **Participants**

The participants in this study were selected from the members of a students' organization operating at faculty level and representing different departments. Fifty-seven of these students were actively involved in a debate that lasted for several months on "How can we make our university a top university?" They were invited to participate in the study by e-mail, signed by the leaders of the organization. The students received information about the purpose of the study (comparing the effectiveness of different problem solving techniques), but they did not know what the problem was going to be. Thirty-four students agreed to take part in the study; 19 of them were third-year students, and 15 were fourth-year students.

In the study, students were asked to provide solutions to the same subject of the debate, presented as a small case. A teacher, who the students knew well, led the experimental session. He got instructions before the session from the researchers who themselves were not present during the experiment, but who met with them after the study to give feedback on cognitive styles for problem solving; one of the incentives to motivate students to participate.

### **Instruments**

The study uses two types of measurement instruments. Cognitive style for problem solving is measured by Kirton's Adaptor-Innovator Inventory (1999)—KAI. This instrument consists of 32 items, each scored on a scale from 1 to 5. It identifies the problem solving style of people by locating them on a continuum with an observed range of the general population running from 40 to 150 and having a mean value of 95. The instrument scores very high on various reliability and validity criteria (Kirton, 2003). The value of internal reliability is .87. The construct validity of the instrument has been proved, as it is highly correlated with other stylistic measures and has a very low correlation with measures of cognitive capacity and competencies. KAI established general population norms across ten countries and specific norms for particular occupational groups. The results from each general population sample are normally distributed.

The second instrument is a short questionnaire to identify differences between groups, if any, in terms of experience with such techniques, difficulties with the topic, conditions during the experiment, anxiety, and time available. The participants had to position their reflection on a scale from 1 to 5.

The fluency of idea generation is measured as the total number of ideas an individual has produced. Originality is an expert judgment on the quality of ideas; that is, it is the potential of the ideas to bring about change the current situation of higher education. Some examples of original ideas are "Make sure that the name of the university appears in American teenagers' animation movies;" "University goes to the stock-exchange;" "Introduce entry exams;" "Every student is a shareholder;" "University organizes a sort of 'Oscar' nominations every year for the best learning achievement;" "Organize a scientific road show;" and "Give money for excellent achievement, and let students pay for low achievement." The expert judgment procedure follows the Consensual Assessment Technique (Amabile, 1996; see also Meneely & Portillo, 2005). The interrater reliability of a panel of four experts reached the value of .82, which is well above the acceptable level of .70.

### **Data Analysis**

The basic data analysis technique is one-way, between-groups multivariate analysis of covariance (MANCOVA) so as to the treatment effect on more than one dependent variable and control for a possible effect of a continuous variable, such as cognitive style. Checks for reliability of covariates, normality, multicollinearity, homogeneity of variance, and homogeneity of regression were conducted. The data analysis compares the means of groups to determine whether they are different in terms of experience with the similar techniques,

topic of the assignment, time given, anxiety and experimental conditions. The analysis further transforms the continuous variable into categorical variables to test for a possible interaction effect and post-hoc analysis of the treatment effect.

## RESULTS

The study first checks the assumptions of MANCOVA related to reliability of covariates, normality, multicollinearity, homogeneity of variance, and homogeneity of regression. All forms of the preliminary analysis indicate that the data are safe to be tested for significance and further interpretation.

### Significance test analysis

The analysis that follows tries to determine whether the groups are equal in terms of variance of some variables that may affect the results: experience with similar treatment, topic, distraction effect of the experimental circumstances, anxiety, and time to complete the task. An ANOVA analysis shows that there is not significant differences between groups related to these indicators: experience ( $F(2, 31) = 787, p = .464$ ); subject ( $F(2, 31) = 545, p = .585$ ); circumstances ( $F(2, 31) = 256, p = .776$ ); anxious ( $F(2, 31) = 1.032, p = .368$ ); and time ( $F(2, 31) = 355, p = .704$ ).

The second type of significance analysis is to indicate whether there are statistically significant differences between the three groups on a linear combination of fluency and originality. A one-way, between groups multivariate analysis of covariance was performed to investigate the effect of type of problem solving support and cognitive style on idea generation. A significant difference in the effect of either *group* or *cognitive style* on the combined dependent variable of fluency and originality is found. The value of Wilk's Lambda for group factor is  $F(2, 29) = 5.589, p = .001$ . Style's Wilk's Lambda is  $F(4, 58) = 5.143, p = .012$ . The value of partial eta squared is .278 for the group factor and .262 for the style factor. The figures for both factors represent a large effect size, according to generally accepted criteria (Cohen, 1988; Pallant, 2005; Tabachnick & Fidell, 2001).

A between-subjects test reveals a different picture of the effects of group and style when fluency and originality are considered separately. The group factor keeps the significance level for both fluency  $F(2, 30) = 4.464, p = .020$ , partial eta squared of .229 (large effect size) and originality  $F(2, 30) = 7.760, p = .002$ , partial eta squared of .341 (large effect size), using a Bonferroni adjusted alpha level of .025. Style reaches a significant level on fluency ( $F(1, 30) = 7.011, p = .013$ ), partial eta squared of .189 (large effect size), but not on originality ( $F(1, 30) = 3.840, p = .059$ ), partial eta squared of .113 (moderate size effect). Table 1 presents means and standard deviation figures of the effect of group factor on fluency and originality.

An inspection of the mean scores indicates differences between the direct group ( $M=18, SD = 6$ ), remote group ( $M = 17, SD=4$ ) and the control group ( $M = 13, SD = 7$ ) on fluency. The groups differ also on originality—remote group ( $M = 3, SD=0.5$ ), control group ( $M = 2, SD = 0.4$ ), and direct group ( $M = 2, SD = 0.4$ ). Further a follow-up analysis is needed to determine whether

**Table 1: Mean and Standard Deviation Figures of Group on Fluency and Originality**

Criteria	Group	M	SD
Fluency	Control	13.2	6.87
	Direct	18.1	6.22
	Remote	16.9	4.4
Originality	Control	2.1	0.37
	Direct	2	0.37
	Remote	2.6	0.46

*N* = 34

**Table 2: Means Values of Group and Style Factors on Fluency and Originality**

Criteria	Group	Style	M	SD
Fluency	Control	Adaptor	9.4	4.87
		Innovator	15.1	7.14
	Direct	Adaptor	17.6	7.16
		Innovator	19	5.56
	Remote	Adaptor	16.8	2.92
		Innovator	17	5.95
Originality	Control	Adaptor	2.1	0.25
		Innovator	2	0.43
	Direct	Adaptor	2	0.41
		Innovator	2.1	0.35
	Remote	Adaptor	2.4	0.23
		Innovator	2.9	0.56

*N* = 34

these differences are significant. In addition we want to explore the contribution of cognitive styles on fluency and originality scores. The score on Kirton's Adaption-Innovation defines people as more adaptive or more innovative as comparing them to a particular references point—an individual score, or a group's mean score. In a group supposed to follow a particular problem solving support, KAI divides group's members as more adaptive or more innovative. For the purposes of this analysis, we transformed the continuous variable of problem solving style into two categorical variables: adaptor and innovator on the basis of a mean of  $M = 103$ . Students with a higher score are defined as innovators; those with a lower score are defined as adaptors.

Post-hoc comparisons using the Tukey HSD test indicate that the mean score of the remote group ( $M = 3$ ,  $SD = 0.5$ ) on originality is significantly different from either the direct group ( $M = 2$ ,  $SD = 0.4$ ),  $p = .018$ , or the control group ( $M = 2$ ,  $SD = 0.3$ ),  $p = .009$ . No significant difference is found in the mean scores of the three groups on fluency. Table 2 (page 57) shows the mean values of group and style type on fluency and originality.

The interaction effect of the group treatments and two levels cognitive style do not reach statistically significant difference for either fluency ( $F(2, 28) = .704$ ,  $p = .503$ ), or originality ( $F(2, 28) = 1.224$ ,  $p = .309$ ).

## DISCUSSION

The analysis of the data revealed that both types of problem solving support (direct and remote) and cognitive style (innovators and adaptors) are important determinants of ill-structured problem solving and should be taken into account when designing instruction aimed at promoting learning to solve such problems. When different treatments are compared, it is the remote type of support that yields the highest scores on originality of ideas. Mapping one domain of experience on to another, contributes the most to breaking dominant thinking patterns. This result is consistent with the findings of studies investigating the effect of abstract and concrete cues on memory processes (Paivio, 1986) and the role of far and near analogies for learning (Halpern, Hanson, & Riefer, 1990; see also Robertson, 2001). Paivio found that concrete cues lead to better memory performance than abstract cues, because concrete cues are higher in their image evoking value. Concrete cues are encoded using both imagery and verbal codes, while abstract cues use only a verbal code. The remote technique in the current study, although not directly related to the problem to be solved, is concrete, referring to well known and even emotionally-coloured personal experience. The outcomes of the current study are also in accordance with the position of Halpern, Hanson, and Riefer (1990) who argue that analogies from more distance domains are more likely to enhance understanding of the problem than those from more close domains.

Another conclusion is related to the role of hints in constructing and applying a remote analogy. We applied a force-relationship stimulus to bring together the domain of the problem to be solved (target) and the experience of participants with another domain (base). The approach is similar to one of the experimental conditions in a study of Gick and Holyoak (1983) where the experimental subjects were able to notice an analogy only if they were given a hint. The current research followed a production rather than reception stimuli arrangement in the analogical problem solving. Once the hint was given, the participants were encouraged to work out their own analogy. The reception arrangement is assumed to restrict the search for structural relationships and to bring an artificial analogical reasoning.

With respect to quantity of ideas produced, it was the direct group that scored the highest. However the quantity of ideas does not necessarily mean that the ideas are more original. Quantity does not always lead to quality—a result of this study that is not in line with some of the suggestions coming from the literature on creative problem solving (Michalko, 1998; Van Gundy, 1997).

This study indicates that the most effective way of managing the restricting part of the paradox of knowledge structure is through problem-solving support that explicitly suggests first referring to a domain that is different from the original problem before the requirement for connecting two domains. The data confirmed the assumptions that both innovators and adaptors are capable of generating creative solutions, but that they do so in different manners (Kirton, 2003). Although innovators produce more ideas, they are not more creative than adaptors; adaptors arrive at creative solutions on the basis of a few ideas. Adaptors and innovators have preferences for different types of problem solving support. Innovators can more easily map different domains for the purposes of a problem solving. Adaptors are more prone to idea generation within the conceptual borders given by a problem definition. Both styles, however, are able to manage unfavourable types of support for a short period of time. To do this they apply the mechanism of coping behaviour, a type of behaviour forced by circumstances, which is outside of the style preferences (Kirton). Coping behaviour is a strong explanatory mechanism of the lack of significant difference in the performance of different styles on originality when supported by different problem solving techniques.

Based upon the results of this study, four implications have been formulated for designing and developing technological arrangements for learning to solve ill-structured problems.

1. If the goal is to have students learn to solve ill-structured problems, then involve them in real-life, authentic situations.
2. If the goal is to have students learn how to solve ill-structured problems, then provide them with both domain-specific knowledge and skills and domain generic knowledge and skills in terms of specific techniques for analysis of problem situation, generation of ideas, selection of ideas, and implementation of ideas in practice.
3. If the goal is to have the student generate more creative solutions to a problem, then the most effective problem solving techniques are those based on a remote and postponed reference to the problem. Examples of such techniques include taking on different roles, creating picture portfolios, and generating multiple perspectives (see Michalko, 1998).
4. If students are involved in exploratory social constructivist learning, they face two major difficulties. The first relates to the fact that the problems are ill-structured which require the student to integrate domain-specific knowledge and generic knowledge and skills. The second difficulty relates to the cognitive style of the student. If a software application is involved, it should include guidelines how to manage the diversity of cognitive styles.

We have defined three lines of research for further elaboration on the ideas developed in the current study. The study focused on the idea generation phase. We believe that this is the stage of the problem-solving process where the paradox of knowledge structure can be most clearly demonstrated. Problem-solving support is also needed for the other stages of the problem solving process. The crucial question is: How do we know whether to explore the enabling or limit-

ing part of the paradox of knowledge structure in a problem situation? This has to do very much with the problem-solving phase of analysing the problem situation where the first task is to identify different knowledge structures. Probably different techniques should be applied in each problem-solving stage.

Another line of future research is to investigate the effects of two types of instructional arrangements on problem-solving performance: preference-match to type of instruction and compensation-match to type of instruction. The idea behind the preference match is an instruction that supports the strengths of a particular cognitive style. This is what people would like to do and feel comfortable with. The compensation match assumes that it is important to support remediation of the weaknesses of a particular style, encouraging individuals to use an instruction that is in opposition to their preferred style, because this is what they need.

A third and final line of future research could be on the group aspects of the relationship between group composition based on problem solving styles (homogeneous vs. heterogeneous), type of problem and type of problem solving support.

### Contributors

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