Meet Open Problems

(A reading for scientists and scholars)

With the world changing at a terrifying speed, education is lagging behind just as fast.
Computers and other modern gadgets in classroom will not set the things right.
It is the education content that needs change. But what kind of change should it be?
In this article we shall cover just one aspect, i.e. the transfer from closed to open problems.

Two Real-Life Cases

Thirty whiz kids, winners of math and science contests, are ready for battle, with problems handed out and the clock is running. In about 20 minutes I come up to an obviously perplexed young fellow and ask what's wrong.

"You know, the problem looks easy to solve but I've no idea where to place this figure."

So I have to read the condition:

> In 1785, French aeronaut Jacques Charles threw down a stone from his balloon rising at 1 meter per second.
> How long will it take the stone to reach the ground from a height of 300 meters, with air resistance neglected?

Although it's a simple problem just to warm up, the youngster was dumbfounded by the date of 1785. Actually, the guy had been taught to think that the condition contains only relevant data.

There are thirty teachers of physics in front of me who receive a seemingly tricky problem:

> How the water level in a bath will change after a brick is placed inside?

The audience is immediately perplexed, wondering about the bath and the brick details. I suggest assuming average standard dimensions. As a result, practically everyone solves the problem with confidence in no time. The displaced water volume equals the brick volume. Simple as pie, isn't it?

Then I ask if they have really thought it over. And a bright idea promptly arrives. "What if the bath is full to the brim? In this case the water level will remain the same, with some water just spilled over!"

"Fine, is that all?"

"Oh, no!" thunders the animated audience. "There may be just too little water. The condition omits the bath water volume. If the water does not cover the brick, the water will be displaced only by its submerged portion. If you know the water depth, you can calculate the volume…"

Then I sum up the discussion.

"Within this problem, your task has been to supplement the condition with missing elements. You have actually made a mini-research to effectively define three different conditions:

1. The water level is below the brick height.
2. The water covers the brick, its level not reaching the bath brim.
3. The bath is full.

This is an **open problem** that you have tackled. Let us try to research the open problem condition a bit further. The condition says “a brick is placed inside”. Try to imagine how the solution may change depending on how the brick gets inside the bath.

The audience gets lively again.

“The brick may fall in the bath at high speed to splash the water out!”

“Or even make a hole!”

“The high-speed contact will heat and evaporate the water!”

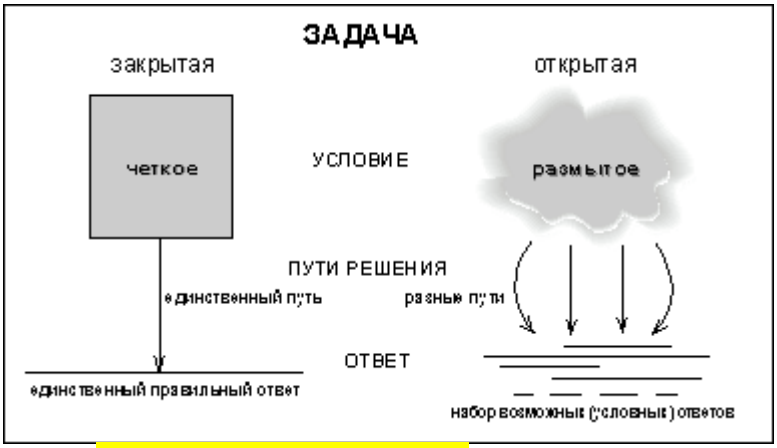
“What kind of brick is it? There are different brick types. Are there bricks lighter than water? I better check the encyclopedia.”

“The brick might have easily been hot since the condition says nothing! Then we can easily calculate how much water evaporates and how the level changes…”

“That will do,” I bring the debate to a close, “I see you have acquired a taste for it. Proceeding from our experience, we can now make up several traditional restricted-response problems about the bath and the brick and solve them in a customary manner to obtain numerical results…”

What Kind of Problems Do We Solve?

The answer is simple. These are the problems we have been taught to solve. And the school teaches us to solve closed problems. The closed problem formula involves a clear-cut condition + an approved solution method + the only correct result. Any deviation from the approved solution method (which also means an approved thinking method) brings a lower grade.



Подрисуночные подписи:

PROBLEM

RESTRICTED-RESPONSE		OPEN
Clear-cut	CONDITION	Fuzzy
	SOLUTIONS	
Single		Multiple
	RESULT	
A single correct result		A number of possible (conditional) results

Psychology distinguishes two types of thinking – convergent (closed, non-creative) and divergent (open, creative). Personality type with dominating convergent thinking is referred to as *intellectual*, and the one with divergent thinking – as *creative*. The intellectual is ready to solve intricate problems of traditional nature with known solution paths, i.e. *closed problems*. But a creative individual can see and formulate problems, trying to trespass the boundaries of a fixed condition. Obviously, every person possesses both intellectual and creative abilities, though in different degrees. With age, the creative component fades away. High-school and college students are predominantly conformist and afraid of self-dependence. They shy away from imaginative thinking and gravitate to masticated and distinctly arranged data. Quite naturally, they fear vague conditions and multiple solutions of creative problems.

You cannot teach a caged bird to fly. You cannot grow a *creative muscle* without flying out to the vast expanse of open problems that allow different approaches to solutions, a varying degree of immersion into the problem, and variable answers.

Problems around Us

There is no human activity without a open problem. They exist in technology, science, arts, human relations and other fields… Want to see some examples?

Cat and Starlings (Everyday life)
As soon as nestlings started cheeping in the birdhouse on the tree, a cat turned up to smell prey, walking around and smacking his lips. The boy who built the birdhouse decided to help the birds. He devised a way to reliably cut off the access for cats. What did he do?

Answer: The boy wrapped the tree with broad metal tape.

Swordfish Power (Science)
How do the fish and dolphins manage to move in dense water at speeds more typical for flying in the air? According to some sources, a swordfish may reach 130 km per hour. To do so, the swordfish must develop a car-engine power of about 100 hp. Living beings draw energy from oxidation processes. But fish are cold-blooded and their body temperature is just a bit above the temperature of water where a minor amount of oxygen is dissolved. For them this power is absolutely unattainable! It may be surmised that the fish considerably diminish water resistance. But how? There is still no answer.

How to win a name (Human relations)

The Boldai tribe in Papua used a most cruel ancient rite to choose a name for a newborn. Parents find a clever, laborious and respectable man in a neighbor village, and then kill him to come into possession of his name for their baby. Their neighbors did not like this ritual, but could not help it. But Chibu, the Boldai village elder, managed to defeat this ghastly, barbaric prejudice. How did he alone manage to something beyond the reach of many generations?

Answer: Chibu brought a lot of videos, statuettes and pictures of sports and film stars from the city. He managed to convince his tribesmen that their names were good enough for the task. So, to assign the name of a film star to their first-birth, all they needed was just to buy a postcard and tear it apart it.

Perspective in ballet (Arts)
Staging a ballet, the director decided to produce a visual effect and make the figures of hunters diminish as they disappear in the wood, just as in real life. But the stage dimensions are not sufficient for the dancers' figures to reduce in height. What is do be done?

> **Answer:** The director arranged the dancers in six groups by their height. The tallest hunters passed along the path nearest to the audience. On the next path, the second group of dancers replaced them. Shorter hunters passed along the third path. In the procession rear there were the shortest hunters, the children crossing a bridge. The illusion was so good that the audience saw the same six persons walking along different forest paths. The same gradation applied to the music and costume colors that were fading away.

School seems to be the only place for closed problems, which are virtually non-existent in real life. NC machines, computers and other clever gadgets easily handle closed problems.

> "How to settle relations with the neighborhood hoodlums?"
> "How to get acquainted with a boy or a girl?"
> "Where to continue education after school?" And so on.

Without doubt, these teenager problems may be equaled to open problems. Youngsters that fail to handle them mar their personality, as well as life for themselves and people around.

The school teaches to solve closed problems, whereas life demands the ability to tackle those of the open type. But the efforts of teachers and motivation of students plummet into the gap between school realities and life challenges.

Dim-Witted Talents

Nicky, a regular low-grader and troublemaker seemed to be quite witty. After his routine conflict with his lady-teacher we had a private discussion.

"There is nothing I can respect her for," says Nicky. "She had been cramming this textbook for five years at the university and also has keys. If you give me the key book, I will be as bright as she."

Later I found that this stereotype is quite natural for youngsters. There are loads of gifted children who cannot adapt to the school environment and get lost. I mean bright and dynamic kids, who often look stupid in class. Numerous recollections of brainless Einstein, Mendeleyev, Brodsky and other great thinkers at school fall in the same line. As a matter of fact, their free and open minds just did not fit the school designed for mass production.

> It was in the first grade when the teacher publicly rated the future genius a brainless idiot, and the indignant mother took him away from school. As a result, formal education of Thomas Edison lasted only several months, and he had to obtain knowledge guided by his mother. Luckily, the boy read a lot and, unlike other children, used to make his toys himself instead of harassing his parents into buying them. By the age of ten he opened his invention list by making a minute sawmill and a toy railroad.

Sasha is a student of my new 8-A class and impresses people by seemingly incorrigible stupidity. During the test I give him several problems and the textbook to find the answers and copy them. And he failed even to locate the relevant subject. But some time later I learned that Sasha was known as a motorbike expert who could disassemble and repair engines. Not quite a job for a dimwit, right?

I nosed around and made friends with the guy. Bull's eye! It was the same dead case with complete absence of motivation. He was just doing time in school, with real life beyond its limits. But why? Gradually we managed to rectify the situation, and Sasha passably finished the 8th grade.

I believe that permanent taming of a creative child's free thinking, as well as attempts to make him think in a template manner, drives certain children into isolation. You may ask what to do in this case, since these templates or thinking rules, solutions and even formulas may turn quite helpful. Surely, it is true – as true as the statement that a building needs a roof. But if the roof suppresses the head and prevents the individual from standing up, expect a curved spine or a broken roof.

> The test featured a problem how to measure the skyscraper height with help of a barometer. Checking the papers at night, the teacher saw that many students properly understood how to use the barometer for height measurements, i.e. to take atmospheric pressure at the first and the top stories. But one student wrote that he could apply trigonometry because he knew that that the mercury height in the barometer glass tube was 30 inches, and he could measure the length of the building and the barometer shadows and then calculate the height.
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> The next day the teacher called the student and said. "I would be wrong to rate your solution as improper. But this is a fact of life. I meant an aneroid but you have used a mercury barometer. Now that you know, what kind of answer would you suggest?"
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> The boy promptly said that he would go up to the roof, let the aneroid fall down and measure its flight time to obtain the result through the free fall acceleration.
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> "And again you are both right and wrong," said the teacher, "Try again assuming you have no watch."
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> "Then I would find the janitor and ask him about the building height in exchange for the aneroid."

The boy is a typical creative thinker. Imagine he enters a school that punishes every nonstandard solution by poor grades, or encourages only template solutions, which is actually the same thing. What would happen to him in several years? Will he like going to school or resist any kind of education offered? The question is purely rhetorical, as we know what would happen. We clearly see it in the modern grassroots school. Just a reminder: you cannot teach a caged bird to fly…

Factors of Success

What determines success in business? This was my starting question at the seminar with law teachers in Moscow. On the blackboard we wrote about 30 most important factors of success and then discussed historical and everyday examples to make up the hierarchy of success.

Money and startup capital? Sure. But there are many examples of making really big money out of insignificant startup capital, provided it was backed by a bright idea and the ability to solve problems.

> In 1975 Steve Wozniak sold his HP calculator and Steve Jobs his old Volkswagen van for $ 500 each to establish Apple Computer, Inc. Now the company has nearly 35 thousand full time employees and in 2009 had worldwide annual sales of $42.91 billion.

Multimillionaire ship owner Aristotle Onassis, financial royalty Nathan Rothschild, oil tycoon John Rockefeller, pioneer car manufacturer Henry Ford – all of them were creators, inventors and open problem solvers.

By the way, history knows many examples when people lost all their savings due to a single wrong decision.

What about the school and university education? We know that far from all A-students succeed in life. Even in science discoveries are not necessarily made by people known for their academic success in school.

> An outstanding American astronomer Asaph Hall left school at 16 to follow the trade of a carpenter and started to study geometry and algebra only in his twenties. He is world famous for discovering the moons of Mars (namely Deimos and Phobos) and determining the orbits of satellites of other planets and of double stars, the rotation of Saturn, and the mass of Mars,
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> Samuel Morse was not a scientist – he was a professional artist who spent many years abroad as an itinerant artist with a particular interest in portraiture. On his homeward voyage to America at the age of 42 he overheard a shipboard discussion on electromagnets. This was the seed out of which the electric telegraph grew. Morse is remembered for his Code, still used, and for the invention of landline telegraphy.

Maybe, it is health? Sure, but there are many exceptions.

> Vassily Yeroshenko's starting point was dreadfully low, as seen from mistakes in his father's letter. But the farmer's blind son Vassily Yeroshenko did obtain higher education in several fields and became an Esperanto professor not only in Beijing but also in the Tokyo University.
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> Yeroshenko's achievements are immense, including three short-story collections in Japanese. And now Ero-san, as he is known in Japan, is a literature classic, whose fairy tales are compulsory for studying in Japanese junior school. In China he is known as prose and drama writer Ailosyanke. He was the first recorder of Siamese and Burmese folklore. He also wrote for newspapers in English, German and Esperanto. In Turkmenistan blind children still use his Braille alphabet to learn reading, and he nearly completed the same job for the Chukchi language.
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> Yeroshenko developed a unique method of language teaching and training the blind to move and orient themselves without others' support. As for himself, he walked without a cane even in unknown cities, and one could see his blindness only at close range.
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> Theoretical physicist Stephen W. Hawking is a prominent British cosmologist suffering a rare Lou Gehrig disease that makes him immobile. He can operate only two fingers to type words on the computer and communicates through an electronic voice synthesizer.

There seems to be only one quality absolutely essential for a major success, i.e. the ability to adequately solve open problems in professional, everyday, psychological and other spheres of life.

Do you happen to know the specifics of a creative individual? He can see open problems around him. He can find them in situations where a standard person would notice only bad luck or heavenly punishment. One should only learn to open his eyes, and the world will look as a single infinite open problem, in which physicists, biologists and educators are to find their own sub-problems. You should learn to see your problems in the way blind Yeroshenko did it. And here is a pedagogical problem he managed to handle in a most elegant manner.

> Searching for the Turkmen school pupils, which he also did himself, Yeroshenko ran across a blind orphan Durdy, who had surprisingly survived in most harsh conditions. All he knew at the age of six was hunger and continuous beating for begging. He was convinced that all people were monsters and he was non grata in this world. Yeroshenko brought him to his school and gave him food. In cases like this it ordinarily takes several years to melt the child's ice of distrust and win his confidence. But Yeroshenko could not wait even a day and, being an experienced climber, took the boy to the mountains. They reached a peak, where Yeroshenko asked the boy to cry out his name. "I am Durdy!" shouted the boy. And the echo repeated his name several times. "So you see," said the tutor, "Even here, in the mountains, everybody knows and loves you." After Yeroshenko's death Durdy Pitkulayev became director of that school for many years.

What do a Greek tycoon Aristotle Onassis and a blind Russian country boy Vassily Yeroshenko have in common? Both were successful, though in different environments and in different times. One of

them could remain a nighttime dispatcher in an American port, and the other – a poor peasant in a Russian village. But both could identify problems, did not hesitate to seek and find solutions, made problem-solving part of their existence and set an excellent example for others.

Survival Issues

All simple problems have already been tackled, if they ever existed. Now the mankind faces complex and very complex tasks and has to grow wiser if it wants to survive.

Absolutely novel and diverse problems arise, for example, embedding microcomputers in the bodies of people. The development of these technologies has a very promising future. First, high-tech medical sensors will emerge, say, to warn a patient about an approaching fit of epilepsy. Humans cannot anticipate it, so the sensor will do the job to warn the patient, his relatives and the doctor. Additional protection will be given to heart sufferers, another high risk group. Apart from early warning, the gadget may provide first aid, i.e. inject medicine or perform electrical stimulation. The prospect seems quite real and the first human-computer symbiosis is in the offing.

Such discoveries open up new vistas. If you do have an embedded computer in your body, why not add several harmless functions like a phone, an electronic code to open your safe, garage or apartment. And so on and so forth.

Some will say that such things are extravagant and expensive. But let us not forget, that in early 1950s a semiconductor transistor cost about 50 dollars, ten years later – two dollars and now a transistor in a microchip is as cheap as 1/100000 of a cent.

Gadgetry has already become an integral part of our life and there is no way to stop their further advance. Or is there? What should our reaction be? A pious man I know quite seriously believes that cell phones are a devilish invention. But he still uses one, since there is no alternative. How to regard the process results in an open ethical problem. What will the attitude of the church to the human computerization be? What about anti-globalists' and communists' attitude, not to mention others? What kind of shocks should the society expect as a result of this process? What can be done to prevent pain or bloodshed? That's how an ethical problem turns into a social one. But who is ready to solve these problems?

> A research by global charity *Wellcome Trust* shows that British school graduates are not prepared to face complicated ethical problems generated by modern science.
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> Almost nothing has been done to teach youngsters to reasonably consider such problems as embryonic cloning of humans, animal testing and genetically modified food. The students fail to base their opinions on scientific facts.
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> Teachers are concerned about the students' lack of interest to important developments and news in general. They also note that students shape their opinion on the issues of animal rights and cloning based on scant facts.

Relatively habitual scientific and technological problems also become more and more complicated. As long as people live on the Earth ecological problems will only aggravate. The stronger the man becomes, the more costly his mistakes turn out to be.

Mistakes are fraught with sinking ships, spilled oil, destroyed forests and fighting nations. Correcting errors requires huge expenses. This is why the ability to find adequate solutions for open problems becomes such an urgent necessity for the survival of the mankind.

The Heart of the Matter

Do you happen to know the essence of the man-technology relationship? The man invents gadgets that oust him out of habitual activities. Stone scrapers and knives ousted fingers in skinning the prey of primitive hunters. When describing it we usually use the word “liberated”, which does not really change the point. Was it good? Surely! Human fingers turned more tender and sensitive, and could be used for finer operations. However, certain stubborn and strong-fingered pithecanthropuses unwilling to change might have thought otherwise.

Taming animals combined with simple tools like the plough or the harrow ousted human energy out of land cultivation. Tamed fire and steam replaced the muscle effort. Each engine revolution testified to the weakness of the human flesh and the strength of the human brain. Engines conveyed their energy to machine-tools that were spinning, sewing, elevating, rocking, breaking and building. Machine-tools not only saved human energy, but at the same time raised the man to a higher level of activity. Somebody had to control machine-tools. And the man believed that no machinery could replace him in this sphere of activity.

But he was wrong. Smart automatic machines and computers are driving the man out of this sphere as well. But where to? Can we at last just relax and enjoy ourselves? Not quite so. Rather, quite the opposite.

Imagine a plane during a flight – a sophisticated machine controlled by an autopilot. This automaton is really good and reliable but only for standard conditions. In an emergency it is the man who takes over control. Emergency is actually qualified as a nonstandard situation because it is indistinct and cannot be split into simple standard components. The solution path is not ostensible, while the answer is probabilistic. In fact, any nonstandard situation comes down to an open problem. And here seems to be the man’s proper position, which is true for all fields, including engineering, science, sociology, culture, arts and education.

Finally, we have come to the historic turning point of education development. Education of the industrial period aimed at teaching standard operations is a thing of the past, though it will fight for survival through irrelevant modification, empty talk and distraction. But the teaching skills of the information-oriented tomorrow have yet to be developed. For now, we only know the basic goal, i.e. to teach people to meet unconventional challenges and find adequate answers to open problems.