Guiding the Development of Problem Solving Skills
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Today’s Mission

Share my education philosophy.
Share some great problems to challenge you students.
Share some ideas to motivate your students.
Provide some intellectual stimulation.
Have some fun!
Introduction

Education
My first job, scientist, 1989
Solving problems
Recruiter
Switch to academia, 2000
Four problem solving courses
Gedanken Institute director
Outline

Caveat
Human Evolution
System I and System II
Human vs Computer
Job Interviews
Mental and Physical Shape
Problem Solving Fun
Human Evolution

Over the past 50-100 years the world has changed dramatically. The skills we need for success in today’s society are very different from the skills we needed to succeed as a species during the, say, quarter-million years of human evolution.
Human Evolution

Early hominids made decisions quickly based on instinct, intuition. Often there was no time to ponder the future ramifications of a decision. The decisions were fight-or-flight types of decisions.
Human Evolution

The theory is that about 50,000 years ago we started to develop a different type of thinking: careful, logical, multi-step reasoning.

It began when humans started producing representational art and sophisticated tools.

Named System I and System II thinking.
System I

Used most of the time.
Whether you find someone attractive.
Reacting to a sudden noise.
When driving a car on an open road.
Doing chores.
Listening to a lecture.
Multiplying two one-digit numbers.
System I

System I is instinct.
It makes you suspicious.
System I evolved to keep us alive.
Ants have a System I.
It’s stimulus - response.
System I

When you go to a magic show, the magician only wants the audience members to use their System I.

When you go to buy a car, the salesman only wants you to use your System I.

TV ads are directed at System I.

Most politicians focus solely on the voters’ System I.
System I

System I makes judgments and takes action without waiting for our consciousness to catch up with it.

System I is wrong quite often, but in the “jungle” it is often better to be fast and wrong than slow and right.
Systems I and II

When solving any problem, the human brain first tries system I.
This is not laziness, it is efficiency.
Engaging system II takes effort, concentration and focus.
The pupils dilate, other stimuli are blocked.
When we were evolving this made us vulnerable.
Teachers should understand that the student has evolved to resist engaging system II because it requires them to “let down their guard.” Nevertheless, today’s challenging, complicated problems require the use of System II.
Systems I and II

To get students to use their System II, first provide an atmosphere in which System II thinking is encouraged and provide interesting System II problems to think about.

The problems should require a NEW level of understanding or the grasping of a NEW concept.
Brain Chemistry

The human brain has evolved to reward a new level of understanding with a shot of dopamine, a neurotransmitter. The dopamine provides the pleasure and excitement of a “Eureka” moment when something is figured out.
Brain Chemistry

Similarly, the human brain releases cortisol when a lack of understanding is present in stressful and frustrating situations.

Often solving a challenging problem involves fighting through the frustrating period to get to the Eureka moment.
Question for You

The postage and packaging together cost $11. The postage was $10 more than the packaging. How much was the packaging?

System I answers…

System II answers…
System II Problem

The sum of the monkey's age and her mother's age is 4 years.

In addition, the monkey's mother is twice as old as the monkey was when the monkey's mother was half as old as the monkey will be when the monkey is three times as old as the monkey's mother was when the monkey's mother was three times as old as the monkey. What are the ages of the monkeys?
Systems I and II

When I worked as a research scientist, I uncovered a lot of mistakes that cost companies a lot of money. Virtually all of them can be attributed to employees using their System I when they should have been using their System II.
Systems I and II

Just to be clear; Avoiding the mistake did not require genius or some skill that the employee did not possess. It just required that the employee’s system II be engaged. The employee was on “auto-pilot.”
Systems I and II

Afterwards, the employee usually says something like, “Oh, yeah, I should have thought of that.”

“I just wasn’t thinking.”

“I don’t know what I was thinking.”

“I should have known…”
Systems I and II

System II should be engaged when making important relationship decisions, important financial decisions and important career decisions.

Here’s a real-life example of a situation where System II should have been employed instead of System I.
Kansas City Hyatt Regency - 1981
Walkways Down
#1 Architectural Disaster in US

114 people were killed.

200+ injured.

All because of a design flaw resulting from engineers using their System I when they should have been using their System II.

If you can engage your System II, you might be able to spot if even if you are not a trained engineer.
Schematic of the Two Designs

Original Design

Modified Design

Upper Walkway

Lower Walkway

Supporting nuts

Lower Walkway

Upper Walkway

ORIGINAL DESIGN
A person with a well-developed system II can consider all the possibilities and thus efficiently, creatively, and scientifically attack a problem.

That is, System II thinkers are great problem solvers.

And this is a universally marketable skill.
Demand for Problem Solvers

Business leaders have made it clear that they want the educational system to produce graduates who can solve problems.

But…
Demand for Problem Solvers

“Despite the importance of problem solving, it is one of the least engaged intellectual skills in K-12 and university education.”

-- Center for the Study of Collaborative Problem Solving - University of Missouri
Demand for Problem Solvers

"Successful firms primarily need problem solvers."

Demand for Problem Solvers

"More than ever, an education that emphasizes general problem solving skills will be important."

- Bill Gates, The Road Ahead
Demand for Problem Solvers

“Looking closely at the American economy today you find two growing categories of work. The first involves identifying and solving problems.”

-- Robert Reich, Former Secretary of Labor
Demand for Problem Solvers

“A company needs someone that can confront a problem, analyze it, and come up with solutions that minimize cost and maximize profits. That is what you are hired to do - make the company more money. The way you make the company more money is to solve its problems...
No matter what job you get, no matter what you are hired for, the bottom line is that the company has a problem, or collection of problems, that it needs solved.”

-- Greythorne, International IT recruiting firm
Demand for Problem Solvers

“It doesn’t matter what school you attended, where you worked before, or how you dress. All that matters is your logic, imagination and problem-solving ability.”

-- William Poundstone, Moving Mount Fuji
“The formerly straightforward courtship ritual between employer and employee has become more one-sided; a meat rack in which job candidates’ mental processes are poked, prodded and mercilessly evaluated. More and more candidates are expected to “prove themselves” in job interviews. They must solve puzzles, avoid getting faked out by trick questions and perform under manufactured stress.”

-- William Poundstone, Moving Mt Fuji
The Interview Process

Perhaps a good goal as a teacher is to prepare students for their first job interview.

That is, use their first job interview as a training target.

Help them build their mental toughness, strength and stamina.
“Heard on the Street”

INTRODUCTION:

This book bridges the considerable gap between the typical education and the knowledge required to successfully answer job interview questions.
“Heard on the Street”

The considerable gap arises because interviewers must separate the “wolves” from the “sheep.”

The sheep are confined by the boundaries of their education.

The wolves are not.
“Heard on the Street”

Of course, most interviewers are wolves. Unfortunately, most interviewees are sheep.

The “butchering” that can take place in these interviews is horrific.
My Job Interviews…

Test the candidate’s ability to think and to solve problems.

Separate the people who think problem solving is fun and those who think it is work.

• Don’t say, “I didn’t have this in school.”
• Don’t say, “I give up. Tell me the answer.”
My Job Interviews…

Don’t say, “I don’t KNOW.”

I don’t care what you KNOW.

I want to know what you can FIGURE OUT.

Candidates always tried to impress me with their knowledge.
Job Interviews

Heat a metal washer.

Pentagons and Hexagons.
Job Interviews

Samantha is 20 and thus twice as old as Allison was when Samantha was as old as Allison is today. How old is Allison?

Split this deck…
My Job Interviews

My favorite questions…

“What’s the best idea you ever had?”

“Of what intellectual achievement are you most proud?”

“What’s the hardest problem you have ever solved?”
My Job Interviews

Many times I felt like telling the candidate, “You should sue the university. I don’t know what you have been doing over the past four years, but it certainly was not developing your ability to think, reason and solve problems.”
Give them a Chance

When you next get in front of a class, ask the students, “What’s the best idea you ever had?”

What’s the hardest problem you ever solved?

If you don’t get some good answers, give them some good problems.
Give them a Chance

One that might take a few weeks or a couple of months.

Post it on the wall in big letters so they see it every day.

The first thing every day, ask the class if anyone has made progress on the problem.
Give them a Chance

Working hard to solve a challenging problem can be a life-changing, confidence-building event.

You can do this outside of class for the entire student body.

Mr. Benson’s “Problem of the Week.”
“I-Squared” Bill of 2013 would increase the cap on H-1B visas that allow employers to supplement their current workforce with highly skilled foreign workers in specialty occupations, and would increase the number of permanent resident “green cards” available to foreign-born graduates with advanced STEM degrees.
The Current Job Market

Why are employers focused so much on Problem Solving?

Computers. Computers are much better than humans at storing and retrieving information. This is what a computer is for.

Humans are much better than computers at thinking and solving problems.
Computers vs Humans

The skills that an education should develop are the skills that complement rather than compete with those of a computer. Computers are all System I. They are great rule-followers. They can store a lot of information. Computers are not good problem solvers. They are not innovative, creative or brilliant.
Knowledge vs Brilliance

While it is true that a computer can do the work of 100 ordinary people…
It is also true that no number of computers can do the work of one extraordinary person.
Someone that has a good System II.
Someone that can solve a NEW problem.
Someone that can have a NEW idea.
Knowledge vs Brilliance

If teachers are supposed to prepare the next generation of humans to sustain humanity, their collective goal should be to produce creative, clever, problem solvers.

This is what humanity needs the most. There are no employers saying, “We need people who can factor.”
Knowledge vs Brilliance

There are no employers saying, “We need people who can take a derivative.”

There are no employers saying, “We need people pass a standardized test.”

There are no employers saying, “We need people who are walking encyclopedias.”
Here’s my Goal as a Teacher

BEFORE

AFTER
The Teacher’s Job

Personal trainer for their brain.
Get the student mentally fit.
Develop their mental strength and stamina.
So they contribute to society.
So they can have a NEW IDEA.
The Teacher’s Job

I give them hard problems and I blow my whistle. Go.
Think hard.
Think harder.
Keep thinking.
Give me ten more minutes.
Here’s another one.
The Teacher’s Job

Students say, “I don’t know how to do this problem.”

Students say, “You’re the teacher, you have to show us how to do it. That’s your job.”

Students say, “I give up, tell me the answer.”
The Teacher’s Job

School is not a place to collect answers. Answers to yesterday’s problems are useless in today’s world. No one is going to hire you simply because you have answers stored in your memory. This is what a computer is for.
The Teacher’s Job

Nonetheless, students are answer-seekers. They want to KNOW.

But, when trying to develop problem-solving skills, the answer is meaningless.

It’s “4.”

Who cares?

What do you do with a crossword puzzle when you are finished with it?
The Teacher’s Job

Students say, “Professor Meyer, I worked two hours on that problem last night and didn’t get the answer: what a waste of time.”

Students say, “Professor Meyer, when am I EVER going to have to calculate the strength of a magnetic field?”
The Teacher’s Job

Make the analogy between getting into physical shape and getting into mental shape.

To get into physical shape you exercise your muscles and they grow.

To get into mental shape, you exercise your brain and it grows neurons and networks.
The Teacher’s Job

To get into physical shape by running, it doesn’t matter whether you go anywhere particular. The purpose is to get exercise. To get into mental shape by thinking, it doesn’t really matter if you get the answer.
Physical and Mental

The key difference is that getting into physical shape is easily measurable whereas getting to mental shape is not… Unless you have an MRI in your bathroom.

To quantify you physical fitness you can; time yourself, weight yourself, take your pulse, plot a graph.
Physical and Mental

Mental fitness, unfortunately, is not outwardly apparent.
However, it is happening.
MRIs have shown that the number of brain cells and the connections between increase with increasing cognitive function – throughout life.
The Teacher’s Job

So, too often students are given protocols to follow and answers to remember rather than problems to solve.
Let’s go over some problems to solve.
We’ll start with arithmetic and see how far we can get.
You can give a student sheets of addition problems, but this is not fun.
Idle Ivan is sitting by a river near a bridge trying to figure out a way to make a lot of money with the coins he had in his pocket. Suddenly the Devil appears and makes him an offer.

He says, “Every time you cross the bridge, the money in your pocket will double.”
Adding and Subtracting

All I ask is that you pay me eight coins every time you cross. Well, Ivan takes the deal. He walks across the bridge for the first time, checks the money in his pocket and it had doubled! He again paid the devil eight coins and then crossed for a second time and he money in his pocket doubled again.
Adding and Subtracting

He again paid the devil another eight coins and then crossed for a third time. His money doubled again, but he only had eight coins left and had to give them all to the devil, leaving him broke. How many gold coins did Ivan start with?
Adding and Subtracting

This is something the young student has to **FIGURE OUT**.

Although many will raise their hand instantly and blurt out guesses because their goal is to simply get the answer.

If you can get the students to sit quietly and figure this out, you are, in my mind, a great teacher.
Adding and Subtracting

This is when the student’s brain is developing the most – when they are quietly trying to solve a challenging problem – not when they are listening to their teacher.
Adding and Subtracting

Farmer Joe keeps chicken and cows. He has a total of 56 animals and they have a total of 150 legs.

How many chickens does Farmer Joe have?

Let the students solve the problem by themselves.
Adding and Subtracting

If they can’t get it after ten minutes…
Wait for them.
No help, just encouragement.
If they spend the entire class on it but don’t get it, that’s OK – as long as they are thinking.
Start the next class with the problem.
Adding and Subtracting

Students will figure things out for themselves.
They will guess and check.
They will count by fours and count by twos.
They will draw a picture of cows and chickens and count their legs.
Adding and Subtracting

Showing them how to write a pair of equations to solve before giving them a chance to think is robbing them of an opportunity to discover something new and get that shot of dopamine.

The purpose of the cows and chickens problem is to develop the child’s ability to attack a new problem – by themselves.
Probability Problems

Wall Street Interview Question:
Russian Roulette
Probability Problems

How many cards do you have to draw randomly from a single deck of cards before you can say you are unlucky that you didn’t get an ace yet?

What’s the probability of getting dealt four deuces?
Probability Problems

A radar note is a paper currency in which the serial number reads the same forward as it does backward. US currency has eight-digit serial numbers. An on-line search will reveal many examples from numerous countries – some of which are for sale.
Examples of 8-digit radar serial numbers include; 67444476, 12344321 and 90844809. Assume that all serial numbers are equally likely, what is the probability that a randomly selected dollar bill is a radar note?
A binary note is one in which the eight-digit serial number consists of only two digits. Examples include 55353355, 744444774 and a true binary 011010111. Assume that all serial numbers are equally likely, what is the probability that a randomly selected dollar bill is a binary note?
There are four identical bags. One has two white marbles. One has two black marbles and two have one of each (see below).
Probability Problems

One of the bags is selected randomly and one marble is drawn from it, also randomly. The ball is black. What is the probability that the other ball in the bag is white?
You, Shooter and Deadeye have a serious argument which cannot be settled by diplomacy. It is agreed that there will be a three-way shooting duel (truel?) among the three combatants with paintball guns. The rules of the "truel," like them or not, are as follows.
The three contestants stand at the corners of an equilateral triangle, each 50 meters apart from the other two. The contestant whose turn it is gets to take a single shot at whomever he/she desires and the opponent is not allowed to shoot back. Turns are taken in order until only one person is not hit by a paintball.
He or she is, of course, the winner. You, unfortunately, are a bad shot and, in this situation, will hit the person you are aiming at only 1/3 of the time. Shooter is twice as good a shot as you as she will hit who she is aiming at about 2/3 of the time. Deadeye NEVER misses.
Because you are a poor shot, you get go first, Shooter is next and Deadeye is last. Who do you shoot at? Who is the favorite to win? What are the chances of each person winning?
Probability Problems

If you got to select the shooting order, what would it be?
What is your chance of winning with this order?
Probability Problems

Suppose it is known that 1% of the population have a certain type of cancer. It is also known that a test for this kind of cancer is positive in 99% of the people who have it but it is also positive in 2% of the people who do not have it. What is the probability that a person who tests positive has cancer of this type?
Imagine a stock that has a value of $100 on January 1st. At the end of each month a fair coin is tossed and the value of the stock is increased by $1 if the coin lands heads-up and the value is decreased by $1 if the coin lands tails-up. After one year (twelve tosses) the value of the stock will range from $88 to $112.
Probability Problems

Now let’s consider an investor that would like to limit his loss to $5. He buys one share of the stock and applies a stop order at $95. If at anytime during the year the stock price drops to $95, he sells the stock for $95 and accepts the $5 loss. The question is: How does the stop order affect the AVERAGE outcome? That is, will the stop order result in a different average outcome?
A flight with 100 seats on it is full. Each person has a ticket for an assigned seat. The first person in line to board the plane drops his boarding pass on the way down the jetway and decides to pick a seat randomly. All the remaining passengers sit in their assigned seat unless it is taken.
Probability Problems

If their assigned seat is taken, they pick a seat randomly from the remaining empty seats. When the last person gets on the plane there is one seat remaining. What is the chance that it is her assigned seat?
Probability Problems

A stick is broken randomly into three pieces, what is the probability that the three pieces can form a triangle?
Autobiographical number?

0’s 9’s 8’s 7’s 6’s 5’s 4’s 3’s 2’s 1’s

First digit in the number is how many zeros are in the number. Second digit in the number is how many nines are in the number. *Et cetera.*
As before, make them think.
There is SO MUCH you can do with
\[ x = v t \]
The problem: “A car travels at a constant speed of 60 mi/hr for 3 hours. How far does it go?” does not require System II thinking.
However, this problem, “I’m 200 yards behind a red car and I’m traveling at a constant speed of 60 mph. It takes me 30 seconds to catch up to the red car. How fast is the red car going?”

Gives the student an opportunity to figure something out.

Draw a picture. THINK.
What about…

A express train and a local train travel on parallel tracks. One train is 400 feet long and the other is 200 feet long. When they are traveling in the same direction, it takes 15 seconds for the express train to pass the local train.
When they are traveling in the opposite direction, it takes 5 seconds for the express train to pass the local train. How fast is each train going?

All you need is the equation $x = v \cdot t$ and the ability to solve problems.
At Cedar Point, a roller coaster is essentially at rest at the top of the first hill. Let’s assume it reaches the bottom of the hill with a speed of 60 mph and that the acceleration is constant. Where was it going 30 mph? One-fourth of the way down the hill, halfway? three-fourths of the way?
A car going 60 mph can stop in a distance of 180 feet once the brakes are applied.

Assuming that the deceleration rate is the same, how fast would a car going 80 mph be traveling 180 feet after the brakes were applied?

\[
\begin{align*}
\text{180 ft} & \quad \rightarrow \quad 60 \text{ mph, } v = 0 \\
\text{80 mph, } v = ? \\
52.9 \text{ mph!}
\end{align*}
\]
Physics Problems

Heat a metal washer.
Physics Problems

It takes 40 seconds to fill a watering can with a garden hose with no attachment. With a high-speed nozzle attached, will it take longer, shorter or the same time to fill the can?
A styrofoam cup \( \frac{3}{4} \) filled with water is weighted on a triple-beam balance. A student dips his finger into the water up the first knuckle without touching the cup.

How does this affect the balance of the scale?
A push broom is balanced horizontally. It is cut in half at the point of balance. What is the relationship of the mass of the handle and the mass of the bristle side?
Operations Research

Give the student (or group of students) a complete suit of cards A-2-3-4-5-6-7-8-9-10-J-Q-K

Ask them to order the deck such that the procedure of flip the top card face up on the table, put the next card on the bottom, etc., will result in the cards appearing in order: A-2-3-4-5-6-7-8-9-10-J-Q-K.
There is a power failure and you need a flashlight. In a drawer, you have four dead batteries (which you like to keep for some reason), a pack of four new batteries and a flashlight that requires two batteries.
As you open the four-pack of new batteries in the dark, they spill into the drawer, so now you have a mixture of four good and four dead batteries and you can’t tell which is which. You can test them only by placing two batteries into the flashlight and seeing if it works.
What battery checking protocol will minimize the number of tests needed to find two good batteries?

What is the minimum number of tests needed?
There are three hungry cannibals and three missionaries traveling together. They must use a boat to cross a river. The boat can be operated by anyone but it holds a maximum of two.

What order of operations will get all six members of the party safely to the other side without the cannibals outnumbering the missionaries at ANY time.
There are five gopher holes in a line. Every night midnight the gopher moves to an adjacent hole, and every noon a fox comes and looks in one hole in an attempt to find the gopher. If the fox picks a hole randomly, it could take a long time to find the gopher.
However, the fox can adopt a foolproof strategy that is guaranteed to catch the gopher after a certain number of attempts. What is the minimum number of attempts and what is the hole-checking procedure?
As always, make them think.
Pythagorean theorem.
What an opportunity for discovery!
Get their system two in gear.
Don’t ask, “What is the hypotenuse of a right triangle that has sides of 3 and 4?”
The legs of the triangles are $A$ and $B$ and the length of the hypotenuse is $C$.

The area of each triangle is $\frac{AB}{2}$ and the area of the large square is $(A+B)^2$.

The area of the “inside” square is $C^2$.

1. Find the center of the square in the upper right.
2. Draw horizontal and vertical line on this square through its center.
3. Cut out these four pieces.
4. Cut out the smallest square.
5. Rearrange these five pieces on the largest square to show that $A^2 + B^2 = C^2$
A lighthouse is 30 meters high. That is, the light is 30 meters above sea level. The light from the lighthouse, of course, does not reach the entire surface of the earth. In fact, the lighthouse illuminates a circle on the surface of the water around it. What is the radius of this circle?

Have them make an guesstimation and write their answers on the board – another way to make them think.
Geometry

Consider a long rectangular box that is 24 cm by 5 cm by 5 cm. The problem is to connect point B to point A (at the middle of the edges shown) with the shortest length of wire along the surface of the box. Determine the length of the shortest path.
A circle is inscribed inside of a square. The shaded rectangle in the figure is 1 by 2 cm. What is the radius of the circle?
Geometry

You have 20 right triangles, any two of which can form a 1 x 2 rectangle. Construct a square quilt from them.
Geometry

It looks like these two shapes are constructed from the same four pieces – two trapezoids and two triangles. But calculating the area gives different results.
Congruent Halves

Divide a given shape into two identical pieces.
Geometry

Congruent Halves

Divide a given shape into two identical pieces.
Geometry

Congruent Halves

Divide a given shape into two identical pieces.
Geometry

Divide a given shape into two identical pieces.
Topology With People

1. Escape from the Handcuffs

2. Reverse the Sweatshirt
Other “Ice Breakers”

1. Bridg-it Tournament

2. Hex Tournament
Bridg-it Tournament

White

et cetera

Black
Hex Tournament
Absent? Give Them a Problem.

1. A hat for every student.

2. Two-Switch Problem.

Make Them THINK.

Check one box quiz (first day of class).

Instructions: Check one of the two boxes below.

BOX #1  □

BOX #2  □
Make Them THINK.

Grading: If all the students in the class check box #1, all the students will receive a score of 20/20 on this quiz. If at least one student checks box #2, all the students who checked box #1 will receive a score of 10/20 and all the students who checked box #2 will receive a score of 15/20. Then give the SAME quiz the next day.
Make Them THINK.

1. Write down a number that will be 4/5 of the class average.
2. Write down the lowest unique integer.
Closing Thoughts

To best prepare today’s student to be a contributing member of a global society, a teacher should guide the development of the student’s ability to think of clever ways to solve new problems.

The best way to do this is to present interesting problems that have the appropriate level of difficulty.
Closing Thoughts

If the student can’t solve the problem, tell them, “It’s OK that you can’t solve it. It’s a very hard problem.”

Try to get the students to stop “collecting answers,” and start thinking hard.

Don’t measure progress in the classroom by the number of answers the students got, measure it by how hard they thought.
Closing Thoughts

You should encourage, ask questions that might lead them down the right path with the purpose of developing in them the ability to ask themselves the “right” questions.

You can’t do the work for them.

You have to inspire, guide, motivate and coach.
Closing Thoughts

This is a NOBLE cause.

It is so important to the ability of the human race to thrive on this planet.

Who else is more responsible for the success of the human race than the teachers?
Closing Thoughts

Thanks for this opportunity to share my thoughts!

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