# Teacher Guide
# College and Career Competency: *Problem Solving*

## Definition:

Problem solving is the process of determining an unknown "series of actions" to take in order to find a solution (Muir, Beswick, & Williamson, 2008) and involves calculations, application of various strategies, rationalization, beliefs, and social influences (English & Sriraman, 2010).

## Essential Components for Students:

1. Apply a disciplined approach that begins with identifying the problem, making a plan for a solution, applying the solution, and then reflecting on outcomes.
2. Modify strategies to solve a problem based on new information or outcomes.

## Research:

- In academia, problem solving is a fundamental approach to accomplishing successful learning in subjects such as science and mathematics because it engages students in a multi-step cognitive process that requires them to dissect and understand the problem, construct creative strategies to address the problem, and test these strategies in order to find an effective solution (Liu, Cheng, & Huang, 2011).
    - The theory of ***constructionism*** (introduced by Seymour Papert) indicates that supporting students in constructing problem-solving theories on their own in order to effectively engage their focus and appropriately challenge them to create original solutions is more conducive to learning problem-solving skills than simply teaching students content knowledge (Liu et al., 2011).
    - Traditional problem-solving skills training supports students' acquisition of a ***conceptual understanding*** of problem-solving procedures. Often, students go through the motions of a set of learned procedures to solve problems without understanding how or why those procedures work. By prompting students to think about the various steps in the problem-solving process – for example, by asking students how they evaluated the information or broke the information down into smaller components – the teacher can focus on the types of things that successful problem solvers do. This, in turn, can aid the teacher in ***modeling***—or demonstrating—effective problem-solving strategies for students who are working on improving their problem-solving skills (Muir et al., 2008).
- Selçuk, Çalışkan, and Erol (2008) found that instruction in problem-solving strategies enhanced achievement in a college science course.
- The *Adult Literacy and Life Skills Survey* results showed a strong positive relationship between problem-solving skills and literacy (OECD and Statistics Canada, 2011).
- Students in middle school science classes that used inquiry-based materials were found to perform significantly better on a standardized achievement test than their peers (Geier et al., 2008).
- Studies that focus on problem solving outside of the classroom have found that students' mastery of "mathematical modeling," or the ability to adapt mathematical models in order to

solve new problems, is valuable in the modern world, which is comprised of complex systems. Mathematical modeling is when "students paraphrase, explain, draw diagrams, categorize, find relationships... quantify, or make predictions" (Chan, 2009, p. 39) to develop a conceptual system. Mathematical modeling allows students to bridge abstract mathematical concepts to real-life problems, which promotes meaningful learning while preparing students for problem-solving experiences outside of the classroom (English & Sriraman, 2010).

- Research shows that students' problem-solving skills training can be effectively supported by students working on problems with others.
    - **Teamwork**, also known as *collaborative learning*, can have a better impact on learning than when students work alone. Working in groups enables students to retain larger quantities of information and promotes brainstorming of new ideas (Kuo, Hwang, & Lee, 2012).
- A successful problem solver must be able to interpret information, apply logic and make plans, review results, and attempt different strategies when necessary. In addition to these skills, problem solvers are also impacted by a variety of intrinsic and extrinsic factors (Muir et al., 2008).
    - *Beliefs or misconceptions.* Understanding that the steps in the problem-solving process are more important than completing an assignment quickly is critical to good problem solving. For example, if a student believes that successful problem solving is demonstrated by the speed at which he/she can find a solution, then the student is less likely to dedicate ample time to the problem-solving process and may skip crucial steps, which can result in an incomplete solution (Muir et al., 2008).
    - *Attitudes and feelings.* Students with low **self-efficacy** or **motivation** have been shown to be less successful problem solvers (Muir et al., 2008).
    - *Metacognition*. The state of active consciousness of one's thought processes, which enables problem solvers to make methodical decisions. Examples include applying heuristics, or "rules of thumb;" choosing strategies; planning steps towards reaching a solution; and making changes to those plans when necessary (Muir et al., 2008).
- Computer simulation games can offer an effective setting for problem-based learning by providing students with a series of "ill-structured problems," such as those normally found in real life, that stand in the way of the player's progress. Unlike well-structured problems, which have clear-cut solutions, ill-structured problems offer students a more meaningful problem-solving experience; they promote students' application of various problem-solving tactics while fostering the discovery of new rules and concepts and engaging students as active learners of content material (Kiili, 2005).
- Research indicates that working on improving students' abilities to search for information can result in an enhanced ability to solve problems in a web-based environment (Kuo et al., 2012).

## Assessments:

- The Association of American Colleges and Universities (AACU) offers an instrument that can help assess students' problem-solving abilities: *The Problem Solving VALUE Rubric* (Association of American Colleges and Universities, 2010). An excerpt is shown below. The full version of the *VALUE Rubric* can be accessed from the AACU website at http://www.aacu.org/value/rubrics/problem-solving. There is no charge, but you are required to create an online account.

### PROBLEM SOLVING VALUE RUBRIC

*for more information, please contact value@aacu.org*

Association of American Colleges and Universities

**Definition**

Problem solving is the process of designing, evaluating, and implementing a strategy to answer an open-ended question or achieve a desired goal.

*Evaluators are encouraged to assign a zero to any work sample or collection of work that does not meet benchmark (cell one) level performance.*

| | Capstone 4 | Milestones 3 | Milestones 2 | Benchmark 1 |
|---|---|---|---|---|
| **Define Problem** | Demonstrates the ability to construct a clear and insightful problem statement with evidence of all relevant contextual factors. | Demonstrates the ability to construct a problem statement with evidence of most relevant contextual factors, and problem statement is adequately detailed. | Begins to demonstrate the ability to construct a problem statement with evidence of most relevant contextual factors, but problem statement is superficial. | Demonstrates a limited ability in identifying a problem statement or related contextual factors. |
| **Identify Strategies** | Identifies multiple approaches for solving the problem that apply within a specific context. | Identifies multiple approaches for solving the problem, only some of which apply within a specific context. | Identifies only a single approach for solving the problem that does apply within a specific context. | Identifies one or more approaches for solving the problem that do not apply within a specific context. |
| **Propose Solutions/Hypotheses** | Proposes one or more solutions/ hypotheses that indicates a deep comprehension of the problem. Solution/ hypotheses are sensitive to contextual factors as well as all of the following: ethical, logical, and cultural dimensions of the problem. | Proposes one or more solutions/ hypotheses that indicates comprehension of the problem. Solutions/ hypotheses are sensitive to contextual factors as well as the one of the following: ethical, logical, or cultural dimensions of the problem. | Proposes one solution/ hypothesis that is "off the shelf" rather than individually designed to address the specific contextual factors of the problem. | Proposes a solution/ hypothesis that is difficult to evaluate because it is vague or only indirectly addresses the problem statement. |
| **Evaluate Potential Solutions** | Evaluation of solutions is deep and elegant (for example, contains thorough and insightful explanation) and includes, deeply and thoroughly, all of the following: considers history of problem, reviews logic/ reasoning, examines feasibility of solution, and weighs impacts of solution. | Evaluation of solutions is adequate (for example, contains thorough explanation) and includes the following: considers history of problem, reviews logic/ reasoning, examines feasibility of solution, and weighs impacts of solution. | Evaluation of solutions is brief (for example, explanation lacks depth) and includes the following: considers history of problem, reviews logic/ reasoning, examines feasibility of solution, and weighs impacts of solution. | Evaluation of solutions is superficial (for example, contains cursory, surface level explanation) and includes the following: considers history of problem, reviews logic/ reasoning, examines feasibility of solution, and weighs impacts of solution. |
| **Implement Solution** | Implements the solution in a manner that addresses thoroughly and deeply multiple contextual factors of the problem. | Implements the solution in a manner that addresses multiple contextual factors of the problem in a surface manner. | Implements the solution in a manner that addresses the problem statement but ignores relevant contextual factors. | Implements the solution in a manner that does not directly address the problem statement. |
| **Evaluate Outcomes** | Reviews results relative to the problem defined with thorough, specific considerations of need for further work. | Reviews results relative to the problem defined with some consideration of need for further work. | Reviews results in terms of the problem defined with little, if any, consideration of need for further work. | Reviews results superficially in terms of the problem defined with no consideration of need for further work |

- The *Mathematics Problem Solving Official Scoring Guide* is a rubric that supports students in applying math in a variety of settings through rating process dimensions of: a) making sense of the task, b) representing and solving the task, c) communicating reasoning, d) accuracy, and e) reflecting and evaluating. It is available at http://www.ode.state.or.us/wma/teachlearn/testing/scoring/guides/2011-12/mathpsscoringguide_eng.pdf (Oregon Department of Education, 2011).
- The *Program for International Student Assessment* (PISA) measures how well 15-year old students can apply knowledge and competencies in areas like mathematics, reading, science, and problem solving. The most recent PISA, conducted in 2012 by the Organization for Economic Cooperation and Development (OECD) across 65 countries, found that boys showed better problem-solving skills than girls. The study also found that when working on problem-solving exercises, girls were better at "planning and executing" processes than boys. These processes measure the ability to use content knowledge previously learned to develop a plan for addressing a problem. However, boys scored higher on "representing and formulating" processes, which measure the ability to make sense of the information in the problem by re-

organizing key factors and identifying any relationships between those factors (OECD, 2014). To see the 2012 PISA results for problem solving, go to http://nces.ed.gov/surveys/pisa/pisa2012/pisa2012highlights_11.asp.

- Self-assessment activities incorporated in problem-solving skills training can help students identify the types of problems they struggle with as well as the mistakes they make while working on problems. Students can then work with teachers to specifically address the areas that they can improve in (Long & Aleven, 2013).
    - The 18-item *Problem-Solving Skills Self-Assessment* (ASDAN, 2012) is available from the Online Resource Bank (ORB) website at http://www.theorb.org.uk/resources/159-10-4-2012-08-23%2015:23:06. Items are scored "Always," "Sometimes," or "Hardly Ever."
        - I recognize when I have a problem.
        - I know when I've solved a problem.
        - I can usually see more than one possible solution to a problem.
        - I always check that I understand the problem.
        - People ask my advice about problems.
        - I can work out what resources I need to resolve problems.
        - I suggest ways of solving problems.
        - I ask other people for advice when I'm stuck on a problem.
        - I avoid jumping at the first solution that I come up with.
        - My solutions to problems take account of safety.
        - I listen to other people's suggestions and take note of them.
        - I can weigh up different options to find the best solutions to problems.
        - I think about how I'll know if a problem has been solved.
        - I can find out about risks involved in tackling problems.
        - I can work with other people to solve problems.
        - I can work out solutions for myself.
        - I stay calm when people don't accept my solutions.
        - If my solution doesn't work, I find out why.

## Instructional Practices:

- Instructors can help students learn problem solving and at the same time facilitate **teamwork** and cooperative learning by guiding learning through a problem-based exercise, where students work in a small group to solve concrete problems (Hmelo-Silver, 2004).
    - The exercise begins with a realistic and ill-structured problem. The students identify facts, generate ideas, and identify concepts ("learning issues") that they need to learn more about before they can solve the problem. They independently research the learning issues, then regroup to share what they learned. The students also reconsider any hypotheses or generate new hypotheses based on the learning. Finally, the students reflect on the problem as well as their self-directed and collaborative learning experiences.
    - The teacher's role is to facilitate the learning process and model the reasoning and problem-solving strategies.
    - Collaboration occurs as the students negotiate ideas and understand what new knowledge each team member brings to the group.
    - Tools can include a structured whiteboard with columns identifying the facts, ideas, learning issues, and an action plan.

- Stories are a powerful tool for learning how to solve problems in the real world because they offer authentic examples of "ill-structured problems," which are complex, multifaceted problems that can be solved in multiple ways. Students can use lessons that they've learned from stories and adapt them to adequately address new problems. This learning strategy gives students the opportunity "to gain experience vicariously" as they obtain insight into effective problem solving from experts through stories that recount problem-solving experiences (Jonassen & Hernandez-Serrano, 2002).
    - "Social stories" have been widely used in helping students with autism learn positive behaviors when confronted with problematic situations. This behavioral intervention strategy can also be used in working with other students who may require social and behavioral support. A teacher can develop a social story or "narrative" for a student by analyzing the student's inappropriate behavior and depicting a similar situation in the story where the student demonstrates positive and appropriate behavior (Vicker, 1998). Additional information and resources for using social stories in the classroom can be found at http://carolgraysocialstories.com/social-stories/what-is-it/ (Gray, n.d.).
- When teaching mathematical concepts, incorporate problems that can take place in the real world in order to promote students' development of complex problem-solving skills through many rounds of interpretation (English & Sriraman, 2010). Other strategies for teaching mathematics through problem solving include beginning with an exploration of the problem situation, which will tend to be open-ended (Cai, 2010). This exploration, which is guided by the teacher, is an essential part of this instructional strategy as students apply "any approach they can think of, and draw on any piece of knowledge they have learned" (p. 255). The advantage is that "students have ownership of the knowledge because they devise their own strategies to construct the solutions" (p. 255).
- Apply the *Learning Together* (LT) model (Johnson & Johnson, 1987) in the classroom by assigning problem-solving tasks to groups of four to six students and encouraging them to collaboratively work together to come up with a single solution for each task. Assigning students to work in groups of mixed skill levels has been shown to have a positive influence on learning achievement for students who struggle with problem solving (Kuo et al., 2012).
    - Additional information on cooperative learning strategies like this one can be found at http://www.co-operation.org/what-is-cooperative-learning (Johnson & Johnson, 2011).
    - Ideas for collaborative learning strategies for classrooms can be found at http://www.acu.edu.au/__data/assets/pdf_file/0003/405768/Large_Group_Lectures_LTC.pdf (Australian Catholic University, 2012).
- *Cognitive apprenticeship* is a six-step, hands-on learning model that has been proven to help students in developing cognitive and metacognitive thinking skills. When applied to problem-solving skills training, students first observe problem solving demonstrated by an expert and then work together with the expert or instructor to replicate techniques used in the model demonstration (Kuo et al., 2012).
    - Apply the cognitive apprenticeship model in the classroom by assigning an experienced problem solver to teach students exemplary problem-solving techniques through demonstration and elaboration of cognitive processes. The procedure outlined within this learning model allows teachers to assess students' individual levels of problem-solving expertise during steps two through four, which are also known as "Coaching," "Scaffolding," and "Articulation." Students have the opportunity to assess their own problem-solving skills compared to their classmates and the expert instructor during step five, also known as "Reflection" (Kuo et al., 2012). More detailed information on this learning model can be found at

http://www.learner.org/courses/learningclassroom/support/08_cog_app.pdf (Darling-Hammond, Austin, Lit, & Martin, n.d.).

- Problem-posing activities, in which students generate their own problems, have been proven to help students develop their problem-solving skills while strengthening their understanding of ideas presented in course material, supporting the advancement of their metacognitive and cognitive skills, and preparing them to efficiently solve similar problems in the future. This learning activity consists of four steps: "problem-posing," "planning," "carrying out," and "looking back." In the last step, students reflect on their process and decide whether the correct problem was posed. Then, they may decide to pose new problems (Chang, Wu, Weng, & Sung, 2012).
    - For example, a teacher could present a historical event that the students are studying, like the American Revolution, and ask the student to identify a problem (e.g., Washington's troops running out of supplies). The student would then construct their own solution through planning and execution, then reflect back on it.
- Implement the *Case-Based Reasoning Cycle* (Aamodt & Plaza, 1996, as cited by Jonassen & Hernandez-Serrano, 2002) in problem-solving skills training by teaching students to apply previously learned lessons to new problems. Encourage students to adapt or revise old solutions when necessary. When students are unable to recall an applicable case to solve a new problem, they generate a new solution that can be used to solve future problems (Jonassen & Hernandez-Serrano, 2002).
- Use the *Question Analysis Strategy* to help students analyze information presented in a problem more deeply prior to hypothesizing a solution by following five steps: "(1) Read one or two sentences, (2) Underline the key words, (3) Reorganize the information in the section you have just read, (4) Recall the areas of *chemistry**, (5) Relate your knowledge of *chemistry** with the information in the problem" (Sutherland, 2002).
  *This Question Analysis Strategy was designed to be used in a Chemistry class, but it can be adapted for use in other areas of study.

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