Is this problem likely to be solved?

A cognitive schema of effective problem solving.

Raanan Lipshitz, Daphna Leshem Levy

Department of Psychology

and

Keren Orchen

School of Social Work

University of Haifa

Haifa, Israel 31905

Raanan@psy.haifa.ac.il

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Abstract

(159 words)

The present study tested the existence of a cognitive schema that guides people's evaluations of the likelihood that observed problem solving processes will succeed. The hypothesized schema consisted of attributes that were found to distinguish between retrospective case reports of successful and unsuccessful real world problem solving (Lipshitz and Bar Ilan, 1996). Participants were asked to evaluate the likelihood of success of identical cases of problem solving that differed in the presence or absence of diagnosis, the selection of appropriate or inappropriate solutions, and the pairing of diagnosis with a appropriate or non-appropriate solutions. Consistent with the proposition, diagnosis affected perceived likelihood of success, albeit only when solution quality was held constant and appropriate diagnosis with a compatible solution produced higher perceived likelihood of success than appropriate diagnosis with incompatible solutions. In addition, results showed that solution quality plays a significant role, and compatibility with the six phase rational model plays no role in judging likelihood of success.

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Acting as parents, managers, educators, or spectators, people frequently judge the quality of their own and other people's problem solving efforts. Studies of decision evaluation show that decisions (and by extrapolation problem solving) are predominantly evaluated by their outcomes: good outcomes indicate effective solutions and bad outcomes indicate ineffective solutions. This method is flawed because it requires knowledge of results, when it is too late for following midcourse evaluation with improvement and because in situations of uncertainty high quality solutions may fail and low quality solutions may succeed (Lipshitz & Barak, 1995). Two alternative methods of evaluation resolve these criticisms: Evaluation by process –judging the quality of solutions by quality of the process that generated them, and direct evaluation -- judging the quality of solutions based on some substantive knowledge regarding their effectiveness. The purpose of this study is to test the hypothesis that there exists a general cognitive schema that guides people's evaluation of the quality of problem solving efforts in the absence of outcome information. The hypothesis is based on the results of a study (Lipshitz & Bar Ilan, 1996) which tested the validity of a six phase problem solving model in a sample of retrospective reports of real world problem solving. Consequently, we begin with a brief review of problem solving phase models, Lipshitz & Bar Ilan, (1996), and some relevant follow up studies.

Beginning with Wallace (1926) and Dewey (1933) numerous descriptive and prescriptive phase models of problem solving were presented in the literature (e.g.,

Brim et al., 1962; Bransford & Stein, 1984; Kast & Rosenzweig, 1979; Mintzberg, Raisingahni, & Theoret; 1976; Nutt, 1984; Polya, 1957; Witte, 1972). The descriptive phase models assume that problem solvers “go through certain stages or phases in the process of solving problems” (Bales & Strodtbeck (1951, 485). For example, according to Dewey (1933), problem solvers go through the phases of experiencing a sense of perplexity or doubt; identifying a problem; searching for relevant facts; formulating possible solutions; testing the solutions and, if necessary, reanalyzing the problem; and choosing and implementing the correct solution. The prescriptive models presume that “problem-solving would somehow be more effective if some prescribed order were followed" (Bales & Strodtberg, ibid). Exemplifying these models, Bransford, Sherwood, and Sturdevant (1987) proposed that problem solvers should follow an "IDEAL" process consisting of “Identifying the existence of a problem, Defining the problem, Evaluating available alternatives, Applying the best alternative, and Looking back" (i.e., evaluating the outcome).

Few studies testing the descriptive validity or prescriptive utility of problem solving phase models can be found in the literature. Based on a survey of these studies, Lipshitz and Bar Ilan (1996, p. 50) concluded that these studies provide little support for either the descriptive validity or the prescriptive utility of problem solving phase models, consistent with Nutt's (1984, p. 446) conclusion that the linear process which phase models describe "seems rooted in rational arguments, not behavior" (Nutt, 1984, p. 446). The latter conclusion is also supported by studies which show that proficient problem-solving does not go through an orderly sequence of phases (Chi, Glaser, & Farr, 1982; Klein, Calderwood, Orasanu, & Zsambok, 1993), and by studies which show that processes of organizational decision making are characterized by truncated information search (Cyert & March, 1963), disjointed progress

(Braybrooke & Lindblom, 1963), and coincidental confluence of problems, solutions, and choice opportunities (Cohen & March, 1972). These results do not rule out the utility of phase models altogether, as they can be used as templates for describing the forward jumps, backward loops and complete cycles that actual problem solving processes trace through the sequence of phases that they posit (Klein, 1996, Lipshitz & Adar-Pras, 2005; Mintzberg, Rainsingani, & Theorét, 1976; Smith, 1989).

A study by Lipshitz and Bar Ilan (1996) suggested the possibility that while phase models do not describe how problems are actually solved, they operate as a cognitive schema which guides the retrieval of problem solving episodes from long term memory. These researchers tested the descriptive validity and prescriptive utility of a six-phase problem-solving model in seventy-five pairs of retrospective case reports of successful and unsuccessful problem solving in organizational settings. In cases of success the problem was solved. In cases of failure it persisted or was replaced by another problem. The cases were written by experienced military officers and managers on the basis of their personal experience and were analyzed by mapping the narrative onto a six phase problem solving model consisting of identification (deciding that a problem exists); definition (specifying the problem as a discrepancy between a desired and an actual state of affairs that needs to be addressed); diagnosis (identifying the cause of the discrepancy which constitutes a problem); generation of alternatives (identifying which measures can counteract the causes of the problem; evaluation of alternatives (weighing the pros and cons of the various solutions); and choice/action (choosing and implementing the preferred alternative). Descriptive validity was tested by the degree to which the cases conformed (probabilistically) with the model in terms of two essential characteristics of phase models: (1) Given a phase model with n phases and an observed problem-solving process with k steps the

observed process is compatible with the model if phase i is more likely to occur in step i than all other phases of the model. (2) Given a phase model with n phases and an observed problem-solving process with k steps, the observed process is compatible with the model if phase i is most likely be followed by phase i+1 regardless of the two steps' location in the observed process. (E.g., the second step in the process is most likely diagnosis and diagnosis is most likely to be followed by evaluation regardless of its appearance in any step in the process). Prescriptive utility was tested by hypothesizing that the two characteristics were more likely to appear in cases of success than in cases of failure.

Results confirmed the descriptive validity and disconfirmed the prescriptive utility of the phase model in the retrospective reports. The location of phases in the processes reported in the narratives and the order of consecutive phases regardless of their location were consistent with the six-phase model in both success and failure cases. In addition, there was a marked tendency to jump forward from early phases to choice/action. The results also revealed several attributes that distinguished between successful and unsuccessful processes of problem solving: Although both processes were characterized by a low incidence of diagnosis, there was a statistically significant higher incidence of this phase in cases of success. Diagnosis was more likely to be performed in the early steps and to precede action in cases of success than in cases of failure. Successful problem solvers were more likely to produce at least two alternative solutions, to choose a solution that was compatible with their diagnosis in general, and which answered all aspects of multi-facet diagnoses in particular. Finally, successful problem solvers were less likely to choose standard operating procedure type solutions or to apply repeatedly the same solution (the "more of the same" syndrome).

A plausible interpretation of Lipshitz and Bar Ilan's findings, given the nature of their data, is that the orderly structure of the retrospective reports reflects the operation of underlying schema that directs the reconstruction of problem solving from long-term memory, imposing on them more order than they actually had. The proposition that problem solving and the encoding and retrieval of information from long term memory are schema driven is not novel (Gick & Holyoak, 1980; Marshall, 1995, and Brewer & Dupree, 1983; Mandler, 1978, respectively). The proposition that the schema which drives the retrieval of problem solving episodes from long term memory is compatible with a problem solving phase model has not been considered before.

Three studies tested the hypothesis that the six phase problem phase model operates as a cognitive schema by applying standard methods employed in schema research to the model used by Lipshitz and Bar Ilan (1996). Loterman (1996) presented eighty undergraduate students with two versions of two cases analyzed by Lipshitz and Bar Ilan (1996). The cases included all six phases in the Lipshitz and Bar Ilan model in organized in random order without outcome information, allowing half of the cases to be presented as a case of “success” and the other as a case of “failure.” Participants were given two minutes to “try to understand what actually happened” in each case, performed a diversion task for five minutes, and then reconstructed the case “as it had actually happened.” This procedure was designed to maximize the likelihood of schema induction as follows: Requiring participants to organize as well as memorize the information presented to them increased the likelihood of schema induction both in coding the information and in its retrieval (Bower, Black & Turner, 1979; Yussen Huang, Mathews, & Evans, 1988); the diversion task insured that information would be retrieved from long-term memory (Ericsson & Simon, 1984);

labeling cases as success or failure increased the likelihood of inducing schemas that specifically pertain to these outcomes (Bransford & Johnson, 1972). In addition, induction of order-imposing schema was helped by encouraging participants to construct plausible reconstructions of the event masked by the scrambled information presented to them. After reconstructing the cases participants answered the question "What features of the sequence of events caused the case to end in success/failure?"

Results replicated the findings of Lipshitz and Bar Ilan (1996) regarding the descriptive validity of the model. In both "success" and "failure" cases, phase j of the model was more likely to appear in step j then any other phase, and phase j + 1 was the more likely phase to follow phase j than any other phase. The tendency to jump directly to choice/action was also replicated. In contrast, only one of the characteristics that Lipshitz and Bar Ilan (1996) found to distinguished between cases of success and cases of failure was replicated: action tended to appear later in cases of success than in cases of failure. As for the query regarding the causes of success or failure, most subjects attributed it to the same factor: the selection of a correct or an incorrect solution, respectively. Thus, the same action was deemed appropriate (i.e., leading to success) or inappropriate (leading to failure) depending on whether the (outcome-less) case was labeled as a "success" or a "failure."

One feature of weakness of Loterman's 1996) design which favored the schema hypothesis was her use of scrambled cases that contained all six phases, thus increasing the probability that all six phases will appear in the reconstructed cases. To correct for this deficiency, Meshy (2000) used a different standard methodology for testing the existence of schemata: asking participants to reconstruct a case from which one of a hypothesized schema's elements had been deleted (Agostinneli, Sherman, Fazio, & Hearst, 1986; Maki, 1989; Pedzek, Maki, Valensia-Laver, Whettstone,

Stockerert, & Dougherty, 1988). Specifically, Meshy presented 48 undergraduate students with three scrambled problem solving cases from which either diagnosis, generation of alternatives, evaluation of alternatives had been deleted. In addition, the mix of scrambled case segments included text that was irrelevant to the six-phase model. Two of the cases were based on Loterman (1996); one was constructed for the study. Analysis of the reconstructed cases supported the schema hypothesis: 1) Deleted phases were reinstated in the reconstructed cases at above-chance level (albeit at lower frequencies than either in Loterman's findings or in the reconstructions of the cases from which they were not deleted in the present study); 2) both the location and order of appearance of the deleted phases was consistent with the six-phase model and, 3) model-related text segments were far more likely to appear in the reconstructed cases than model-irrelevant text segments.

Loterman (1996) and Meshy (2000) borrowed methodologies from schema research to untangle the confound between veridical and schema induced reconstruction of past events. Lipshitz and Adar-Pras (2005) tried to achieve the same end by observing how problems are solved in real time. They asked 22 undergraduate students to think-aloud as they solved 2 problems. The problems were presented visually by means of Thematic Apperception Test pictures (Morgan, 1995) accompanied by verbal instructions that established the situation depicted in the pictures as either a well-defined or an ill-defined problem. Analysis of the think-aloud protocols revealed certain similarities as well as certain differences between the reconstructed processes studied by Lipshitz and Bar Ilan (1996), Loterman (1996), and Meshy (2000), and problem solving in real time.

The underlying phase structure of concurrent and retrospective problem solving case reports were similar in that both were dominated by choice/action, and both

showed a strong preference for moving forward from early to late phases, most notably to choice/action. The dissimilarities between these processes were more noteworthy and more pronounced with the ill-defined problems. Firstly, think aloud protocols revealed the operation of meta-cognitive processes that are not included in the phase model. Secondly, the on-line processes were less orderly, that is, instead of the predominantly smooth linear progression found by Lipshitz and Bar Ilan (1996), Loterman, (1996), and Meshy (2000); real world problem solving included numerous leaps forward and loops backward.

In conclusion, the findings of Lipshitz and Bar Ilan (1996), Loterman (1996), Meshy (2000), support the proposition that the reconstruction of problem solving episodes from long term memory is guided by a schema that describes problem solving as the progression through the sequence of phases specified by the model employed by Lipshitz and Bar Ilan (1996). The purpose of the present study is to complement the studies reported above by testing the proposition that the attributes that Lipshitz and Bar Ilan (1996) found to differentiate between cases of success and failure reflect a schema of effective problem solving which (1) informs people's judgments of the likelihood that a problem solving process which they observe will succeed or fail and (2) directs their problem solving in action (an implication that was not tested in the study). This schema has three components corresponding to Lipshitz and Bar Ilan's (1996) findings which are framed as hypotheses:

Hypothesis 1 (Diagnosis effect): Problem solving processes that include a diagnosis are more likely to succeed than identical processes that do not include diagnosis.

Hypothesis 2 (matching effect): Problem solving processes in which solution matches diagnosis are more likely to succeed than identical processes in which solution does not match diagnosis.

Note that hypotheses 1 and 2 refer to only two of phases of the complete six phase model and do not require adherence to the order that it specifies. A third hypothesis pertaining to these features was included in the study to validate Lipshitz and Bar Ilan's and Loterman' finding that the six phase model did not serve as a prescriptive schema:

Hypothesis 3 (completeness effect): Problem solving processes that follow the six-phase problem solving model are more likely to succeed from otherwise identical processes that do not include all the phases.

Method

Using the same rationale as Loterman (1996) and Meshi (2000) the study employed a standard method for schema elicitation, the judgment-recognition method. This method elicits schema by requiring participants to assign stimuli (e.g., person descriptions) into different categories (e.g., absenteeism-prone workers, Conlon & Stove, 1992; good vs. bad teachers, Haustein, & Alexander, 1991; or different treatment tracks, Rabinowitz (1993) and identifying common characteristics of the assigned stimuli. In the present study students were asked to assign outcome-less descriptions of problem solving processes that included (or did not include) the phases implied by hypotheses 1-3 to three categories of high, intermediate and low probability of success. Assuming that the execution of the assignment task is driven by an underlying schema regarding which features of problem solving processes are conducive to success or failure, a pattern of results that confirms the first two hypotheses is consistent with the proposition that the differences identified by

Lipshitz and Bar Ilan were produced by a prescriptive schema that drives the reconstruction of successful and unsuccessful problem solving from long-term memory. Disconfirmation of Hypotheses 1 and 2 and confirmation of hypothesis 3 is consistent with the proposition that the six-phase problem solving model is a prescriptive as well as descriptive schema, contrary to Lipshitz and Bar Ilan's (1996) findings.

Participants

Sixty four first year undergraduate students in the Department of Psychology at the University of Haifa participated in the study as part of their course requirements. All students had a relevant background (military service) for understanding the cases used in the study.

Design

The design was a 2 (diagnosis/no diagnosis) x 2 (appropriate/non-appropriate solution) x 2 (complete/incomplete process) factorial.

Independent Variables

The independent variables were manipulated by including problem identification, definition and choice in all cases and varying the remaining phases in 8 versions of 8 problem solving cases taken from the sample of cases analyzed by Lipshitz and Bar Ilan (1996).

Each subject was presented with 8 substantively and structurally different cases as presented in Table 1. The three factors were completely balanced: Each subject received all the 8 basic cases, four with diagnosis and four without diagnosis, four with solutions that matched the diagnosis and four with solutions that did not match it, and four with complete and four with incomplete structure. Furthermore, the 8 structural variants specified in Table 1 were equally distributed on the 1-8 locations in

the order of presentation, and all variants had an equal probability of following each other in the order of presentation.

Insert Table 1here

The 8 variants of the basic cases were pre-tested and, if necessary, adjusted in a three-phase pilot study. Phase A tested the feasibility of the experimental task and clarity of instructions. Phase B checked the plausibility of the diagnosis and the perceived compatibility of the appropriate solutions to the diagnoses. Phase C tested the clarity of the dependent variables. The independent variables were manipulated as follows:

Diagnosis (included/not included in the problem solving process): This variable was manipulated by including or deleting the text segment relevant to diagnosis in the original case.

Case structure (complete/incomplete): Complete cases consisted of all 6 phases in the model (5 in the no diagnosis condition). Incomplete cases consisted of definition and Choice/action (plus Diagnosis in the appropriate conditions).

Solution (appropriate/non-appropriate): This variable was manipulated by including the appropriate or non appropriate solutions as confirmed in the pilot study.

The complete process-diagnosis included-appropriate solution version of one of the cases used in the study is presented below with the 6 phases identified in square brackets.

Participants in divisional field exercises are required to use topographical maps of the exercise area. During the preparation for the last exercise I assigned some non-commissioned officers (NCOs) in the operation center to prepare the exercise for a specified date. A short time before the exercise I found out that the NCOs did not

complete this assignment and were unlikely to do so on time [identification + definition]. The officer in charge claimed that the time originally allotted for the assignment was too short [diagnosis]. I could threaten the NCOs that unless they completed the task on time they would be punished or enlist 5 additional soldiers to finish the task [generation]. After deliberating the merits of the various options available to me [evaluation] I decided to enlist the additional clerks [choice of appropriate solution].

The remaining 7 case versions were formed by deleting the sentences corresponding to these phases consistent with the experimental condition which they formed. For example, the incomplete process x no-diagnosis x non-appropriate solution read as follows:

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Dependent Variables

Participants were asked to rate the likelihood of success of each case by assigning it to one of three categories, “low probability (0%-33%)”, “intermediate probability (34%-67%)” and “high probability (68%-100%).” In addition to the categorical assignment participants were asked to provide a numerical estimate within the range specified for the assigned category. Participants were asked to distribute 2 cases each

to the low and high probability categories and four to the intermediate success category in order to prevent a positively attenuated distribution owing to optimism bias (Lipshitz & Barak, 1995; Weinstein, 1980). In addition, participants were asked to answer an open-ended question "What were the reasons for your estimate of success?" Three additional open-ended questions served as manipulation checks: "What was the problem in the case?" "What were the causes for the problem in the case?" and "Does the solution implemented in the case match the diagnosis?

Procedure

1) Participants were told that they were participating in a study on problem solving. Next they received a booklet containing the 8 cases and a separate sheet on which they had to provide the dependent variable. 2) The pages with the estimates were collected by the experimenter who then asked participants to list on a separate page the reasons for the case's likelihood of success. 3) The experimenter collected these pages as well and asked participants to respond to the three open-ended manipulation checks items.

Results

Manipulation Checks

The effectiveness of the manipulations was evaluated by participants' three open-ended questions "What was the problem in the case?" "What were the causes for the problem in the case?" and "Does the solution implemented in the case match the diagnosis?" Responses to these questions were classified as appropriate or non-appropriate according to their correspondence with the experimenters' definitions, diagnoses and action selection, respectively, and as "?" if participants responded that the causes of the problem were unclear. The results (Table 2-a) show a high degree of correspondence between experimenters' and participants' definitions, irrespective of

experimental condition. Table 2-b shows that the inclusion of diagnosis (versions 1-4) increased the frequency of correspondence between experimenters' and participants' diagnoses and lowered the frequency of unclear causes ("?") responses. Finally, Table 2-c shows a strong interaction between case version and participants' judgments of the solution suitability. Perceived suitability was high in case versions that included appropriate solutions with and without diagnosis (versions 1-2 and 5-6, respectively), and lowest in case versions that either combined diagnosis with inappropriate solutions (3-4) or no diagnosis and inappropriate solution (7-8). Explicitly presented diagnosis enhanced, therefore, the distinction between appropriate and inappropriate solutions, but was not a precondition for a recognizing a appropriate solution as the appropriate solution for a given case.

Insert Table 2 here

Tests of Hypotheses

Table 3 presents the means and standard deviations of participants' estimated likelihood's of success in the 8 case versions. Hypotheses were tested by three-way ANOVA and tests of simple effects following significant interactions. Because estimates tended to converge on salient values (e.g., .33, .67, .70, .90) we also tested our hypotheses non-parametrically with Wilcoxon's sign test (Siegel, 1956). The two sets of results were entirely consistent.

Insert Table 3 here

Hypothesis 1 (Diagnosis effect): The four case versions that included diagnosis were not judged as more likely to succeed than the four versions which did not include this phase ($F_{(1,63)} = .012$; *ns*). This non-significant effect was the result of the diagnosis x solution interaction whereby matching appropriate diagnosis with

appropriate or inappropriate solutions canceled out one another: Processes in which diagnosis was matched with an appropriate solution were perceived as most likely to succeed ($p = 0.69$) while process in which diagnosis was mismatched with an inappropriate were perceived as least likely to succeed ($p = 0.42$). Consistent with the hypothesis, the presence of diagnosis increased perceived likelihood of success with appropriate solutions from M = 59.08 s.d., = 16.53 to M = 65.23, s.d. = 13.29, F (1, 63), = 3.96, $p < 0.05$). Disconfirming the hypothesis, the presence of diagnosis reduced perceived likelihood of success from M = 47.32 s.d. = 14.39, to M = 42. 43, s.d. = 15.55, F (1, 63) = 4.84, $p < 0.03$. Thus, the presence of diagnosis influenced estimated likelihood of success as albeit differentially, depending on solution quality. Appropriate diagnosis with an inappropriate solution emphasized the inappropriateness of the solution, thereby lowering perceived likelihood of success. The schema status of the phase mode was thus confirmed inasmuch as both conforming to the schema and deviating from it influenced estimated perceived success of observed problem solving processes.

The effect of diagnosis was furthered masked by an unanticipated solution main effect: Cases with appropriate solutions were judged to be more likely to succeed irrespective of the presence or absence of diagnosis in the problem solving process ($F_{(1,63)} = 70.64$. $p < 0.0001$). This result was unanticipated because solution appropriateness was defined (and tested in the pilot study) in terms of the compatibility of the enacted course of action with the diagnosis. Subjects in the no diagnosis condition apparently assessed the superior effectiveness of the appropriate solutions on grounds other that their compatibility with case presented diagnosis (e.g., personal experience). To test the effect of diagnosis holding solution effect constant we tested the significance of the difference between the diagnosis + appropriate

solution condition and the diagnosis + inappropriate solution condition (M = 22.78, s.d. = 19.80) and the difference between the no diagnosis + appropriate solution condition and the no diagnosis vs. inappropriate solution condition (M = 10.05, s.d. = 24.85). The result (M = 12.74; t_{63} = 13.58; $p < .002$) shows that the second hypothesis was confirmed when solution effect was held constant. Specifically, the inclusion of diagnosis in the problem solving process increased the perceived likelihood of success beyond the contribution of the solution main effect.

Hypothesis 2 (matching effect): The diagnosis x solution interaction was significant ($F_{(1, 63)} = 9.97$, $p < 0.02$). The second hypothesis was confirmed by the significant simple effect comparing the perceived likelihood of success in the diagnosis + appropriate solution with the diagnosis + non-appropriate solution (M = 65.23, s.d. = 13.29 vs. M = 42.43. s.d. = 14.39, $F_{(1, 63)}$, = 84.79, $p < 0.05$.

Hypothesis 3 (completeness effect): This hypothesis was disconfirmed -- cases that included 5 or six problem solving phases were not judged as more likely to succeed than cases that included 2 or 3 phases ($F_{(1,63)} = 2.65$, ns). This result replicates Lipshitz & Bar Ilan (1996) and Loterman (1996) and confirms that the 6 phase model does not constitute a prescriptive schema.

Reasons for potential success or failure

Four categories of approving of the solution adopted in the case and 7 categories of criticizing it were identified in participants' answers to the open-ended question “What were the reasons for your estimate of success?” Two students who were blind to the hypotheses of the study coded participants' responses using the 11 categories, first working independently and then reaching consensus in cases of disagreement. Results (Table 4) show that participants were more inclined to criticize than to approve the problem solving processes in the cases, and that, consistent with the

significant solution effect, they focused their criticisms on the appropriateness of the selected solution.

Insert Table 4 here

To test the hypothesis that the unanticipated solution resulted from the fact that participants were allowed to conduct their own diagnosis we compared the frequencies of general solution approval and approval based on appropriate solutions in the diagnosis + appropriate solution condition and no diagnosis + appropriate solution condition (Table 5-a), and of general criticism and criticism based on lack of diagnosis-solution appropriate in the diagnosis + non-appropriate solution and no-diagnosis + non-appropriate solution (Table 5-b). The results (χ^2 (1) = 10.60, $p < .01$ and χ^2 (1) = 5.33, $p < .05$, respectively), refuted this explanation. Participants used different patterns of reasons for potential success in the presence or absence of diagnosis, showing that they were clearly sensitive to this manipulation. This result, and the fact that participants referred to prior experience but not to diagnosis in their reasons, indicates that participants were able to identify the appropriate solution as appropriate on other grounds than its compatibility with an explicit diagnosis. The latter conclusion is also (weakly) supported by the more frequent references to three types of reasons in the absence of diagnosis: general approval of the appropriate solution, the superiority of the appropriate solution over the alternative solution, and personal experience.

Insert Table 5-b here

Insert Table 5-b here

Discussion

The present study tested the proposition that assessments of the likelihood that a given problem solving process will succeed (i.e., evaluating the quality of problem solving efforts in the absence of outcome information) is guided by a cognitive schema of effective problem solving. The schema consists of diagnosing (or failing to diagnose) the causes of the problem, and selecting a appropriate solution. The findings can be summarized as follows: (1) The presence of diagnosis influenced perceived likelihood of success: Processes that included diagnosis were perceived as more likely to succeed than identical processes that did not include diagnosis when solutions matched diagnosis and as less likely to succeed when solutions did not match diagnosis. (2) Cases in which diagnoses were matched with compatible solutions were judged as more likely to succeed than identical cases in which diagnoses were matched with incompatible solutions. (3) Processes with appropriate solutions were evaluated as more likely to succeed than processes with inappropriate solutions in the absence of diagnosis. (4) Solution appropriateness increased perceived likelihood of success and was mentioned by participants as the dominant consideration in estimating this likelihood.

The first two findings are consistent with the proposition that estimates of likelihood of success are driven by the hypothesized cognitive schema. The last two findings suggest a simpler, somewhat trivial account: The likelihood that problem solving will succeed is determined solely by solution quality which can be gauged either by the results of diagnosis, or by personal experience, social desirability, social convention and such like factor that are not included in the hypothesized schema. Thus, the study's findings can be attributed to a design fault which allowed these factors to vary systematically between appropriate and non-appropriate solutions.

The interpretation above is inconsistent with the finding that the presence of diagnosis contributed to perceived likelihood of success beyond the effect of selecting an appropriate vs. inappropriate solution. This explanation leaves open the question regarding the significance of the unanticipated solution effect on the posited schema. In retrospect it seems to us that this possibility could have been derived from schema theory, since the theory posits the existence of numerous domain specific substantive schema which help problem solvers to identify the nature of specific situations and to generate expectations, goals, and actions appropriate for them (Lipshitz & Ben Shaul, 1997; Reason, 1990). The fact that these schemas, (assuming that they were indeed operative in the present experiment), prescribed the same solutions as compatibility with diagnosis could not have been predicted prior to the study. Thus the results suggest that assessments of likelihood of success are guided by two types of schema, a general process schema that focuses on performing a diagnosis and selecting a appropriate solution, and domain specific substantive schema which guide the selection of situation (or problem) specific solutions.

The apparent confound between substantive and process schemas could have been avoided by using hypothetical scenarios to manipulate the independent variables rather than real world cases for which participants had some relevant knowledge. We used the particular sample of cases for two reasons. First, we wanted to maximize the similarity between the present study and the study of Lipshitz and Bar Ilan (1996) from which the hypothesized schema was derived. More importantly, since we construe diagnosis as an acquired rather than genetically determined skill, diagnosis and appropriate solutions with its results cannot be performed and evaluated without some relevant substantive knowledge. Thus, rather than disconfirming the hypothesized cognitive schema, the results produced a more complicated and, in our

opinion accurate understanding of how people assess the effectiveness of solution processes without outcome information.

The influence of the two significant process features (diagnosis and matching) is interesting for two reasons. First, the sensitivity of participants to the presence of diagnosis is impressive given that the experimental manipulation was fairly minimal (a relatively slight change in the text of the problem presentation). Second, given that when inquired about their reasoning participants referred only to solution quality (i.e., the problem solver "did the right thing" or "chose the right solution"), the prescribed cognitive schema acts as tacit knowledge (Leonard, 1998). The analysis of the deep features of the case reports show that participant seem to know more than they can tell directly.

It is reasonable to assume that a process schema that guides the evaluation of the effectiveness of observed problem solving efforts would also guide such efforts. Neither Lipshitz and Bar Ilan (1996) nor the present study examined problem solving in real time. It is interesting to note, however, that Lipshitz & Adar Pras (2005), who analyzed problem solving in real time with the six-phase problem solving model, concluded that the processes which they observed were consistent with the Recognition Primed Decision model (Klein, 1998). According to this model, experts match situations with appropriate actions, and situation recognition is based on prior experience and on mental simulation, a form of teleological diagnosis in which decision makers make sense of a situation by constructing stories that render them plausible.

In conclusion, the present study provides some preliminary evidence for the existence of a prescriptive cognitive schema that captures lay notions of effective problem solving. Two directions for future research of this schema are studies that

analyze problem solving in real time in terms of the hypothesized schema, and studies that test the validity of the schema by examining its existence in actual successful and unsuccessful problem solving efforts.

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Table 1

Case Version	Diagnosis	Solution	Structure
1	Included	Matches diagnosis	Complete
2	“	“ “	Incomplete
3	“	Does not match diagnosis	Complete
4	“	“ “ “ “	Incomplete
5	Not included	Matches diagnosis	Complete
6	“ “	“ “	Incomplete
7	“ “	Does not match diagnosis	Complete
8	“ “	“ “ “ “	Incomplete

Table 2: Manipulation Checks

a. Problem identifications within case versions

Case version	1	2	3	4	5	6	7	8
Appropriate	62	60	59	60	62	63	62	60
Non-appropriate	2	4	5	4	2	1	2	4

b. Problem diagnoses within case versions*

Case version	1	2	3	4	5	6	7	8
Appropriate	56	52	52	49	29	27	22	9
Non-appropriate	17	21	21	22	36	25	41	38
?	4	2	4	4	14	23	19	24

* Column sums exceed 64 because some participants identified more than a single cause.

c. Solution rating within case versions

Case version	1	2	3	4	5	6	7	8
Appropriate	53	43	20	21	39	32	18	26
Inappropriate	6	10	34	34	11	12	16	19
?	5	11	10	9	14	20	30	19

Table 3: Estimated likelihood of success within case versions

Case Version	Diagnosis	Solution	Structure	M	s.d.
1	+	+	+	68.50	19.93
2	+	+	-	61.95	22.49
3	+	_	+	41.68	22.15
4	+	_	-	43.17	24.50
5	_	+	+	60.65	20.66
6	_	+	-	57.51	23.62
7	_	_	+	51.46	22.00
8	_	_	-	46.59	21.10

Table 4

Reasons for approval (A) or criticism (C) of selected solutions

Diagnosis Solution Structure	+ + +	+ + -	+ - +	+ - -	- + +	- + -	- - +	- - -	Σ
Unspecified A	14	9	7	15	21	16	16	17	115 (60)[ψ]
A owing to appropriate	36	30	4	2	18	18	2	4	114 (102)
A owing to the selected solution	5	-	3	-	7	1	2	2	20 (16)
A based on personal experience	2	2	5	5	10	1	7	8	40 (15)
∑ A	57	41	19	22	56	36	27	31	289
Unspecified C	1	5	6	9	3	7	5	8	44 (16)
C owing to lack of appropriate	5	1	31	24	1	3	11	5	81 (10)
C owing to mistaken diagnosis	11	11	3	5	10	13	8	6	67 (55)
C owing to lack of information or absence of diagnosis	2	2	1	5	6	9	7	8	40 (19)
C based on personal experience	8	16	10	13	17	12	16	20	112 (53)
C owing to mistaken choice of action.	4	-	14	11	4	1	12	1	47 (9)
Suggesting a different solution from those in the case	3	7	4	13	3	7	7	10	54 (20)
∑ C	34	42	69	80	44	52	66	58	445

[ψ] Frequency in versions with appropriate solutions

Table 5

Frequencies of general and appropriate-based approval (a) and criticism (b)

a

Case version	General approval	Approval owing to appropriate
Diagnosis + appropriate solution	23	66
No-diagnosis + appropriate solution	37	36

b

Case version	General criticism	Criticism owing to lack of appropriate
Diagnosis + non-appropriate solution	15	55
No-diagnosis + non-appropriate solution	13	16