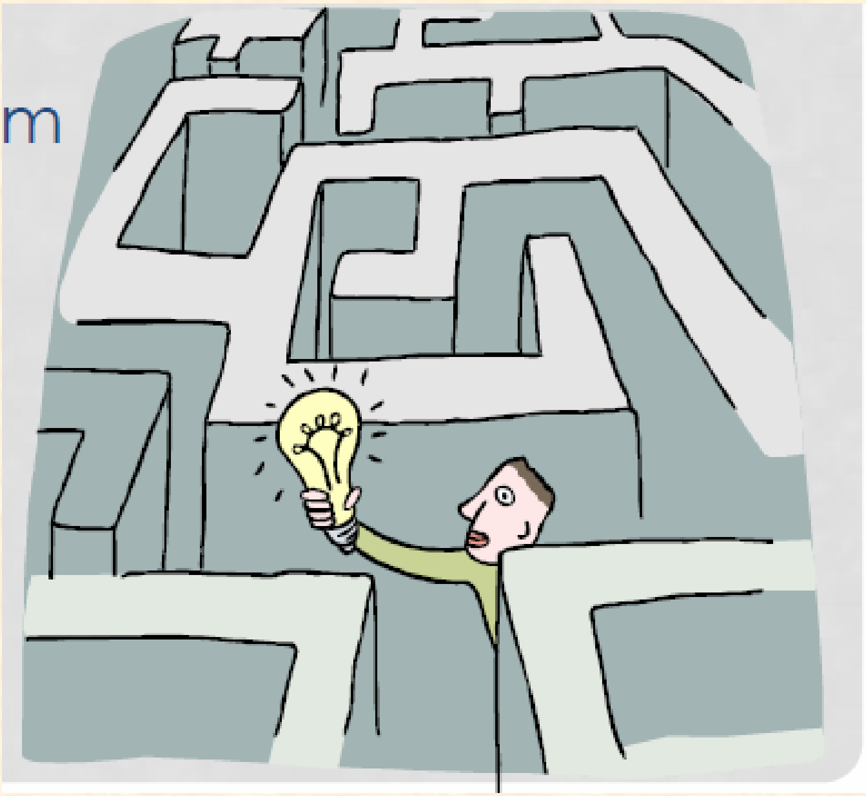
Problem Solving, Critical Thinking and else ….



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Fostering critical thinking skills is becoming one of the chief goals of education, particularly at the college level, where a variety of pedagogic techniques are being used to develop critical thinking skills in students.

(Irenton, Manduca and Mogk, 1996).

- The study of scientific disciplines offers to students extremely powerful tools for developing the skills of critical thinking that they will need to live in modern societies.

- Rapid scientific and technological progress, and unprecedented societal transformation require the ability to face new situations, analyze them, and quickly adapt to the changes. Citizens of the 21st century must become adept problem solvers. Problem-solving ability is the cognitive passport to the future.

- Critical Thinking and Problem-Solving skills are some of the most important assets that the study of physics can offer to students at any level, no matter what their future career paths will be.

Education research has demonstrated what great educators have always known:

Students acquire and retain knowledge most effectively when they must understand new information well enough to apply it to new situations, or to reformulate it into new ideas and knowledge.

Four fundamental features of natural human learning
(Schank et al., 1995):

Learning is

- goal-directed,
- failure-driven,
- case-based,
- it best occurs by doing.


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Is it possible to teach problem-solving abilities?

Yes, but ……

- Understand what problem solving and critical thinking are
- Recognize the importance of heuristics
- Goal Management and Metacognition
- Intuitive learning: Provide an intuitive basis to concepts
  - The role of imagination and examples
  - Assumptions and Inferences
- Errors and uncertainty

What is Problem Solving?

It is the process of moving toward a goal when the path to that goal is uncertain. We solve problems every time we achieve something without having known beforehand how to do so.

What is Critical Thinking?

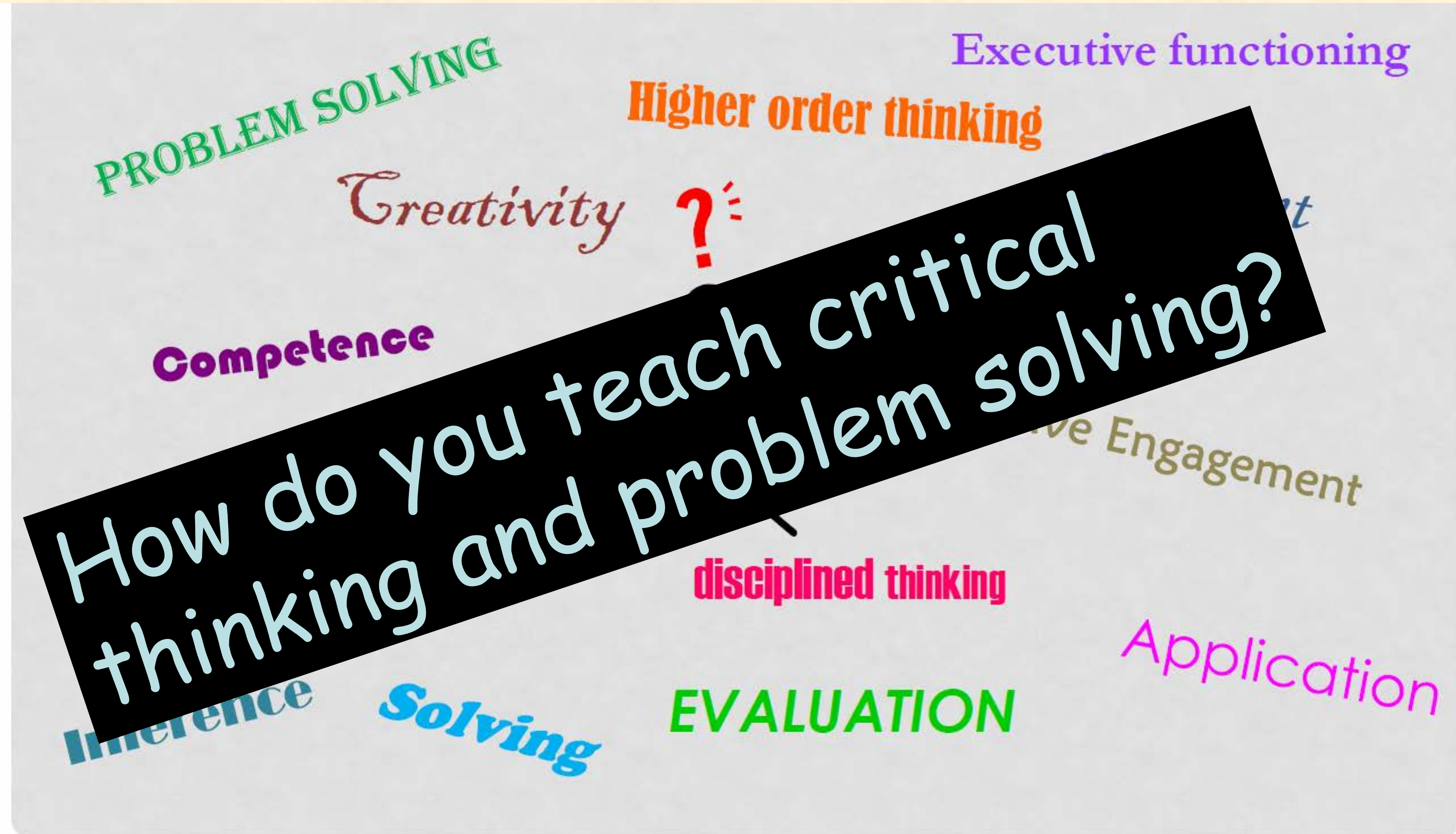
The intellectually disciplined process of actively and skillfully conceptualizing, applying, analyzing, synthesizing, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action.

In its exemplary form, it is based on universal intellectual values that transcend subject matter divisions: clarity, accuracy, precision, consistency, relevance, sound evidence, good reasons, depth, breadth, and fairness.

as Defined by the National Council for Excellence in Critical Thinking, 1987
A statement by Michael Scriven & Richard Paul,
presented at the 8th Annual International Conference on
Critical Thinking and Education Reform, Summer 1987.

What is critical thinking?

What is problem solving?



How do you teach critical thinking and problem solving?

The Nature of Problem Solving

Problem Solving is the process of moving toward a goal when the path to that goal is uncertain. We solve a problem when we do NOT know beforehand how to do it.

There are NO SCRIPTS, NO FORMULAS for true problem solving. If we know exactly how to get from point A to point B, then reaching point B does not involve problem solving.

Once we have mastered a skill, we are no longer engaged in problem solving it. For a task to require problem solving again, novel elements or new circumstances must be introduced or the level of challenge must be raised.

Problems defy one-shot solutions: need to be broken down, with constant sub-goals monitoring

Problem Solving

No script, no formulas

vs.

Algorithms

straightforward
procedures
guaranteed to work
every time

The Nature of Critical Thinking

Critical thinking

- a set of information and belief generating and processing skills

- the habit, based on intellectual commitment, of using those skills to guide behavior

vs.

- retention of information alone

- the mere possession of a set of skills, because it involves the continual use of them

- the mere use of those skills ("as an exercise") without acceptance of their results

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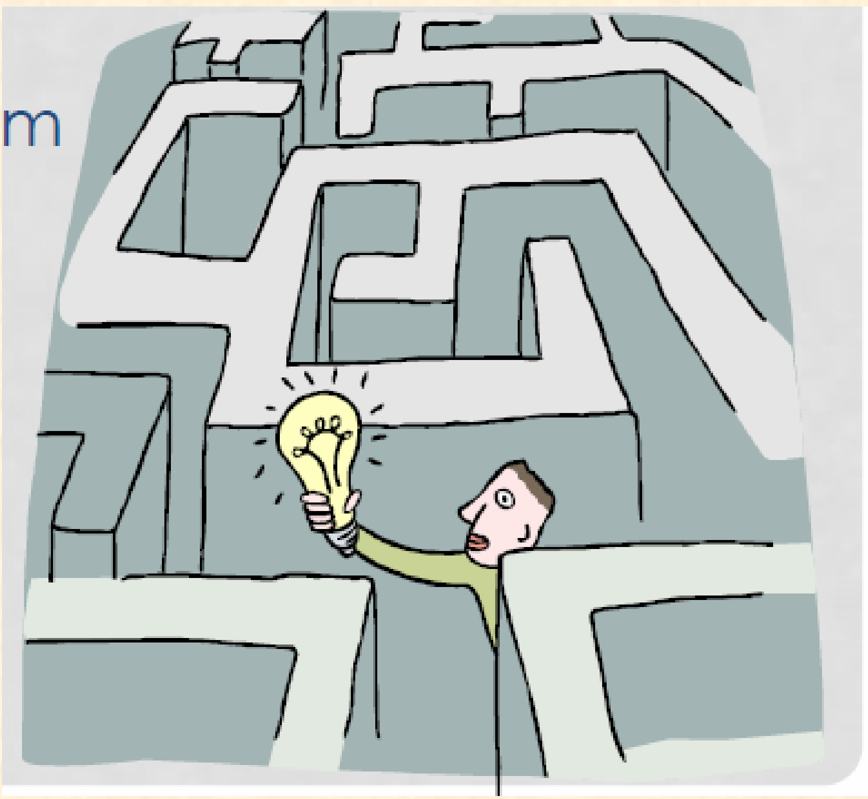
Problem Solving → **Heuristics**: cognitive "rules of thumb"

Like a maze: choose the path that seems to result in some progress toward the goal → An example of Heuristic



A heuristic is a rule of thumb, like a strategy which is powerful and general.

Heuristics are usually picked up incidentally rather than identified and taught explicitly in school.

This situation is NOT ideal.

Problem Solving → Heuristics: cognitive "rules of thumb"

A curriculum that encourages problem solving needs to offer explicit instruction in the nature and use of heuristics.

“In teaching problem solving, major emphasis needs to be directed toward extracting, making explicit, and practicing problem-solving heuristics”

Herbert Simon

NOT absolutely guaranteed to work.

Heuristics and knowledge are the "two blades" of effective profession al education, and "two bladed scissors are still the most effective kind.“

Herbert Simon

Heuristics: examples

means-ends analysis: form a sub-goal to reduce the discrepancy between your present state and your ultimate goal state.

i.e.: do something to get a little closer to your goal

Problems defy one-shot solutions; they must be broken down. Means-ends analysis accepts <u>incremental advancement toward a goal</u>. The method is not fail-safe

Application of a series of tactical steps gets you closer toward the goal. Not simply a process of trial and error, steps taken are not blind or random. Rather,

The benefits conferred by means-ends analysis may be as much emotional as intellectual. Success in a small piece of a complex problem can motivate one to persist. JUST DO IT!!!

Heuristics: examples

Working backward: First, consider your ultimate goal.

From there, decide what would constitute a reasonable step just prior to reaching that goal.

What would be the step just prior to that?

Beginning with the end, you build a strategic bridge backward and eventually reach the initial conditions of the problem.

Working backward makes "next steps" plainer than simply wishing and hoping that dreams will materialize.

Heuristics: examples

Successive Approximations	Start from a simpler problem and build up the complexity Start with a seed and improve it
External Representation	Pictures, flow-charts

The chosen representation of a problem may help the solver see the problem in a new way

Facilitate communication with other individuals

Facilitates goals management

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Goal Management

The process of generating sub-goals from goals, and then tracking the ensuing successful and unsuccessful pursuits of the sub-goals on the path to satisfying higher-level goals

All heuristics help break down a problem into pieces
The decomposition of complexity consists of the recursive creation of solvable sub-problems, but the cost of creating embedded sub-problems, each with [its] own sub-goals, is that they require management of a hierarchy of goals

Then one cognitive challenge becomes goal management - keeping track of what to do and when.

Goal management is a major aspect of intelligent thought

Metacognition

Goal Management is an example of a more general phenomenon:
one common feature of problem solving is the capacity to examine and control one's own thoughts. This self-monitoring is known as metacognition.

Metacognition is essential for problem solving,
need to be aware of the current activity and of the overall goal, the strategies used to attain that goal, and the effectiveness of those strategies.

The mind exercising metacognition asks itself,

What am I doing? How am I doing?

These self-directed questions are assumed in the application of all heuristics. However, in practice, teachers cannot simply assume that students will engage in metacognition; it must be taught explicitly as an integral component of problem solving.

Metacognition

Problem solving requires both the vigilant monitoring and the flexibility permitted by metacognition

When solving problems, means shift continually depending on one's position relative to desired goals. Maintaining flexibility is essential.

Too often we feel wedded to a chosen strategy and continue to apply that strategy even if it leads us nowhere ……

"What do I do now, given my goal, my current position, and the resources avail able to me?"

Getting off course along the way is fully expected.
Cool-headed reappraisal is the best response –
not mind less consistency, panic, or surrender.

Do not let anxiety take hold

Anxiety is a spoiler in the problem-solving process. It stalks right behind uncertainty, ready to pounce.

Demanding and uncertain environments, the seedbeds of all problem solving, are fertile ground for anxiety. Uncertainty is an integral part of the business of solving problems.

Those who cannot bear situations in which it is impossible to see the way clearly to the end are emotionally ill-prepared to solve problems.

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•Errors and uncertainty

Intuitive basis to abstract thoughts

We can learn concepts at various levels of depth

Concepts and ideas are truly understood only when we can effectively and insightfully use them in a wide range of circumstances.

If we memorize an abstract definition of a word and do not learn how to apply it effectively in a wide variety of situations, →

NO intuitive foundation for our understanding.

We lack the insight into how, when, and why it applies,
we lack "feeling for it".

Intuitive basis to abstract thoughts

Traditional school learning is abstract and unconnected to everyday life and experience learning.

Learning for grades and approval, not to gain knowledge, skill, and insight.

As long as students are performing in certain standard ways, we assume they "understand", that they are building a basis for using what they learn, that they will eventually be able to take what they learn and put it to use in the everyday world. This assumption is rarely justified.

This is probably the fundamental reason why so much school learning is not effectively transferred to real life. It lacks the intuitive basis, the insights for the translation of abstract concepts into reality.

Missing: the intuitive synthesis between concept and percept, between idea and experience, between image and reality

Intuitive basis to abstract thoughts

Failure at all levels of education to teach in a way that fosters intuitive learning.

Develop intuitive critical thinking intuition
Intuitive means "quick and ready insight"
(Webster's New Collegiate Dictionary)

Intuition: the process by which one translates the abstract into the concrete

the process of translating back and forth between the abstract and the concrete,
the general and the particular,
the academic and the "real".

Intuitive basis to abstract thoughts

Focus on the ability of students to move back and forth comfortably and insightfully between the abstract and the concrete,

→ they develop and discipline their imaginations so as to be able to generate cases that exemplify abstractions.

Develop critical thinking intuitions

→ gain the practical insights necessary for a quick and ready application of concepts to cases in a large array of circumstances.

Intuitive basis to abstract thoughts

Students have experienced hundreds of situations that exemplify any number of important abstract truths and principles.

But they are virtually never asked to dig into their experience to find examples, to imagine cases, to illustrate principles or that abstract concepts.

The result:

undisciplined and underdeveloped imagination combined with vague, indeed muddled, concepts and principles.

Experiences that are blind, experiences from which they learn few truths, ideas that are empty, that they cannot relate perceptively to their experience.

Imagination and examples

Solid critical thinking always requires
fundamental insights,
fundamental intuitions, to guide it.

The Power of Examples

Everything in the natural world is concrete and particular. Whatever is abstract must ultimately translate, therefore, into what is concrete and particular.

The dramatic, the concrete, and the highly visual and
imaginative, are crucial instrumentalities for this purpose

Examples are a powerful way to help students learn.

Furthermore, one of the best ways to assess student learning is to determine the extent to which they can give examples of what they are learning.

Imagination and examples

The Power of Imagination

Critical thinking requires an extensive use of the student's imagination.

Abstract meanings, understanding or assessing a statement or belief, attempting to predict a consequence, or determining the implications of an action, require the use of imaginations effectively.

Most students are not practiced in this use of their imaginations.

Difficulty in exemplifying abstract meanings.

Students recognize the case when someone else thinks it up, but they often have difficulty in thinking them up, imagining them, on their own.

Develop basic intuitions --- Assumptions and inferences

Learning to distinguish inferences from assumptions is important in critical thinking.

Assumption: An assumption is something we take for granted or presuppose. All human thought and experience is based on assumptions. Assumptions can be unjustified or justified, depending upon whether we do or do not have good reasons for what we are assuming.

Inference: An inference is a step of the mind, an intellectual act by which one concludes that something is so in light of something else's being so, or seeming to be so. Inferences can be strong or weak, justified or unjustified.

When students misread a mathematical problem, for example, they make the wrong inferences about it, usually as the result of having made false assumptions about it.

Assumptions and inferences

Assumptions and inferences permeate our lives precisely because we cannot act without them.

Judgments, interpretations, and the beliefs we form are the result of the mind's ability to come to conclusions, to give meanings to what we experience, to make inferences.

And the inferences we make depend on what we assume

So quickly and automatically do we make inferences that we do not, without training, learn to notice them as such.

One of the most important critical thinking skills is the skill of noticing and reconstructing the inferences we make, so that the various ways in which we inferentially shape our experiences become more and more apparent to us.

Assumptions and inferences

This skill enables us to separate our experiences into analyzed parts.

We learn to distinguish the raw data of our experience from our interpretations of those data, i.e. from the inferences we are making about them.

Eventually we realize that the inferences we make are heavily influenced by our point of view and the assumptions we have come to make about people and situations.

Being able to broaden the scope of our outlook, to see situations from more than one point of view, to become more open-minded.

Assumptions and inferences

Important critical thinking skill:
noticing and reconstructing the inferences we make.

All human thinking is inferential in nature

→ the command of our thinking depends on command of the inferences embedded in it and on the assumptions that underlie it.

→ Sensitizing students to the inferences they make and to the assumptions that underlie their thinking enables them to begin to gain command over their thinking.

Assumptions and inferences

Many Opportunities: Every subject we teach provides us with opportunities for facilitating student recognition of inferences and assumptions. Physics requires making correct assumptions about the content of what we are studying and that we become practiced in making justifiable inferences.

The difficulty: we ourselves are not practiced in this very art, hence we miss most of the opportunities inherent in the everyday classroom.

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Errors and uncertainty

Traditional school setting exalt perfect performance.

Errors are seen as failures

Worse still, errors are sometimes ridiculed.
Mistakes and embarrassment often go hand in hand.

Errors and uncertainty

Perfect performance is incompatible with problem solving.
If no mistakes are made, then al most certainly no problem solving is taking place.

What can reverse this sorry state of affairs?
A better understanding of the nature of problem solving is a place to start.

Need to revise our attitude toward errors that are a reasonable consequence of significant problem solving.

Errors and uncertainty

Problem solving involves errors and uncertainty. The possibilities of failure and of making less-than-optimal moves are in separable from problem solving.

John Dewey linked tolerance of uncertainty to reflective thinking:

Reflective thought involves an initial state of doubt or perplexity.... To many persons both suspense of judgment and intellectual search are disagreeable; they want to get them ended as soon as possible.... To be genuinely thoughtful, we must be willing to sustain and protract the state of doubt, which is the stimulus to thorough inquiry.

How do we grade?

Grade the SAME problem for all of the students

→ Homogeneity and fairness in the grade

→ Divide the tests based on the mistakes made
(This works very well for large classes)

→ Explain in words what type of mistake a certain pile of tests corresponds to

→ You get a rubric automatically!

→ The rubric will suggest the points

How do we grade?

The total energy of an electron is 1 MeV.
Find its velocity and its De Broglie wavelength.

Problem # 3
3. Treat as two parts: finding velocity and finding wavelength

3a) Finding velocity
A) Correct (13pts)
B) Arithmetic error or incorrect units (12pts)
C) Particle treated non-relativistically (10pts)
D) Electron treated as photon (2pts)
F) Wrong (0pts)
+) Found velocity higher than speed of light, but recognized that was too high (+2 pts)

3b) Finding wavelength
A) Correct (12pts)
B) Arithmetic error (11pts)
C) Particle treated non-relativistically (9pts)
D) Electron treated as photon (1pt)
F) Wrong (0pts)

Critical thinking is,

self-directed, self-disciplined, self-monitored, and self-corrective thinking.

Rigorous standards of excellence and mindful command of their use.

It entails effective communication and problem solving abilities and a commitment to overcome our native egocentrism and sociocentrism.

(Taken from Richard Paul and Linda Elder, *The Miniature Guide to Critical Thinking Concepts and Tools,* Foundation for Critical Thinking Press, 2008)