CHAPTER 6

Problem-solving characteristics in gifted and advanced learners

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Cognitively advanced learners approach and solve problems using processes that are similar to those used by all problem solvers, but in some respects unique and fascinating. Some differences are related to the nature of the problems, others to the capabilities comprising giftedness. Some differences are more social. We summarize below how cognitively advanced learners find, create, and solve problems; the nature of their skills; and their preferences, highlighting the voice of one such problem solver.

WHAT IS PROBLEM SOLVING?

All problems share the common features of having a beginning or initial state and an end called a goal state. All the possible paths from the beginning to the end are called the problem space. Most narrowly, problem-solving occurs in a well-defined problem space such as doing practice examples from school lessons. These often have a known "right answer" (sometimes printed in the back of textbooks), relative clarity in what information is needed to solve the problem, and only a few paths from the beginning to the end. They commonly require just minutes to solve, usually individually by each pupil. Advanced learners often find these kinds of problems to be repetitive and uninteresting, especially after the first few. They do them quickly and accurately.

At another extreme are the world's great challenges: health, poverty, peace, equity, water, food, education, climate, racism, and more. These ill-defined problems have no clear end state to indicate when they are solved, there is uncertainty regarding what information is needed to address the problem, and the problem space includes possibly infinite paths. When given an opportunity, young people have played critical roles in addressing these, too.

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In between these extremes, there is a wide range of school and home tasks that provide practice and invoke organizational and social skills, creativity, and finding the next topic to explore. Teachers and parents sometimes suggest topics, as in science, history, or other knowledge fairs, or students can choose or invent the questions. Sometimes even the experts do not know the answers to questions learners ask. These are learning experiences that build inquisitive dispositions, content knowledge, and methodological skills that can be combined and extended to bigger theoretical and practical challenges in the future. A problem is an opportunity to connect interests and motivation to knowledge about the material and how to understand it, and to ask important and challenging questions. These activities can extend over days, weeks, and months. Sometimes they can be tackled alone, but other times collaboration is an advantage, and sometimes group work is essential.

Problem solving mostly refers to school tasks that engage learners in complex thinking and that require a pause to think through the challenge before plunging in to begin providing an answer. Problems can arise from any source: the learner's own imagination, music lessons, sports, drama clubs, puzzle books, or elsewhere. Especially, valuable are learning experiences that involve tasks carefully selected to require the learner to go beyond what they already know, or can achieve alone without any help from peers, family, teachers, and other sources.

WHAT DO WE MEAN BY GIFTED?

We use the word gifted, but are not fixated on a single meaning. Many school districts define giftedness in terms of high IQ. IQ tests are collections of rather brief verbal, mathematical, or visual problems in which a higher score is obtained by quickly and accurately producing the one correct answer. Being accurate is more important than being quick, although excessive dawdling or daydreaming is counterproductive. Creativity is another aspect of giftedness, one that is expressed in seeing more than one solution to a question and coming up with original or unique questions or answers. An educationally useful way to understand giftedness is that it involves thinking and developing like an expert. Expertise differs across subjects: Chemists make new discoveries differently from historians. Nevertheless, most experts share some characteristics. They are passionate about their interests, plan before they act, self-evaluate, and are open to new evidence to update their knowledge.

In gifted or advanced learners, there is another important side to problem solving that happens more often than with many other children: problem finding. Advanced learners more often identify complex or big questions they are curious about, even though all children are curious. Even though all children ask questions, children identified as advanced learners typically ask more questions (surely, we have been hounded by why? how? and other questions we do not know the answers to!). One of our favorite stories is about the physics Nobel Laureate, Isidore Rabi. A magazine interviewer asked how he became a scientist (Schulman, 1993). He replied, most parents asked what their children learned in school that day. His mom asked what good questions he asked!

HOW ADVANCED LEARNERS SOLVE PROBLEMS – WHAT IS UNIQUE?

Let's begin with 12-year-old Emma's recollection, in her own words, of her science-fair project a year earlier. We'll then pick out some of the main points.

> Science fair is an important annual initiative at my school. Students work alone or with a peer on open-ended investigations, usually with countless solutions and driven by the student's interest. Reflecting back on my process, I see five major steps emerging.
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> The first step was brainstorming. Unlike the majority of my peers, I prefer to work alone, and this proved itself as an asset during my brainstorming process. Numerous ideas went through my mind as potential topics for my science-fair project and I did not need to compromise on one idea that usually is approved in a democratic way by the majority, which oftentimes does not suit my needs. This time, I could allow myself to drift to different fields of science and explore, soon to find out that brainstorming requires not only reflection but also a great deal of research and learning in order to figure out the question one wants to pose. I specifically looked for examples and articles that would fit in with my ideas. I had three main ideas: (a) the design of a blood-pressure bracelet device connected to 911, which I decided to leave for a future science fair because of its complexity; (b) the exploration of an environmentally friendly alternative to the salt used to defrost streets during winter, which damages our fresh water streams and its fauna, not to mention our pets' paws and even our shoes, and finally (c) the investigation of a project on critical thinking that proved itself worthy and led me to receiving a bronze medal. It must have been early September when mom placed an article on my nightstand, as she usually does, that caught my attention. It was written by psychologist Daniel Willingham who shared about a classic experiment conducted in the 80s, in which university students were asked to solve a problem. They were asked if and how a malignant tumor could be treated with a particular type of ray that causes major collateral damage to the healthy tissue. Very few participants were able to solve the problem in the allotted 20 minutes. Prior to the problem-solving activity, the same group of students read a story describing a military situation similar to the medical problem. Instead of rays attacking a tumor, rebels were this time attacking a dictator hiding out in a fortress. The military story described the solution, but despite reading it moments before trying to solve the medical problem, participants did not see the analogy: Disperse the forces to avoid collateral damage and have forces converge at the point of attack. Simply mentioning that the story can help solve the medical problem boosted solution rates to nearly 100%. Using the analogy was not hard; the problem was thinking

to use it in the first place. Willingham made the point that university students fail to use generic thinking skills in their everyday life and questioned whether students are wasting their time learning these skills. This article was my Eureka! I wanted to learn if the same result holds true when the experiment is given to high school students, like me. So, my science-fair study looked at whether general critical thinking strategy transfers from a subject to another and to real world problems in general. If it does not transfer then I would agree with Dr. Willingham, in that learning about these skills in disconnect from discipline would be a waste of time for students and their teachers.

The second step was planning. It was important for me to get all my elements ready for my final project and organize them well. First, I read some research papers with similar experiments as the one I described above. The readings helped me develop the methods of investigation and helped me decide on the problems, I will give to the participants in my study. I hoped to get about 20–30 participants. Science fair was in February, and I had finished my planning stage in late December to early January.

The studies I read showed there is not yet a strategy proven effective to teaching generic thinking skills but there is a good understanding of how to teach more specific critical thinking skills. Willingham (2019) proposed a four-step plan that really talked to me and to the teachers who were curious about my science-fair project.

1. Identify what is meant by critical thinking in the specific domain.
2. Identify the content domain that students need to learn.
3. Teach the specific skills and knowledge explicitly and then have students practice them.
4. In order for skills to stick with students forever, or at least for a long time, the skills must be practiced in different ways over and over for a minimum of three to five years.

The third vital step was the actual experimentation process. Participants were expected to read two scenarios and solve two situational problems adapted from Gick and Holyoak (1980, 1983). The first was a science scenario and the problem required participants to apply a specific thinking strategy in order to solve it. For the science scenario, I wrote a paragraph explaining Newton's third law of motion (for every action there is an equal and opposite reaction) using the rocket-propulsion example. The problem that follows this explanation shows an astronaut who, while repairing the shuttle, starts drifting away with his toolbelt. The participants were asked to solve the problem by using their knowledge of Newton's third law of motion to bring the astronaut back to the shuttle safe and sound.

The second scenario was generic, and the problem connected to it required participants to apply a general thinking strategy. Both the scenario and the problems were inspired by Willingham's article, in which rebels trying to take over a well-protected fortress were led by a highly skilled general whose successful tactic was to surround the fortress and attack it from every angle at the same time. The problem required participants to pretend that they needed to cure a tumor using a type of chemical ray that could kill a tumor, but if used at high intensity could harm the healthy tissue. However, if used at low intensity, the ray had no effect on the tissue or the tumor.

Using critical thinking, participants were expected to find the similarities between the examples and exercises and solve the problems. If participants failed to solve the tumor problem, they were prompted to use the analogy (the tactic applied by the general). Participants were asked to record their time from start to end of the activity.

The fourth step was making sense of data and writing up my results. Unfortunately, from the 20 consent forms that I shared with potential participants that fit my criteria (12 to 14 years of age, strong in science) only five returned their completed tasks by deadline, so I have to work with a limited amount of data. In my analysis, I created a table and compared participants' solutions to the two problems with the solutions offered by experts in Willingham's article, while also considering whether my participants required any prompting along the way.

The results of this study, in agreement to research I read, show that general critical-thinking strategy is not an effective teaching and learning tool. My results made it clear that students are better off mastering lots of specific skills within a subject domain as opposed to learning a small amount of general skills (applicable across domains).

The fifth step in my process was the reflection process. When I look back, I realize how important planning of data collection is in the research process. This was the major setback in my study, and I thought it would be an easy step. I was only able to gather data from five participants, all excellent students. I learned that I should have planned out my experimentation process well in advance and should have allotted it more time.

The science fair was an excellent experience and helped me learn a lot about critical thinking and the problem-solving process by engaging in the actual process. What a better way to learn about content than by experiencing it firsthand? This project is an excellent first reference for what to do and not to do in my next science fair.

PROBLEM SOLVING IN EMMA'S SCIENCE-FAIR EXPERIENCE

Not every cognitively advanced student engages all of these or other processes simultaneously, but there are key processes we can observe. When faced with a new question or problem, nearly all learners do some of these to some degree.

Processes observable before beginning

Larger and more interconnected knowledge base

Typically, as a result of dialog and reading, and attending to their surroundings, advanced learners have a larger store of relevant prior knowledge and are better at retrieving it when needed. That knowledge is sometimes rather esoteric! Critically, this knowledge is interconnected – one idea leads meaningfully to another. New ideas are not just accumulated separately. They are rapidly integrated into the existing knowledge base through activities that form, alter, or strengthen links with knowledge already present. Cognitively advanced learners make more effective and efficient use (application) of what they already know and know how to do than others. They can illustrate this by drawing a concept or knowledge map in which each idea is placed on a sheet of paper, then drawing lines between knowledge points to show which ideas are connected to each other. Advanced learners make more such connections, connecting also to meaningful events and experience in their lives, and give better explanations of each connection. All learners can create knowledge maps. However, when making a concept map for a new problem, typically developing learners focus mainly on replicating information presented in the problem, whereas cognitively advanced learners include additional relevant information they know.

Support

Advanced learners typically receive supportive attention from adults, especially in early stages of learning, but later they prefer to figure out puzzling problems on their own rather than accepting direct assistance. Mothers of high-IQ preschoolers have been shown to give general prompts when assisting their children to do a puzzle (What do you think we should put here?) rather than specific hints (Where is the other green piece?). They also did not suggest what to draw, but asked what they would like to draw. Of course, the causes and effects are intertwined; parents are good at setting suitable levels of challenge for their children, but this poses a reminder to encourage autonomy as much and as soon as possible, while still sharing interesting articles, websites, and other experiences.

Lack of support is the most frequently cited reason students give when they cheat on a science-fair project (Shore et al., 2008), for example: copying data, taking an idea from a project book, and presenting it as their own, or copying work seen elsewhere. Having sufficient time, materials, help, and knowledge are critical. When professional scientists have cheated (remember "cold fusion"?), they give similar excuses! Instead of rushing in with a coil of wire and a screwdriver, we can ask if any help would be welcome, and what it would be – even just discussing their plans – and express appreciation of the thinking and work in progress.

Motivation and social context

Interest is the key to motivation, and advanced learners often have more, more varied, and sometimes weirder interests than other children. When a problem intersects interests, the learner's experience and intrinsic motivation are enhanced. The most positively recalled school experiences are those that offered opportunities to build on interests.

All students need clear and concise instructions for assignments, but advanced learners are more comfortable when they can exercise some influence over how the assignment is framed. This applies to the task itself, and also to the social context. Emma wanted to work alone on her science-fair project specifically because she wanted to pursue her own ideas. Advanced learners shun group work when they anticipate that some collaborating students will not "pull their weight," i.e., invest effort and time to do their best work. This is called the "free rider" effect (Orbell & Dawes, 1981). Parents of advanced learners also sometimes are hesitant about group work because they, too, care about fairness, and also because they realize that group rather than individual work on these kinds of projects could dilute their competitive advantage for scholarships and further education. For group work to be effective teachers need to give clear, well-understood, group-work directions to students, and stay engaged themselves. The contributions of each child, and not just the group overall, should be suitably reviewed. This requires ongoing teacher monitoring of major group-project work; it is reasonable to be wary of group assignments that are never seen by the teacher prior to completion, and in which the individual contributions of all participants are not known. That said, children identified as gifted or advanced learners do not always want to work alone on problem solving; they should be given some say in whom they work with, when, and on what kinds of problems.

Advanced learners sometimes behave in a group in ways that make others uncomfortable. They are more likely to tolerate and even enjoy friendly intellectual competition or sparring; they value both sides standing their ground in disagreements (Barfurth & Shore, 2008; Chichekian & Shore, 2017). Advanced students benefit from talking about how others respond to them, and the need to encourage every member of a group to participate – some other children initially might be shy to speak up, but will do so if someone else in the group stands up for them and reminds others to listen. This is a valuable skill for all children, but cognitively advanced learners may understand and articulate these relationships sooner.

Novelty

Welcoming novelty is characteristic of creativity and giftedness. Novelty takes many forms beyond being new or original. Problems need not be totally new, just new to the learner, or a new twist on an old problem. The military strategy Emma cited was used by General George Washington when his bedraggled army fired cannon down three streets toward the center of Trenton, New Jersey, with nary a casualty in its own ranks, defeating the professional Hessian mercenaries.

Advanced learners more often welcome the challenge of complexity. When we asked advanced learners how to improve a computer game, they suggested making it more complex and adding more difficult levels. They complicate tasks to amuse themselves. Other learners instead asked for more "bells and whistles" (Maniatis et al., 1998).

Advanced learners differ from average peers in their strategy development and preferences, and their use of these on novel problems, yet they use the same toolbox of strategies (Birlean & Shore, 2018). For example, expert mathematicians express aesthetic appreciation for mathematical beauty or elegance in problem solving (defined as simplicity and originality), but this is not especially apparent among mathematically advanced youth. Rather, it is a learned competence, nurtured within the professional community of mathematicians beyond high school. Prior to this level, all students focus on finding solutions.

Processes observable at the outset of solving a problem

Defining the problem

Defining the problem is step one in "self-regulated learning," a goal-focused approach to learning that takes into account the context, the learner's beliefs about her or his abilities and learning preferences, planning, and self-evaluation (Oppong et al., 2019). Effective learners carefully determine the nature of the task that faces them. Is it a new kind of problem or does it fit a known pattern? What do I know that is relevant? What do I know about how to solve it? Students identified as cognitively advanced typically excel at these processes, but do not exclusively own them.

Successful learners more extensively contextualize the problem, read and think widely about it, and brainstorm. When given several problems with instructions to categorize or group them, more able learners, unprompted, group them in terms of "deep" qualities such as underlying subject matter and effective solution strategies (Pelletier & Shore, 2003). They sometimes create subgroups. Less capable learners group problems on "surface" characteristics, for example, word-based versus numerical problems. All students can group problems, and all students group more when prompted to do so.

Proficient problem solvers initially better discern the problem to solve and set subgoals as they move toward the final solution. Perhaps you remember science or mathematics problems in which not all the information is given directly. Some measurement units needed to be converted, or some given information needed to be manipulated first, then combined with the rest; that illustrates a subgoal. When we taught both high and average performers to draw concept maps with the given information, the maps revealed the subclusters and all students improved their subsequent performance on multi-step problems (Austin & Shore, 1994).

Advanced and creative learners sometimes adapt, redefine, or personalize an assigned problem. So do others, but not as often or without a prompt or permission. To a greater degree, advanced learners enjoy finding or creating their own problems. They more readily set priorities and articulate goals, then focus on a specific question. They also more often see or represent a problem in different ways, with different solution paths. People who cannot understand a problem will not find and use suitable strategies, nor can they explain what they are doing and why, so ultimately they become unmotivated.

Planning

Emma spent months planning but only one month actually executing her project. Advanced learners more spontaneously and systematically generate appropriate solution sequences, rather than considering just one step at a time. All students know how to plan, but making a great plan is a sign of high ability. Outlining a story, sketching a sculpture or room decor, and specifying research steps, all exemplify planning. Successful learners spend relatively more time planning compared to actually executing a problem, in comparison to other learners.

Cognitively advanced learners do the actual solving of a problem more quickly than others, especially with one-step (e.g., plug in the numbers), trivial, or familiar tasks, mainly because of their fine-tuned procedural knowledge (automaticity developed through deliberate practice). They also spend relatively more time in the planning stage on nontrivial problems.

Processes observable especially during the actual problem solving

Commitment

The most impactful problem-solving experiences take place over extended periods of time, from hours to months. Perseverance and curiosity help. Even when difficulties arise, such as participants dropping out, they persist.

Many characteristics that distinguish learners with giftedness are learned. "Flow" (Csikszentmihalyi, 1990) or "being in the groove" is a feeling we experience when deeply immersed into the task at hand; we lose track of time, and do not hear the bell or the call to supper. All students experience flow from time to time, especially in their favorite subject. Regardless of the classroom teaching methods, high-achieving students experience more flow, but the most is reported by high-achieving students in inquiry-based classrooms. Students in these settings learn commitment or perseverance.

Monitoring progress on the task

Cognitively advanced learners think many steps ahead – forward thinking – when solving a problem. This is the same mental process that helps chess players anticipate early that a game is unwinnable. Emma asked herself if she could do all the steps of her project in the available time. Advanced learners more often and more effectively monitor their solution pathway and, if necessary, select another. They do not always wait until the end to find out if they got the "right answer." Genuine, important problems do not always have right answers. Rather, they have the best possible answer at that time.

Another way we can see superior problem solvers use a common strategy more effectively is called breaking a response set. Often several examples in a row require a particular approach, but then an example is given that requires shifting mental gears. Advanced learners typically analyze each problem, selecting the most appropriate strategy from their larger repertoire. They are less likely to be tricked by the shift.

Psychologists studying this sometimes then insert a new example that can be solved the old way as well; high ability learners more often spot it and switch strategies before they must. A famous example involves combining water jars to get a certain total volume. Five examples in a row could need three jars, but the sixth can be done with three or just two, and the seventh only with two. Almost everyone "gets it" eventually; individuals with exceptional IQs do so more spontaneously (Dover & Shore, 1991). However, if they fail to spot the initial pattern change, they can actually make more errors when the shift is needed (Shore et al., 1994); the reason why is not clear – two possibilities might be that they underestimated the difficulty of the task and rushed, or that they were redefining the task in their own minds (as observed by Getzels & Csikszentmihalyi, 1976, in successful young artists) but skirting the point of the originally-given task. Sometimes a reminder is helpful to take your time and focus on the task, not just finishing the task as quickly as possible (which does help with IQ scores).

Gathering evidence

Cognitively advanced learners typically are superior at organizing and analyzing data. They make more detailed tables, graphs, and charts. They make evidence-based decisions, and can be critical of the quality of the evidence. They are more tolerant of ambiguity, incomplete answers, and the need to try again from a different angle.

They are also more able to distinguish relevant and irrelevant information in a complex problem-solving task. This can happen as data occur, or in the planning stage. Do you recall school or puzzle-book problems that contained extra, irrelevant information? Gifted and academically able learners better sift that out.

Thinking adaptively and flexibly

Response-set breaking fits here, but here we want to emphasize solving a problem more than one way. A grade 10 mathematics teacher divided a high-performing class into three teams and asked one group to prove Pythagoras's square-on-the-hypotenuse theorem in right-angled triangles (= the sum of the squares on the other two sides) from Euclidean geometry using algebra; group 2 had to use trigonometry; and group 3 had to use functions. The class did it and shared their solutions. Average-ability students asked to solve mathematical problems in more than one way find the task to be difficult, time-consuming, and to require inordinate patience.

Despite superior strategic abilities, advanced learners acquiring and implementing freshly learned strategies are equally likely to be hindered in their problem solving, but they more quickly move out of this phase. When a solution appears to fail, they are more likely to choose another valid strategy and remain focused, rather than to give up or guess wildly. Typical learners more often resort to trial-and-error or guessing – they do not have or create a Plan B.

Processes observable after problem solving

Reflection on outcomes

When more able students complete a task, they more thoroughly reflect on the solution and the solution processes. They worry less about incomplete or ambiguous results. Reflection is the final step of self-regulated learning, and it can be learned to some degree by all students. Emma ended her description with what she learned about allowing more time for effective data collection, but also affirmed her results were consistent with the research that inspired her.

Discipline-based thinking

For decades, a number of critical-thinking programs have been marketed to schools and parents. However, the best way to build effective thinking and problem-solving skills in general is with problems that are real either in life or within specific subjects. Emma wrote, "students are better off mastering lots of specific skills within a subject domain as opposed to learning a small amount of general skills." Problem-solving first should be deliberately practiced in meaningful contexts, then the similarities and differences between contexts should be examined explicitly. Not only the thinking skills themselves need to be taught and practiced; transferring them among situations at school, home, work, or the community also must be modeled and practiced.

When the situations and contexts are similar, most students can apply known strategies in new problems ("near transfer"). When jumping across different contexts, such as from military to medicine ("far transfer"), more capable students make the connections more spontaneously and more quickly. It is specifically these processes that make advanced learners advanced. And because many of these also involve skills learned through deliberate practice, one can learn to be smarter.

CONCLUSION

Our children sometimes surprise us. Advanced children might do so more frequently. Building on interactions with their friends and family, teacher, the curriculum, and the other resources they encounter, they more effectively and spontaneously use widely available intellectual, creative, and social tools to enhance their ability to find, re-interpret, invent, and solve problems at school and elsewhere. In addition to Izzie Rabi's inspiration – What good question did you ask at school today? – we can encourage and enhance children's problem-solving skills by listening and watching for the processes described above, and asking for explanations and examples from advanced learners as they share their problem-solving experiences with us. Here is another example from Emma:

> This example required some quick thinking on my part to solve a problem in real life. I was vacationing with my family and in order to take advantage of the

beautiful sun, we decided to serve our lunch on the terrace. My seating, however, was not ideal as the sun was glaring straight into my eyes to the point that I started to tear up, even though I was wearing sunglasses. The menus arrived, and because of the pandemic measures, the menus were printed for single use on paper sheets. I took one look at the menu, chose my meal and knew immediately what to do next. I placed the paper on my head and secured it with my sunglasses. Although I looked indisputably strange, the sun was no longer burning my eyes, my face and the top of my head, and I could eat peacefully. Shortly after, other guests on the terrace used my trick to avoid the glaring sun.

Although this may seem like a silly solution to a small problem, I believe this was an excellent solution, given the resources at hand, that allowed my family members and me to eat peacefully and prevented them from listening to my complaints.

Problem solving is not all serious. People of all ages engage in games of skill, puzzles, and hobbies. Problem-solving ranges from obligation to playfulness and sometimes combines the two. Nevertheless, learners – advanced or not – differ in their openness to adventure and comfort with being different; social and emotional issues definitely need to be taken into account, even when focusing on the cognitive side. To become better at problem solving, we need to watch for and encourage opportunities for the processes we have described while engaging in deliberate practice in the context of topics of interest. Let's put that menu around our sunglasses!

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