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Metacognitive knowledge about problem-solving methods

Alessandro Antonietti*, **Sabrina Ignazi** and **Patrizia Perego**

Department of Psychology, Catholic University of Sacred Heart, Milan, Italy

Background. The effective application of a problem-solving method requires the knowledge of what task is relevant, what the abilities involved are and how much effort is needed. However, as yet too little is known about these metacognitive representations.

Aim. This study was aimed at describing beliefs about problem-solving methods and at assessing whether they vary according to the kind of method and of problem and are modified by psychological courses attended.

Sample. Forty-six Italian undergraduates in psychology and 37 in non-psychological disciplines.

Methods. Participants had to rate how frequently each of five problem-solving methods (free production, analogy, step-by-step analysis, visualisation and combining) is employed and how effective and easy each one is to apply. Ratings were requested for interpersonal, practical and study problems. Participants were also asked to identify which abilities they thought would be involved in each method.

Results. According to students' ratings, the most frequently used problem-solving method was analogy, which was also considered the easiest method to apply, whereas step-by-step analysis and combining were considered the most difficult. Problem-solving techniques were perceived as being relevant above all for practical problems, whereas they were conceived as less suitable for interpersonal problems. For study problems the most relevant strategy was step-by-step analysis. Students were aware of the abilities relevant to each problem-solving method.

Conclusions. Undergraduates both in psychology and non-psychological disciplines can identify some critical features in the methods used to solve problems, even though some misconceptions emerged. Since metacognition plays a causal role in problem-solving, trainers should take into account trainees' folk representations of problem-solving strategies.

A variety of methods have been devised in order to help people to solve problems (Anderson, 1980; Isaksen & Treffinger, 1985; Rubinstein & Pfeiffer, 1980; Whimbey &

*Requests for reprints should be addressed to Professor Alessandro Antonietti, Department of Psychology, Catholic University of Sacred Heart, Largo A. Gemelli 1, 20123 Milano, Italy

Lockhead, 1991). Such a variety depends on the fact that these techniques have been designed for different kinds of learners (children, adolescents or adults) with different levels of mastery (novices or experts). Furthermore, general problem-solving methods differ with respect to their field of application and with respect to the context in which they are taught (school, administration, business, organisation, research centres and so on). A third aspect which differentiates such methods is the theoretical framework which underlies them. As far as the last aspect is concerned, five main perspectives can be identified.

For some authors the solution to a new problem is favoured by a process in which a wide range of ideas are produced. The greater the quantity of ideas, the greater the likelihood that at least one of them is good. Thus, in this perspective fluidity of thinking (Guilford, 1986), generation of mental elements (Johnson-Laird, 1993) and the continuous search for new ideas (Weisberg, 1993) are essential to problem-solving. For instance, Johnson-Laird (1993) claimed that creativity involves a multistage process in which a generative phase, where ideas are formed randomly or under the guidance of some criteria, is followed by a selection phase during which ideas are judged. Consequently, individuals should be induced to search and to yield freely as many ideas as possible and to postpone evaluation. Brainstorming (Osborn, 1953) can be considered as the prototype of problem-solving methods grounded on these assumptions. The goal of brainstorming is to produce the largest number of possible solutions to a problem. Problem-solvers are encouraged to think up wild, unusual, imaginative ideas, no matter how silly they seem.

In the second perspective, the solution of a problem can result from attempts to combine the elements of the problem in different ways. For example, Simonton (1984) argued that the basic units of the creative process, which he called 'mental elements', must be free to enter into various combinations; therefore, chance permutation of the elements is regarded as the core mechanism of creative problem-solving. Methods inspired by these theories are, for instance, morphological analysis (Zwicky, 1969) or forced relations (De Bono, 1976). In these cases persons are trained to relate the critical elements of the situation systematically to each other and to consider which suggestions rise from such links.

A particular kind of linkage is analogy. Analogy consists in finding correspondences between two or more situations in different domains. By means of analogies persons can transfer the solution principles embedded in a situation successfully faced in the past to a novel problem (Vosniadou & Ortony, 1989). The more remote the related domains, the more creative the result is (Mednick, 1962). Synectics (Gordon, 1961) is a method which is representative of this third conception of problem-solving. According to synectics, in fact, people are encourage to find similarities between the current problem and other domains: this should prompt the application of previous solutions to the new situation.

In the fourth perspective problem-solving is considered as a process which leads to restructuring the situation at hand. According to Gestalt psychologists (Wertheimer, 1959), productive solutions are reached through insight. This occurs when subjects consider the whole problem, understand its essential features and try to see it from a different point of view. Problem-solving is conceptualised as analogous to perceptual reorganisation. Thus, according to this framework, visualisation seems to be the most

relevant strategy for restructuring problems. Individuals who represent problems in pictures or through mental images are facilitated in considering all the elements of the problem simultaneously, in schematising the structure of the problem and in changing the perspective. Experimental findings support the notion that instructions to visualise help subjects to restructure problems (Antonietti, 1991).

Finally, the solution process is conceived as the application of a series of operators which allow transformation of the initial state of the problem into the goal state. Specific strategies have been proposed to help people in selecting operators to be applied (Hayes, 1981). For instance, means-end analysis suggests choosing the operator that produces the greatest decrease, in comparison with the other operators available, in the distance between the current state and the goal state; in this manner, the problem solver will move closer and closer to the solution. Hill-climbing, subgoaling, backward search are other heuristical strategies underlying, as means-end analysis, the assumption that the solution of a problem is achieved by following a path constituted by a sequence of phases, each of them gradually leading the subject nearer and nearer to the endpoint. This can be reached if individuals can plan their behaviour in order to apply systematically the best sequence of operators (Wickelgren, 1974).

Since these different kinds of methods involve specific sets of mental operations, a distinct pattern of skills is requested by each of them. So, it is important that individuals are aware of this in order to apply the abilities relevant to the technique which they have decided to employ. Furthermore, if a person is aware of the capacities and of the styles of thinking involved in each problem-solving strategy, he or she can choose the method which is more in tune with his or her aptitudes and preferences or tendencies. Besides a correspondence to the personal cognitive profile, selection of the problem-solving procedure to be applied also depends on the features of the situation to be faced. In fact, some techniques are more suitable for well-defined, unique-solution problems, whereas other techniques are more suitable for ill-defined, open-ended problems; some techniques fit intellectual problems better while other techniques fit related practical or interpersonal problems better. Therefore, it is important to choose the kind of strategy which is effective for the specific kind of problem to be solved. Finally, the effort and the degree of difficulty in learning and in applying problem-solving strategies vary according to the kind of the method at hand. Predictions about these aspects can help persons to adopt relevant attitudes and behaviour. In sum, metacognitive competences seem to be required to use problem-solving techniques successfully.

Metacognition concerns, besides control over thinking processes, awareness of various aspects of mental work. More precisely, metacognition includes beliefs and knowledge about the strategies which can be used to carry out a task – when a strategy may be useful, what skills the strategy requires, how much time must be spent in applying the strategy, what obstacles may be encountered, what benefits may be derived and so on – and self-evaluation about one's aptitude, promptness and habits to adopt such strategies. For example, according to Sternberg (1986), the following metacognitive components are involved in problem-solving: a) deciding upon the nature of the problem to be faced; b) selecting components or steps needed to solve the problem; c) selecting the strategy for ordering the components of problem-solving; d) selecting a mental representation for information; e) allocating resources; f) monitoring

solutions. This structure of metacognition in problem-solving has been validated via factor analysis (Allen & Armour-Thomas, 1993).

Experimental evidence supports the notion that high metacognitive levels are associated with best performance in problem-solving. For instance, Swanson (1990) found that high metacognitive students outperformed lower metacognitive students in problem-solving regardless of their overall aptitude level and that metacognitive knowledge enables lower aptitude individuals to perform like their high aptitude counterparts. More precisely, the correlation between metacognition and problem-solving was high in ungifted rather than in gifted students (Swanson, 1992). This supports the idea that metacognition is useful for individuals who can not spontaneously activate cognitive resources that help them in solving problems and so have to learn effective strategies to face problems. Also in learning disabled students metacognition was found to be independent from cognition and an association between good metacognitive levels and problem-solving emerged (Slife, Weiss, & Bell, 1985).

Data supporting a positive correlation between metacognition and problem-solving were reported also in adults. More precisely, Huet, Mariné, and Escribe (1994) found that in a seriation task participants who were not able to predict in advance their performance in the subsequent problem-solving trials failed to carry out the task correctly; in contrast, participants who succeeded in estimating their ability in solving such a task reached the solution, adopted the most effective strategies, changed the solution procedure during the task (this was considered a hallmark of good behaviour) and gave, at the end of the problem-solving task, a subjective evaluation of their response which corresponded to the actual outcome. In general, it has been maintained that metacognition plays several roles in creative problem-solving (Armbruster, 1989). According to these suggestions, various methods to train skills useful to solving problems are deeply grounded on metacognition (Schoenfeld, 1985; Sternberg, 1986).

As yet too little is known about people's beliefs concerning the strategies that can be employed to solve problems. As discussed earlier, different methods are available to face problems and each of them matches specific individual cognitive profiles, tendencies and habits, involves specific abilities, requires different times and degrees of effort in learning, and success depends on the kind of problem the method is applied to. Are persons aware of this? What do they think about their own promptness to use each method, its efficacy, the facility with which it is learned and the capacities involved in its application? The aim of the present study was to answer these questions. More precisely, we were interested in:

(i) realising which problem-solving techniques are considered the most and the least useful, easy to apply and frequently employed;
(ii) verifying whether people can differentiate their opinions about the use, the efficacy and the possibility to apply problem-solving methods according to the kind of problem involved;
(iii) assessing whether persons are able to identify which mental abilities are associated to the application of each problem-solving strategy;
(iv) considering whether metacognitive beliefs about the frequency, usefulness and application of the problem-solving techniques and about the capacities which

they require are influenced by psychological courses attended by individuals. As far as this issue is concerned, the hypothesis was not that training in problem-solving or courses specifically focused on problem-solving techniques modify the representation of the problem-solving methods (this seems to be obvious); rather, we conjectured that basic psychology courses – where problem-solving strategies had never been treated – led students to develop general metacognitive attitudes and to enhance awareness of some aspects of their own mental activities which should result in more adequate opinions about problem-solving strategies as compared to students who did not attend such courses.

Method

Sample

A questionnaire was administered to 83 undergraduates in different disciplines (19 males and 64 females) attending the Catholic University in Milan, Italy. They ranged in age between 19 and 29 years (mean age = 22.14 years, SD = 2.32). Participants were divided into two subgroups according to the faculty attended: psychology (46 students) and non-psychological disciplines (humanities, law, economics). Psychology students were recruited in first and second year courses, where they dealt only with general psychological topics. None of them had followed courses specifically focused on problem-solving methods or, more in general, on mental practice, creativity, reasoning training, programmes aimed at enhancing cognitive skills and so forth. Because of some missing data, subsequent analyses were carried out considering samples constituted by a number of individuals varying from 78 to 82.

Material

We devised a questionnaire constituted by a six-page booklet (see Appendix). On the first page a general introduction to the task was offered and instructions to fill out the questionnaire were given. On the subsequent pages short descriptions of the five problem-solving strategies (free production, analogy, step-by-step analysis, visualisation and combining) were reported. On each page the essential features of a strategy were highlighted. Participants were asked to rate on a 5-point scale (i) how frequently they used such a strategy (*frequency score*), (ii) how effective that strategy was (*efficacy score*) and (iii) how easy the application of the strategy was (*facility score*). Frequency, efficacy and facility ratings were requested for each of three kinds of problems: interpersonal, practical and study problems. Eight mental abilities were listed at the bottom of each page: students were asked to check the ability/abilities that they thought to be required in order to apply the strategy successfully. These abilities were the most frequently mentioned in a pilot study in which 10 psychologists were asked to list capacities required, in their opinion, to apply problem-solving techniques. The inspection of the list shows that one or more abilities can be associated – on the basis of what is reported in the Introduction about the five categories of problem-solving methods – to each technique considered in the questionnaire. For instance, creativity is crucial for free production, memory of past experience for analogy, synthesis for visualisation, logical reasoning for combining, analysis and accuracy for the step-by-step strategy.

Procedure

Undergraduates were contacted in the university campus during their leisure time. They were asked to volunteer in the study by filling out a questionnaire. The questionnaire was anonymous and there were no time limits.

Results

Scores concerning each strategy and each type of problem were analysed according to a 5 × 3 ANOVA model. Both factors were within-subject factors. Analyses were carried out separately for each kind of score (frequency, efficacy and facility).

Table 1. Mean frequency scores (standard deviations in parentheses) of each strategy in each kind of problem

Kind of problem	Strategy					
	Free production	Analogy	Step-by-step	Visualisation	Combining	Total
Interpersonal	2.49 (1.19)	3.20 (1.15)	1.95 (1.05)	2.94 (1.43)	2.06 (0.85)	2.53 (1.13)
Practical	2.49 (1.10)	3.66 (0.81)	3.25 (1.04)	2.99 (1.18)	2.72 (0.90)	3.02 (1.01)
Study	2.16 (1.14)	3.19 (1.06)	3.63 (1.10)	2.96 (1.23)	2.38 (1.00)	2.86 (1.11)
Total	2.38 (1.14)	3.35 (1.01)	2.94 (1.06)	2.96 (1.28)	2.38 (0.92)	

Mean values of the frequency scores (see Table 1) related to the five strategies were significantly different ($F(4,312) = 27.03, p < .001$). Analogy was the most frequently used problem-solving strategy; free production and combining were the least employed procedures. Also differences among the mean scores recorded under the three kinds of problems reached significance ($F(2,156) = 27.07, p < .001$). Participants reported the highest rates of strategy use in practical problems and the lowest in interpersonal problems. A significant interaction between the two main effects emerged ($F(8, 624) = 17.81, p < .001$). The step-by-step analysis was the strategy whose frequency varied most according to the kind of problem: it was often used in study problems and seldom used in interpersonal problems.

Efficacy rating (see Table 2) was significantly affected both by the kind of strategy ($F(4,308) = 27.66, p < .001$) and the kind of problem ($F(2,154) = 43.7, p < .001$). Analogy and step-by-step analysis were maintained to be the most effective methods. Problem-solving techniques were considered productive above all in practical problems; interpersonal problems seemed to benefit less by the application of problem-solving strategies. The interaction effect was significant ($F(8,616) = 16.63, p < .001$). Efficacy of free production was rated low in study and practical problems whereas step-by-step analysis and combining were rated low in interpersonal problems.

Table 2. Mean efficacy scores (standard deviations in parentheses) of each strategy in each kind of problem

Kind of problem	Strategy					
	Free production	Analogy	Step-by-step	Visualisation	Combining	Total
Interpersonal	2.82 (1.03)	3.15 (1.14)	2.23 (1.00)	2.56 (1.19)	2.33 (0.86)	2.62 (1.04)
Practical	2.63 (1.01)	3.76 (0.72)	3.73 (0.86)	3.10 (0.99)	2.86 (0.83)	3.22 (0.88)
Study	2.36 (1.13)	3.33 (1.10)	3.86 (1.04)	3.08 (1.08)	2.60 (1.22)	3.05 (1.11)
Total	2.60 (1.06)	3.41 (0.99)	3.27 (0.97)	2.91 (1.09)	2.60 (0.97)	

For interpersonal problems free production and analogy were considered the most useful methods; analogy was estimated to be highly effective in practical problems whereas step-by-step analysis was noted high in study problems.

Table 3. Mean facility scores (standard deviations in parentheses) of each strategy in each kind of problem

Kind of problem	Strategy					
	Free production	Analogy	Step-by-step	Visualisation	Combining	Total
Interpersonal	2.79 (1.21)	2.86 (0.95)	2.14 (0.96)	2.79 (1.22)	2.10 (0.78)	2.54 (1.02)
Practical	2.83 (1.10)	3.38 (0.65)	2.72 (0.88)	2.92 (0.86)	2.73 (0.73)	2.92 (0.84)
Study	2.64 (1.51)	2.86 (0.85)	2.81 (0.79)	2.54 (0.85)	2.41 (0.80)	2.65 (0.96)
Total	2.76 (1.27)	3.03 (0.82)	2.56 (0.88)	2.75 (0.98)	2.41 (0.77)	

Finally, as far as facility scores were concerned (see Table 3), both the effects due to the kind of strategy ($F(4, 308) = 9.33, p < .001$) and to the kind of problem ($F(2,154) = 19.16, p < .001$) and the interaction effect ($F(8,616) = 7.07, p < .001$) were significant. Analogy was evaluated easy to apply whereas combining and step-by-step analysis were evaluated difficult. Problem-solving strategies obtained the highest facility score in practical problems. The lowest rates were recorded for the combining and step-by-step strategies in interpersonal problems; these findings parallel with what occurred in the efficacy scores.

Table 4. Correlations between frequency, efficacy and facility scores for each strategy and kind of problem

	Frequency-Efficacy	Frequency-Facility	Efficacy-Facility
Free production			
Interpersonal problems	.56***	.43***	.08
Practical problems	.43***	.19*	.11
Study problems	.70***	.23*	.25*
Analogy			
Interpersonal problems	.72***	.30**	.22*
Practical problems	.27**	.51***	.04
Study problems	.72***	.37***	.37***
Step-by-step			
Interpersonal problems	.60***	.12	−.07
Practical problems	.56***	.47***	.38***
Study problems	.48***	.64***	.38***
Visualisation			
Interpersonal problems	.59***	.50***	.19*
Practical problems	.57***	.53***	.39***
Study problems	.76***	.40***	.56***
Combining			
Interpersonal problems	.69***	.31**	.29**
Practical problems	.59***	.41***	.33**
Study problems	.63***	.14	.13

* $p < .05$ ** $p < .01$ *** $p < .001$

Table 4 shows correlations (Pearson's r coefficients) between the frequency, the efficacy and the facility scores for each method in each kind of problem. Frequency and efficacy ratings were highly correlated with each other, whereas correlations were weaker for the frequency-facility and the efficacy-facility relationships. Presumably individuals tend to apply strategies which they perceive as useful, even though such strategies are not easy to apply.

Responses concerning the abilities involved in each strategy were scored as follows: score 1 was assigned to each of the abilities checked by the participant and score 0 was attributed to each of the abilities which were not checked. Mean scores for each ability involved in each strategy are reported in Table 5. The application of a 8 (kind of ability) × 5 (kind of problem) ANOVA model showed that scores were significantly influenced by the two factors (respectively, $F(7,560) = 26.33, p < .001$; $F(4,320) = 6.22, p < .001$) and by the interaction between them ($F(28,2240) = 2.94$, $p < .001$). In students' opinion, speed, accuracy and memory are marginally involved in problem-solving strategies. Step-by-step analysis appeared to be the method which requires the highest mean number of abilities. Free production was associated with the highest involvement of creativity as compared to the other strategies and, together with analogy, with the lowest involvement of accuracy. Memory, which in the other cases always obtained low scores, was rated very high in analogy; for this strategy memory was considered the basic capacity, while speed the least relevant. The main ability for the step-by-step method was analysis; accuracy, in contrast with what occurred in the other strategies,

Table 5. Mean scores (standard deviations in parentheses) concerning the abilities involved in each strategy

Strategy	Ability								
	Creativity	Speed	Synthesis	Critical thinking	Accuracy	Memory	Analysis	Logical reasoning	Total
Free production	0.88	0.26	0.40	0.56	0.07	0.17	0.30	0.33	0.37
	(0.33)	(0.44)	(0.45)	(0.50)	(0.26)	(0.38)	(0.46)	(0.47)	(0.41)
Analogy	0.10	0.06	0.38	0.57	0.07	0.81	0.49	0.52	0.38
	(0.30)	(0.24)	(0.49)	(0.50)	(0.26)	(0.39)	(0.50)	(0.50)	(0.40)
Step-by-step	0.04	0.18	0.62	0.60	0.69	0.12	0.75	0.57	0.45
	(0.19)	(0.39)	(0.49)	(0.49)	(0.46)	(0.33)	(0.43)	(0.50)	(0.41)
Visualisation	0.69	0.21	0.48	0.36	0.20	0.10	0.44	0.46	0.37
	(0.46)	(0.41)	(0.50)	(0.48)	(0.40)	(0.30)	(0.50)	(0.50)	(0.45)
Combining	0.58	0.25	0.52	0.37	0.18	0.18	0.43	0.65	0.40
	(0.50)	(0.43)	(0.50)	(0.49)	(0.39)	(0.39)	(0.50)	(0.48)	(0.46)
Total	0.46	0.19	0.48	0.49	0.24	0.28	0.48	0.51	
	(0.36)	(0.38)	(0.48)	(0.49)	(0.36)	(0.36)	(0.48)	(0.49)	

was considered important. In visualisation the highest value recorded concerned creativity. Logical reasoning was considered the most relevant capacity to combining.

The influence of the kind of courses attended by participants on frequency, efficacy and facility scores was assessed by MANOVAs which were carried out by assuming the faculty (psychology and non-psychology) as an independent variable and the nine ratings requested for each strategy (frequency, efficacy and facility scores for each kind – interpersonal, practical and study – of problems) as dependent variables. Significant principal effects emerged only in the analogy ($F(9,71) = 2.07$, $p < .05$) and in the combining strategy ($F(9,70) = 2.46$, $p < .05$). Similar analyses were carried out by considering the eight scores concerning the abilities involved in each strategy as dependent variables. Significant effects resulted in the analogy ($F(8,73) = 3.19$, $p < .005$) and in the visualisation ($F(8,71) = 2.95$, $p < .01$) strategy. Univariate analyses showed that significant differences between psychology and non-psychology students emerged only in 10 out of 85 cases.

More precisely, as far as the analogy strategy was concerned, it was estimated to be used more frequently by the psychology students than the other ones both in interpersonal (respectively, mean = 3.45, SD = 0.97; mean = 2.88, SD = 1.25; ($F(1,79) = 5.28$, $p < .05$) and in practical problems (respectively mean = 3.87, SD = 0.69; mean = 3.34, SD = 0.91; ($F(1,79) = 8.87$, $p < .005$). Psychology students thought that this strategy was easier to apply in study problems than non-psychology students (respectively, mean = 3.06, SD = 0.70; mean = 2.60, SD = 0.91; ($F(1,79) = 6.64$, $p < .05$). Finally, psychology students considered that analysis and logical reasoning were more involved in the analogy strategy than non-psychology students (respectively, mean = 0.57, SD = 0.50; mean = 0.34, SD = 0.48; ($F(1,80) = 4.44$, $p < .05$; logical reasoning: respectively, mean = 0.64, SD = 0.49; mean = 0.34, SD = 0.48; $F(1,80) = 7.48$, $p < .01$).

Some significant differences were found also in the visualisation strategy, whose efficacy and facility in study problems were scored higher by psychology (respectively, mean = 3.38, SD = 1.01; mean = 2.76, SD = 0.67) than by non-psychology students (respectively, mean = 2.70, SD = 1.13; mean = 2.27, SD = 1.00) (respectively, $F(1,77) = 7.63$, $p < .01$; $F(1,77) = 6.66$, $p < .05$). The first subsample showed a significantly higher involvement of the synthesis ability in this strategy (mean = 0.60, SD = 0.50) than the second subsample did (mean = 0.30, SD = 0.47) ($F(1,78) = 7.08$, $p < .01$).

In the other two cases significant differences between the two kinds of disciplines attended emerged. Critical thinking was considered to be more involved in the step-by-step strategy by psychology (mean = 0.70, SD = 0.46) than by non-psychology undergraduates (mean = 0.49, SD = 0.51) ($F(1,80) = 4.05$, $p < .05$). The combining strategy was maintained to be more efficient in interpersonal problems in the first (mean = 2.51, SD = 0.95) than in the second subsample (mean = 2.09, SD = 0.66) ($F(1,78) = 5.70$, $p < .05$).

Discussion

The study was aimed at:

(i) identifying which problem-solving methods undergraduates perceive as the most and the least useful, easy to apply and frequently employed;
(ii) verifying whether students are able to differentiate their judgments about the use, the efficacy and the possibility of applying problem-solving techniques according to the kind of problem;
(iii) assessing whether they are aware of which mental abilities are involved in each problem-solving strategy;
(iv) assessing whether opinions about the frequency, usefulness and application of the problem-solving techniques and about the capacities which they require are influenced by psychological courses attended by individuals.

As far as the two first issues are concerned, results showed that undergraduates are able to differentiate their opinions about problem-solving strategies according to the kind of problem at hand. It emerged that the most used problem-solving strategy is analogy, consisting in reminding oneself of a previous situation similar to the current one. This may depend on the fact that such strategy is the most spontaneous because it does not involve 'technical' aspects (such as the systematic decomposition of the problem or the systematic combination of its elements) and does not require an intentional attitude to be applied. Free production, step-by-step, visualisation and combining obtained lower, approximately similar, ratings. The step-by-step procedure is seldom employed in interpersonal problems. It is likely that participants perceived these kind of problems as non-cognitive problems, so that a 'cold' analysis of the situation – such as that hinted by this strategy – does not seem appropriate. Alternatively, interpersonal problems are conceived as holistic problems which can not be decomposed into separate sub-problems.

Efficacy scores are consistent with frequency scores. In general, problem-solving methods are considered less suitable for interpersonal problems; for these problems the least effective methods are step-by-step analysis and combining, that is, the most

systematic procedures. Practical problems turned out to be the privileged field of application of problem-solving techniques, obtaining the highest scores both in frequency and efficacy rates. For study problems the most relevant strategy is step-by-step analysis, whose frequency and efficacy rates reached the highest values in this kind of situation.

Facility scores mirror findings about the other two kinds of scores. Analogy is thought to be the easiest method to apply and step-by-step analysis and combining the most difficult. Interpersonal problems are identified as the situations in which these methods are rather difficult to employ.

With respect to the third issue above mentioned, students are able to recognise the abilities which are most relevant for each problem-solving method. For instance, memory is considered the most important skill for analogy, analysis and accuracy for step-by-step, creativity for free production. It is worth noticing that the methods which are rated as most difficult are those which involve the highest number of abilities.

Finally (fourth issue), psychology and non-psychology students rated frequency, efficacy and facility of the problem-solving methods and the abilities involved in such methods approximately in the same manner. The overall picture that emerged is that metacognitive beliefs about problem-solving techniques are scarcely affected by the academic course attended. Significant differences between the two subsamples occurred only in less than 12% of the analyses carried out. In these cases psychology undergraduates obtained mean scores higher than non-psychology undergraduates. Probably, because of the kind of course in which they attend, the former developed a greater sensibility towards the ways in which the mind works; this led them to be more aware of their own use of specific strategies in reasoning and of the involvement of distinct abilities in applying those strategies. The evaluation of the efficacy and of the facility in applying problem-solving methods might be affected also by some general psychological notions acquired by psychology students. However, basic psychology courses seem to have a marginal role in determining the metacognitive representation of problem-solving techniques; such a representation is substantially similar in psychology and non-psychology students. This induces us to maintain that opinions about strategies that can help problem-solving are grounded mainly on common everyday-life experiences and/or on shared educational-instructional acquisitions rather than on domain-specific learning.

Self-report measures show various methodological limitations and the questionnaire employed in the present study is not exempt from these limitations. For instance, the subjective evaluation of how frequently a problem-solving strategy is applied might not correspond to the actual use of that strategy. However, the consistency of the rating patterns which emerged induces us to think that the instrument managed to identify a stable and common system of beliefs. Furthermore, no social desirability or compliance effects seem to have occurred, because there is no reason to suspect that participants had distorted their spontaneous responses in order to make them match external expectations. In any case, all kinds of methods and all kinds of problems considered in the questionnaire should be equally sensitive to the possible influence of these effects.

Metacognition is proposed as an important aspect of the solution of a problem. Studies reviewed in the Introduction converged in supporting the notion that high

levels of metacognition are associated with good performance in problem-solving. Metacognition includes two kinds of variables: (i) awareness, opinions and knowledge about mental activities; (ii) control over such activities. The present study was focused on the first aspect of metacognition, namely, on what people think about mental processes involved in problem-solving methods. However, we can assume that adequate metacognitive representations concerning problem-solving can support the control of the solution procedures. In fact, metacognitive beliefs should orientate toward the selection of the strategy which is considered the most relevant to the problem that is faced, should allow anticipation of the amount of cognitive effort and the kind of mental resources which are required and should induce the monitoring of personal tendency to take advantage of that strategy. All this should yield a better control over the solution process. In other words, good metacognitive conceptions about problem-solving techniques seem to be required by their productive application in specific situations.

The results of our investigation showed that undergraduates with no training in problem-solving methods can identify some critical features of the main kinds of strategies that literature suggests to be useful in facing various types of situations. Students can rate the frequency, the efficacy and the facility of five problem-solving techniques according to the kind of problem at hand and can distinguish the abilities which are required by each technique. However, participants showed also some misconceptions about problem-solving techniques. For example, they believed that such techniques are particularly beneficial only when applied to practical problems or that they are less relevant to interpersonal problems. In short, both adequate and inadequate spontaneous beliefs about problem-solving methods emerge. Trainers should take into account the naive conceptions of trainees in order to yield a productive interaction between the pre-existing knowledge and attitudes and the novel competences that they intend to develop in the learners.

References

Allen, B.A., & Armour-Thomas, E. (1993). Construct validity of metacognition. *Journal of Psychology*, *127*, 203–211.

Anderson, B.F. (1980). *The complete thinker: A handbook of techniques for creative and critical problem-solving*. Englewood Cliffs, NJ: Prentice Hall.

Antonietti, A. (1991). Why does mental visualization facilitate problem-solving? In R.H. Logie, & M. Denis (Eds.), *Mental images in human cognition* (pp. 211–227). Amsterdam: Elsevier.

Armbruster, B.B. (1989). Metacognition in creativity. In J.A. Glover, R.R. Ronning, & C.R. Reynolds (Eds.), *Handbook of creativity* (pp. 177–182). New York: Plenum.

De Bono, E. (1976). *Teaching thinking*. London: Temple Smith.

Gordon, W.J. (1961). *Synectics. The development of creative capacity.* New York: Harper & Row.

Guilford, J.P. (1986). *Creative talents: Their nature, uses and development.* New York: Bearly.

Hayes, J.R. (1981). *The complete problem solver.* Philadelphia, PA: Franklin Institute Press.

Huet, N., Mariné, C, & Escribe, C. (1994). Auto-évaluation des compétences en résolution de problèmes chez adulted peu qualifiés. *Journal International de Psychologie*, *29*, 273–289.

Isaksen, S.G., & Treffinger, D.J. (1985). *Creative problem-solving*, Buffalo, NY: Bearly.

Johnson-Laird, P.N. (1993). *Human and machine thinking*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Mednick, S.A. (1962). The associative basis of creativity. *Psychological Review*, *69*, 220–232.

Osborn, A. (1953). *Applied imagination* (rev. ed.). New York: Scribner.
Rubinstein, M.F., & Pfeiffer, K. (1980). *Concepts in problem-solving*. Englewood Cliffs, NJ: Prentice Hall.
Schoenfeld, A. (1985). *Mathematical problem-solving*. New York: Academic Press.
Simonton, D.K. (1984). *Genius, creativity, and leadership*. Cambridge, MA: Harvard University Press.
Slife, B.D., Weiss, J., & Bell, T. (1985). Separability of metacognition and cognition: Problem-solving in learning disabled and regular students. *Journal of Educational Psychology*, *76*, 437–445.
Sternberg, R.J. (1986). *Intelligence applied: Understanding and increasing your intellectual skills*. New York: Harcourt Brace Jovanovich.
Swanson, H.L. (1990). Influence of metacognitive knowledge and aptitude on problem-solving. *Journal of Educational Psychology*, *82*, 306–314.
Swanson, H.L. (1992). The relationship between metacognition and problem-solving in gifted children. *Roeper Review, 15*, 43–48.
Vosniadou, S., & Ortony, A. (Eds.) (1989). *Similarity and analogical reasoning*. Cambridge: Cambridge University Press.
Weisberg, R.W. (1993). *Creativity: Beyond the myth of genius*. New York: Freeman.
Wertheimer, M. (1959). *Productive thinking*. New York: Harper.
Whimbey, A., & Lockhead, J. (1991). *Problem-solving and comprehension: A short course in analytical reasoning* (5th ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.
Wickelgren, W.A. (1974). *How to solve problems: Elements of a theory of problems and of problem-solving*. San Francisco: W.H. Freeman.
Zwicky, F. (1969). *Discovery, invention and research through the morphological approach*. New York: Macmillan.

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Appendix

The aim of this questionnaire is to investigate what students think about strategies which can be employed to solve problems.
Some problem-solving strategies are described on the subsequent pages of the questionnaire. Each strategy is reported on a separate sheet.
Your task is to rate each strategy according to:
* how frequently you use that strategy when you face problems;
* how effective you think that strategy is to solve problems;
* how easy, in your opinion, that strategy is to apply.
Give ratings according to the following scale:
1 = very little, 2 = little, 3 = enough; 4 = much, 5 = very much.
As far as each strategy is concerned, ratings are requested for each of the following kinds of problems: interpersonal problems, practical problems and study problems.
At the bottom of each page a list of mental abilities is reported. Check the ability or abilities that you think are involved when the strategy is applied.

STRATEGY 1
I let my mind wander freely and try to produce as many ideas as possible, by avoiding to evaluate them at once. I consider each idea, even though it seems irrelevant, impossible to do or crazy. Only after having produced many ideas, I begin to analyse and to judge them and to choose the best ones.

Think of the application of this strategy to *interpersonal problems*:

* how **frequently** I apply this strategy	1	2	3	4	5
* how **useful** I think this strategy is	1	2	3	4	5
* how **easy** I think this strategy is to apply	1	2	3	4	5

Think of the application of this strategy to *practical problems*:
* how **frequently** I apply this strategy 1 2 3 4 5
* how **useful** I think this strategy is 1 2 3 4 5
* how **easy** I think this strategy is to apply 1 2 3 4 5

Think of the application of this strategy to *study problems*:
* how **frequently** I apply this strategy 1 2 3 4 5
* how **useful** I think this strategy is 1 2 3 4 5
* how **easy** I think this strategy is to apply 1 2 3 4 5

Which of the following mental abilities do you think are involved when the strategy is applied?

[ ] creativity	[ ] speed	[ ] synthesis	[ ] critical thinking
[ ] accuracy	[ ] memory	[ ] analysis	[ ] logical reasoning

STRATEGY 2
I try to recall problems successfully solved in the past which are similar to the current problem. I look for previous situations which share some aspects, elements or features with the current problem so that I can transfer some ideas from the former ones to the latter one.

Think of the application of this strategy to *interpersonal problems*:
* how **frequently** I apply this strategy 1 2 3 4 5
* how **useful** I think this strategy is 1 2 3 4 5
* how **easy** I think this strategy is to apply 1 2 3 4 5

Think of the application of this strategy to *practical problems*:
* how **frequently** I apply this strategy 1 2 3 4 5
* how **useful** I think this strategy is 1 2 3 4 5
* how **easy** I think this strategy is to apply 1 2 3 4 5

Think of the application of this strategy to *study problems*:
* how **frequently** I apply this strategy 1 2 3 4 5
* how **useful** I think this strategy is 1 2 3 4 5
* how **easy** I think this strategy is to apply 1 2 3 4 5

Which of the following mental abilities do you think are involved when the strategy is applied?

[ ] creativity	[ ] speed	[ ] synthesis	[ ] critical thinking
[ ] accuracy	[ ] memory	[ ] analysis	[ ] logical reasoning

STRATEGY 3
I try to go on systematically and to look for the sequence of steps or phases which are needed to reach the solution gradually. For instance, I try to decompose the whole problem into sub-problems, to identify intermediate goals, to plan, to schedule and to order hierarchically the operations to be carried out.

Think of the application of this strategy to *interpersonal problems*:
* how **frequently** I apply this strategy 1 2 3 4 5
* how **useful** I think this strategy is 1 2 3 4 5
* how **easy** I think this strategy is to apply 1 2 3 4 5

Think of the application of this strategy to *practical problems*:
* how **frequently** I apply this strategy 1 2 3 4 5
* how **useful** I think this strategy is 1 2 3 4 5

* how **easy** I think this strategy is to apply 1 2 3 4 5

Think of the application of this strategy to *study problems*:
* how **frequently** I apply this strategy 1 2 3 4 5
* how **useful** I think this strategy is 1 2 3 4 5
* how **easy** I think this strategy is to apply 1 2 3 4 5

Which of the following mental abilities do you think are involved when the strategy is applied?

[ ] creativity	[ ] speed	[ ] synthesis	[ ] critical thinking
[ ] accuracy	[ ] memory	[ ] analysis	[ ] logical reasoning

STRATEGY 4

I try to visualise the problem, that is, to represent it in my mind through images. I try to see the situation with my mind's eye; I draw pictures, schemas, graphs, and so on. I actually imagine to be in that situation.

Think of the application of this strategy to *interpersonal problems*:
* how **frequently** I apply this strategy 1 2 3 4 5
* how **useful** I think this strategy is 1 2 3 4 5
* how **easy** I think this strategy is to apply 1 2 3 4 5

Think of the application of this strategy to *practical problems*:
* how **frequently** I apply this strategy 1 2 3 4 5
* how **useful** I think this strategy is 1 2 3 4 5
* how **easy** I think this strategy is to apply 1 2 3 4 5

Think of the application of this strategy to *study problems*:
* how **frequently** I apply this strategy 1 2 3 4 5
* how **useful** I think this strategy is 1 2 3 4 5
* how **easy** I think this strategy is to apply 1 2 3 4 5

Which of the following mental abilities do you think are involved when the strategy is applied?

[ ] creativity	[ ] speed	[ ] synthesis	[ ] critical thinking
[ ] accuracy	[ ] memory	[ ] analysis	[ ] logical reasoning

STRATEGY 5

I try to combine different aspects of the problem. I try to associate, perhaps randomly, some elements of the problem so that I can reach any result, for instance by obtaining new patterns or interesting links which can suggest the solution.

Think of the application of this strategy to *interpersonal problems*:
* how **frequently** I apply this strategy 1 2 3 4 5
* how **useful** I think this strategy is 1 2 3 4 5
* how **easy** I think this strategy is to apply 1 2 3 4 5

Think of the application of this strategy to *practical problems*:
* how **frequently** I apply this strategy 1 2 3 4 5
* how **useful** I think this strategy is 1 2 3 4 5
* how **easy** I think this strategy is to apply 1 2 3 4 5

Think of the application of this strategy to *study problems*:
* how **frequently** I apply this strategy 1 2 3 4 5
* how **useful** I think this strategy is 1 2 3 4 5
* how **easy** I think this strategy is to apply 1 2 3 4 5

Which of the following mental abilities do you think are involved when the strategy is applied?

[ ] creativity	[ ] speed	[ ] synthesis	[ ] critical thinking
[ ] accuracy	[ ] memory	[ ] analysis	[ ] logical reasoning