Instructional Science **26:** 49–63, 1998.

Cognitive, metacognitive, and motivational aspects of problem solving

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Abstract. This article examines the role of cognitive, metacognitive, and motivational skills in problem solving. Cognitive skills include instructional objectives, components in a learning hierarchy, and components in information processing. Metacognitive skills include strategies for reading comprehension, writing, and mathematics. Motivational skills include motivation based on interest, self-efficacy, and attributions. All three kinds of skills are required for successful problem solving in academic settings.

Introduction

Suppose that a student learns a mathematical procedure such as how to find the area of a parallelogram. Later, when the student is given a parallelogram problem like the one she has studied, she is able to compute its area correctly. In short, the student shows that she can perform well on a *retention test*. However, when this student is asked to find the area of an unusually shaped parallelogram, she looks confused and eventually answers by saying, "We haven't had this yet." In short, the student shows that she cannot perform well on a *transfer test*, that is, on applying what she has learned to a novel situation.

This pattern of good retention and poor transfer is commonly observed among school students (Wertheimer, 1959). On *routine problems* – that is, problems that are like those they have already learned to solve – they excel; on *nonroutine problems* – i.e., problems that are not like any that they have solved in the past – they fail. Similar examples can be found in other academic domains, including reading and writing. If a goal of education is to promote transfer as well as retention, then this pattern of performance represents a serious challenge to educators.

How can students learn in ways that support solving both routine and nonroutine problems? How can teachers promote the learning of transferable problem solving skills? More than 50 years ago, Max Wertheimer eloquently posed the questions that motivate this article:

> Why is it that some people, when they are faced with problems, get clever ideas, make inventions, and discoveries? What happens, what are the processes that lead to such solutions? What can be done to help people to be creative when they are faced with problems? (Luchins & Luchins, 1970: 1).

Although Wertheimer can be credited with posing an important question, he lacked the research methods and cognitive theories to be able to answer it.

The mantle of Wertheimer's questioning has been passed to educational psychologists who are concerned with the issue of problem solving transfer (Chipman, Segal & Glaser, 1985; Halpern, 1992; Mayer & Wittrock, in press; Nickerson, Perkins & Smith, 1985; Segal, Chipman & Glaser, 1985). Despite success in understanding how to promote routine problem solving using tried-and-true versions of the drill-and-practice method of instruction, the discipline continues to struggle with how to promote nonroutine problem solving.

What does a successful problem solver know that an unsuccessful problem solver does not know? First, research on problem solving expertise (Chi, Glaser & Farr, 1988; Ericsson & Smith, 1991; Mayer, 1992; Smith, 1991; Sternberg & Frensch, 1991) points to the crucial role of domain-specific knowledge, that is, to the problem solver's *skill*. For example, some important cognitive skills for the parallelogram problem include the ability to identify the length and width of the parallelogram, and to perform arithmetic computations such as multiplying length times width to find area. An instructional implication of the skill-based view is that students should learn basic problem-solving skills in isolation.

Unfortunately, mastering each component skill is not enough to promote nonroutine problem solving. Students need to know not only what to do, but also when to do it. Therefore, a second ingredient, suggested by research on intelligence (Sternberg, 1985) and on the development of learning strategies (Pressley, 1990), is the ability to control and monitor cognitive processes. This aspect of problem-solving ability is the problem solver's *metaskill*. An instructional implication of the metaskill approach is that students need practice in solving problems in context, that is, as part of working in realistic problem-solving settings.

A focus solely on teaching problem solving skill and metaskill is incomplete, because it ignores the problem solver's feelings and interest in the problem. A third prerequisite for successful problem solving is suggested by recent research on motivational aspects of cognition (Renninger, Hidi & Krapp, 1992; Weiner, 1986), that is, the problem solver's *will*. This approach suggests that problem solving skill and metaskill are best learned within personally meaningful contexts, and that the problem solvers may need guidance in their interpretation of success and failure in problem solving.

The theme of this article is that successful problem solving depends on three components – skill, metaskill, and will – and that each of these components can be influenced by instruction. When the goal of instruction is the promotion of nonroutine problem solving, students need to possess the relevant skill, metaskill, and will. Metacognition – in the form of metaskill – is central in problem solving because it manages and coordinates the other components. In this article, I explore each of these three components for successful problem solving.

The role of skill in problem solving

Perhaps the most obvious way to improve problem solving performance is to teach the basic skills. The general procedure is to analyze each problem into the cognitive skills needed for solution and then systematically teach each skill to mastery. Although a focus on teaching basic skills may seem to be the most straightforward way to improve problem solving performance, the results of research clearly demonstrate that knowledge of basic skills is not enough. In this section, I explore three approaches to the teaching of basic skills in problem solving that have developed over the years – instructional objectives, learning hierarchies, and componential analysis – and show how each is insufficient when the goal is to promote problem-solving transfer.

Skills as instructional objectives

Sally wishes to learn how to use a new word processing system, so she takes a course. In the course, she learns how to save and open a document, how to move the cursor, how to insert text, how to delete text, and so on. For each skill, she is given a demonstration and then is asked to solve a problem requiring that skill. She continues on a skill until she can perform it without error; then, she moves on to the next skill. In this way she learns each of the basic skills involved in using the word processing package.

The approach taken in this instruction is to break the subject of word processing into component skills, and then to systematically teach each skill to mastery. In this approach, any large task can be broken down into a collection of "instructional objectives." Each objective is a single skill, such as being able to move the cursor from the end of a document to some point within the document. Bloom et al. (1956) developed a taxonomy of objectives, and programs of mastery learning were developed to insure that students accomplished each instructional objective (Block & Burns, 1976; Bloom, 1976).

Although mastery programs often succeed in teaching of specific skills, they sometimes fail to support problem-solving transfer. For example, Cariello (reported in Mayer, 1987) taught students to use a computer programming language using a mastery or conventional approach. The mastery group performed better than the conventional group on solving problems like those given during instruction, but the conventional group performed better than the mastery group on solving transfer items. Apparently, narrow focus on master of specific objectives can restrict the way that students apply what they have learned to new situations.

Skills as components in a learning hierarchy

Pat is learning how to solve three-column subtraction problems such as, 524 – 251 = __. First she practices simple subtraction facts (e.g., 5 – 2 = __). Then, she moves on to two column subtraction where no borrowing is needed (e.g., 54 – 21 = __). Next, she learns to solve two-column subtraction problems involving borrowing (e.g., 52 – 25 = __). In short, she learns to carry out the simpler computational procedures before moving on to the more difficult ones.

This instructional episode is based on Gagne's (1968; Gagne, Mayor, Garstens & Paradise, 1962) conception of learning hierarchies. A learning hierarchy is a task analysis that yields a hierarchy of subtasks involved in any problem-solving task. Validation of a learning hierarchy occurs when it can be shown that students who pass a higher-level task also are able to pass all prerequisite tasks in the hierarchy (White, 1974). Interestingly, students often are able to pass all prerequisite tasks but still fail to pass the corresponding higher-level task. For example, students who are able to subtract single-digit numbers (such as 6 – 1 = 5 or 15 – 9 = 6) and to regroup two-digit numbers as is required in "borrowing" (such as changing 75 to 6 tens and 15 ones) may not be able to carry out two-column subtraction (such as 75 – 19 = __). In this situation, students possess all the basic skills but still cannot carry out the task; what may be missing is the ability to organize and control the basic skills within the context of solving the higher-level task. Thus, research on learning hierarchies shows that possessing basic skills is a necessary, but not sufficient prerequisite for successfully solving higher-level problems.

Skills as components in information processing

Dan is taking a course to prepare him for college entrance examinations. As part of the training, he learns how to solve analogy problems, such as:

page:book:: room (a. door, b. window, c. house, d. kitchen)

The teacher describes and provides practice for each step in the process of analogical reasoning. First, Dan learns to encode each term: The A term is page, the B term is book, the C term is room, and there are four possible D terms. Second, Dan learns to infer the relation between the A and B term: in this example, page is a part of book. Third, Dan learns to apply the A–B relation to the C–D terms: room is a part of house. Finally, Dan learns to respond: the answer is (c).

This instructional episode is based on a componential analysis of analogical reasoning (Sternberg, 1985; Sternberg & Gardner, 1983). In componential analysis, a reasoning task is broken down into its constituent cognitive processes. For example, to solve an analogy problem, a problem solver needs to engage in the cognitive processes of encoding, inferring, applying, and responding. Training in componential skills, especially inferring and applying, tends to improve students' problem solving performance (Robins & Mayer, 1993). However, expertise in executing the component processes is not sufficient for problem-solving transfer. Based on a series of studies, Sternberg (1985) concludes that in addition to possessing cognitive components, problem solvers need to know how to orchestrate and control the cognitive components in any problem-solving task. Sternberg uses to term *metacomponents* to refer to these required metaskills.

The role of metaskill in problem solving

The foregoing section provides three examples – from research on instructional objectives, learning hierarchies, and componential analysis – in which cognitive skill is needed but by itself is not sufficient to support problem-solving transfer. In addition to possessing domain-specific skills, problem solvers need to be able to manage their skills; in short, metaskill seems to be an important component in problem solving. Metaskills (or metacognitive knowledge) involves knowledge of when to use, how to coordinate, and how to monitor various skills in problem solving. For example, knowing how to summarize is a skill but knowing that one should take detailed summary notes on a to-be-tested lecture requires a metaskill.

An important instructional implication of the focus on metacognition is that problem solving skills should be learned within the context of realistic problem-solving situations. Instead of using drill and practice on component skills in isolation – as suggested by the skill-based approach – a metaskill-based approach suggests modeling of how and when to use strategies in realistic academic tasks. In this section, I explore examples of metacognitive strategy training in reading, writing, and mathematics.

Strategy training in reading comprehension

Mary, a fourth-grader, is a good reader. She can read every word of a story aloud, without making any errors. However, when the teacher asks her what the story was about, Mary does not know what to say. When the teacher asks her a question requiring inference, such as why a character did something, again Mary cannot respond. Thus, even though she possesses the basic skills needed for efficient verbatim reading, she is not able to use what she has read to solve problems.

According to theories of active learning, Mary is not using meaningful reading strategies. For example, Brown & Day (1983) found that children have difficulty summarizing what they have read unless they are taught how to summarize stories. When students are taught how to summarize stories, their ability to answer questions about passages they read improves (Bean & Steenwyk, 1984; Rinehart, Stahl & Erickson, 1986; Taylor & Beach, 1984). In one study, Cook & Mayer (1988) taught students how to outline paragraphs found in their science textbooks. Students who received this training showed improvements in their ability to answer transfer questions based on the material in new passages.

The procedure used in teaching of reading comprehension strategies involves modeling of successful reading within the context of realistic academic reading tasks. In addition, students receive practice in describing their comprehension processes in the context of a reading task. Rather than practicing of basic component skills in isolation, successful comprehension strategy instruction requires learning within the context of real tasks. By embedding strategy instruction in academic tasks, students also acquire the metacognitive skills of when and how to use the new strategies.

Strategy training in writing

As part of an English class assignment, Peter is writing a persuasive essay. He is careful to spell each word correctly, use appropriate grammar, and write grammatically correct sentences. However, in spite of his excellent knowledge of the mechanics of writing, he produces an unconvincing essay that the teacher rates as low in quality. Peter seems to have the basic cognitive skills needed for writing but is unable to use these skills productively.

According to Hayes & Flower's (1986) analysis of the writing process, composing an essay involves planning, translating, and reviewing. Although Peter has the skills needed for translating – that is actually putting words on the page – he seems to lack planning and reviewing skills. He does not think about what is going to write and he does not monitor whether what he writes makes sense.

Through direct strategy instruction, however, students can learn how to plan and revise their essays. For example, several researchers have successfully taught students how to systematically generate a writing plan and how to review and revise what they have written in light of their plan (Fitzgerald & Teasley, 1986; Graham & Harris, 1988). Such programs involve modeling of the writing process by experts as well as having students describe their writing process in detail. Importantly, students who receive writing strategy training show improvements in the quality of what they write.

Strategy training in mathematics

Marco is working on an arithmetic story problem:

> Gas at ARCO costs $ 1.18 per gallon.
> This is 5 cents less per gallon than gas at Chevron.
> If you want to buy 5 gallons of gas,
> how much will you pay at Chevron?

He knows how to add, subtract, multiply, and divide. He knows the meaning of every word in the problem. Yet, when he sits down to work on the problem, he produces an incorrect answer. He subtracts 0.05 from 1.18, yielding 1.13; then he multiplies 5 times 1.13, producing a final answer of 5.65.

Although Marco possesses the basic skills for solving the gas problem, he fails. According to Mayer's (1985, 1992) analysis of mathematical problem solving ability, solving a story problem requires representing the problem, devising a solution plan, and executing the plan. Marco is able to carry out the arithmetic operations needed to execute the solution; however, he seems to misunderstand the problem. It follows that his problem solving performance would improve if he learned how to represent the problem within the context of actually trying to solve it. For example, when Lewis (1989) taught students how to represent story problems using a number-line diagram, students' problem solving performance improved dramatically and they were able to transfer what they had learned to new types of problems.

Similarly, Schoenfeld (1979) successfully taught mathematical problem-solving strategies, such as how to break a problem into smaller parts, and found that the training transferred to solving new types of mathematics problems. These studies show that, in addition to mastering the needed arithmetic and algebraic skills, students need to be able to know when and how to use these skills – knowledge that Schoenfeld (1985) refers to as *control*. The most successful instructional technique for teaching students how to control their mathematical problem-solving strategies is cognitive modeling of problem-solving in context, that is, having a competent problem solver describe her thinking process as she solves a real problem in an academic setting (Mayer, 1987; Pressley, 1990).

In summary, research on strategy training shows that knowledge of basic skills is not enough for successful performance on complex academic tasks such as reading comprehension, writing, and mathematical problem solving. In each case, students benefited from training that was sensitive to the metacognitive demands of the task, that is, from learning when and how to apply domain-specific learning strategies. The term "conditional knowledge" can be used to describe this aspect of metacognition.

The role of will in problem solving

The role of motivation in learning to solve problems has a long history in educational psychology, yet theories of problem solving instruction have not always emphasized the role of motivation. This section examines three approaches – interest theory, self-efficacy theory, and attributional theory. Although they differ in many ways, the three approaches also share a cognitive view of motivation – the idea that the will to learn depends partly on how the problem solver interprets the problem solving situation.

Motivation based on interest

In preparation for a physics test, Mary learns to solve every computational problem in her physics textbook involving the laws of motion. In contrast, Betsy has decided to build a roller coaster as a class project and in order to accomplish this goal she finds that she needs to understand the physical laws of motion. Both students learn to solve motion problems but Mary learns based on effort and Betsy learns based on interest.

Who will learn more deeply? More than 80 years, John Dewey (1913) eloquently argued that the interest-based learning of Betsy results in qualitatively better learning than the effort-based learning of Mary. According to Dewey, the justification of educators favoring an effort-based approach is that "life is full of things not interesting that have to be faced," so teachers should not spoil students by making school a place where "everything is made play, amusement . . . everything is sugar coated for the child" (Dewey, 1913: 3–4). In contrast, the interest-based approach assumes that when a child "goes at a matter unwillingly [rather] than when he goes out of the fullness of his heart" the result is a "character dull, mechanical, unalert, because the vital juice of spontaneous interest has been squeezed out" (Dewey, 1913: 3).

Effort theory and interest theory yield strikingly different educational implications. The effort theory is most consistent with the practice of teaching skills in isolation, and with using instructional methods such as drill-and-practice. The interest theory is most consistent with the practice of teaching skills in context, and with using instructional methods such as cognitive apprenticeship. Dewey (1913: ix) pleads for the central role of interest in education: "Our whole policy of compulsory education rises or falls with our ability to make school like an interesting and absorbing experience to the child." Rather than forcing the child to work on boring material, Dewey (1913: ix) argues that "education only comes through willing attention and participation in school activities."

Although Dewey's writings are based on logical arguments rather than empirical research, modern research includes empirical studies of two types of interest – individual interest and situational interest (Renninger, Hidi & Krapp, 1992). Individual interest refers to a person's dispositions or preferred activities, and therefore is a characteristic of the person; situational interest refers to a task's interestingness, and therefore is a characteristic of the environment. In both cases, interest is determined by the interaction of the individual and the situation.

Interest theory predicts that students think harder and process the material more deeply when they are interested rather than uninterested. In a recent review of 121 studies, Schiefele, Krapp & Winteler (1992) found a persistent correlation of approximately $r = 0.30$ between interest – how much a student liked a certain school subject – and achievement – how well the student performed on tests in a certain school subject. In another set of studies, Schiefele (1992) found that students who rated a passage as interesting engaged in more elaboration during reading the passage and were better able to answer challenging questions than students who rated the topic as uninteresting. These results are consistent with the predictions of interest theory, and show how the learner's cognitive activities on school tasks is related to the specific significance of the material to the learner.

Interest theory also predicts that an otherwise boring task cannot be made interesting by adding a few interesting details. Dewey (1913: 11–12) warned that "when things have to be made interesting, it is because interest itself is wanting." To test this idea, Garner, Gillingham & White (1989) asked students to read passages about insects that either did or did not contain seductive details – highly interesting and vivid material that is not directly related to the important information in the text. Similar to the findings of other studies (Wade, 1992), adding seductive details did not improve learning of the important information although the details themselves were well remembered. Wade (1992) suggests that educators should focus on techniques that increase cognitive interest – being able to make sense out of material – rather than emotional interest – overall arousal and excitement.

According to interest theory, students will work harder and be more successful on problems that interest them than on problems that do not interest them. For example, in one study, some elementary school children learned how to solve mathematics problems using personalized examples that contained information about the individual student's friends, interests, and hobbies, whereas other students learned from non-personalized examples (Anand & Ross, 1987). Consistent with interest theory, students who learned with personalized examples subsequently performed better on solving transfer problems. Similarly, Ross et al. (1985) compared nursing and education students who learned statistics using examples that either did or did not come from their disciplines. As predicted by interest theory, subsequent transfer performance was best for nursing students who had received medical examples and education students who had received examples based on teaching.

These results are particularly important because they focus on problem-solving transfer. The theme in this line of interest research is that students learn more meaningfully when they are interested in the material. Unfortunately, researchers have not yet been able to clearly specify the mechanism by which interest affects what is learned, or even to clearly specify what interest is. However, on-going research on interest is useful, especially in light of the role that interest seems to play in promoting problem-solving transfer.

Motivation based on self-efficacy

Sally is taking a class on how to use a new graphics program. She has never used graphics program before so she is somewhat nervous and unsure of herself. After a few minutes of hands-on experience, she finds she is able to draw some figures quite easily, so her self-efficacy increases. She looks over to see that other first-time users like herself are also able to use the program to make drawings. Again, her self-efficacy grows because she reasons: "If they can do it, I can do it." Her instructor walks by Sally's computer and says, "You can do this!" This vote of confidence pushes Sally's self-efficacy even higher. Eventually, she loses her initial state of high anxiety, including high heart rate and nausea, and she becomes relaxed in front of the computer. This change in body state signals an increase in Sally's self-efficacy.

Self-efficacy refers to a person's judgments of his or her capabilities to accomplish some task. This scenario exemplifies four sources of self-efficacy, namely, when Sally interprets her own performance, the performance of others around her, others' assessments of her capabilities, and her own physiological state. According to Schunk (1991: 209): ". . . students derive cues signaling how well they are learning, which they use to assess efficacy for further learning." Furthermore, Schunk (1991: 209) concludes that "motivation is enhanced when students perceive they are making progress in learning."

Self-efficacy theory predicts that students work harder on a learning task when they judge themselves as capable than when they lack confidence in their ability to learn. For example, Zimmerman & Martinez-Pons (1990) found that students' ratings of their verbal skills was strongly correlated with their reported use of active learning strategies on a verbal task. Pintrich & De Groot (1990) found strong correlations between students' self-efficacy and their use of active learning strategies in various classes. Schunk (1991) reported a positive correlation between self-efficacy and persistence on exercise problems during arithmetic learning. These kinds of results support the prediction that self-efficacy is related to deeper and more active processing of information during learning.

Self-efficacy theory also predicts that students understand the material better when they have high self-efficacy than when they have low self-efficacy. For example, Schunk & Hanson (1985) found that students' ratings of problem difficulty before learning were related to test scores after learning to solve arithmetic problems. In particular, students who expected to be able to learn how to solve the problems tended to learn more than students who expected to have difficulty.

Finally, self-efficacy theory predicts that students who improve their self-efficacy will improve their success in learning to solve problems. Schunk & Hanson (1985) provided self-efficacy instruction to some students but not to others; the instruction involved watching videotapes of students successfully solving arithmetic problems, while occasionally making positive statements such as "I can do that one" and receiving positive feedback from the teacher. Students who received training learned to solve arithmetic problems more effectively than students who did not. These findings support the idea that self-efficacy can influence how students learn to solve problems in an academic setting.

Motivation based on attributions

As the teacher passes back the math tests, Joe squirms in his seat. At last, the teacher hands him his paper, and right at the top the teacher has written a failing grade in red. Joe searches for a justification for this outcome. He could attribute the failing grade to his ability: "I'm not very good in math." Instead, he might attribute his failure to lack of effort: "I really didn't study very hard." Perhaps, the cause of his failure is task difficulty: "That was a hard quiz." Alternatively, he might judge the cause of his failure to be luck ("I made some unlucky guesses"), mood ("I just had a bad math day"), or hindrance from others ("The guy in front of me was so loud I couldn't concentrate").

These are examples of attributions that learners may give for their failures or successes on academic tasks. According to attribution theory, the kind of causal ascriptions that a student makes for successes and failures is related to academic performance (Weiner, 1986). In particular, students who attribute academic success and failure to effort are more likely to work hard on academic tasks than students who attribute academic success and failure to ability. Furthermore, students infer that they lack ability when teachers offer sympathy or pity in response to failure whereas students infer the need to work harder when teachers encourage persistence on a task.

When faced with failure on a problem, some students quit whereas others simply work harder. Borkowski, Weyhing & Carr (1988) have devised an instructional program to encourage students to attribute failure to lack of effort rather than lack of ability. Learning disabled students were given strategy training in how to summarize paragraphs and attribution training which emphasized the importance of trying hard and using the strategy. Students who received both types of training performed better on answering transfer questions about passages than students who received only strategy training. These results show that students need to learn cognitive strategies such as effective study aids and motivational strategies such as the belief that academic success depends on effort.

When teachers show a student how to solve a problem, they may be conveying the message that the student is not smart enough to figure out how to solve the problem. For example, Graham & Barker (1990) asked elementary school students to view videotapes in which two students solved math problems on a worksheet and then were told they had done well, correctly answering 8 out of 10 problems. In the videotape, one of the students was helped by the teacher who happened to be walking by his desk, whereas the other student worked on the problems without any hints from teacher. Students viewing the videotape rated the helped boy as less able than the unhelped boy, even though neither student asked for help and both did well on solving the problems.

In a related study by Graham (1984), students were given a series of puzzles to solve, with one minute allowed for each puzzle. If students failed to solve a puzzle within one minute, the teacher told them to stop and then displayed the correct solution. For some students the teacher expressed pity by saying she felt sorry for the student, whereas for others she simply told them they had failed. Pitied students were more likely to cite lack of ability as the cause of their failure than were unpitied students. These studies show that when the teacher provides unsolicited help or expresses pity, students may infer that the teacher has a low opinion of their ability. Students may then come to accept this assessment, which in turn causes them to give up when faced with a difficult academic problem-solving task.

In summary, in this section I have explored three possible sources of motivation to learn, namely interest, self-efficacy, and attribution. In each case, the will to learn can have significant influence on students' problem-solving performance. Future research is needed to determine whether any one of these three approaches is sufficient, or whether each contributes something unique to student motivation. In contrast to classic approaches to motivation, these three views of motivation share a focus on the domain-specificity of motivation, on connecting motivation with cognition, and on examining motivation in realistic academic settings. In short, research on academic motivation points to the important role of will in problem solving.

Conclusion

Tom is working on geometry problem that he has never seen before. He begins enthusiastically, but he soon runs into a dead end. Not knowing what to do, he quits saying, "We haven't had this yet." Why did Tom fail? Perhaps he lacked the cognitive tools he needed, such as basic knowledge of geometry. We give him a short test of basic geometry and find that he is highly knowledgeable, so we rule out cognitive factors as a source of the failure. This leaves two other possibilities – metacognitive and motivational factors may be involved. On the metacognitive side, Tom may not know how to devise, monitor, and revise a solution plan, so whenever the most obvious plan fails he is lost. On the motivational side, Tom may have a low estimation of his ability to solve this kind of problem, so whenever he runs into trouble he wants to quit.

How can we help students like Tom to become better problem solvers? The theme of this article is that three components are needed: skill – domain-specific knowledge relevant to the problem-solving task; metaskill – strategies for how use the knowledge in problem solving; and will – feelings and beliefs about one's interest and ability to solve the problems. According to this view, instruction that focuses only on basic skills is incomplete. Problem-solving expertise depends on metacognitive and motivational factors as well as purely cognitive ones.

Continued research is needed to understand (a) how skill, metaskill, and will together contribute to problem solving; (b) why skill, metaskill, or will alone is not sufficient for far-transfer to occur; and (c) how best to help students acquire needed skill, metaskill, and will for successful problem solving.

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