Session 2248

Solving Problems or Problem Solving: What are we teaching our students?

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Abstract

This paper positions Effective Problem Solving as not just *a tool*, but *a way of thinking* for our personal, academic and professional lives. This is the philosophy behind a new collaborative teaching and cooperative learning Freshman Year Initiative (FYI) in the Electronics programs at DeVry Institute of Technology (Dallas campus). The pedagogical hub of our FYI, launched in Spring 2000, is a Critical Thinking & Problem Solving course on which faculty members build applications for the technical courses. While never compromising the terminal course objectives for any of the five first-term courses, the sequence of topics and the scope of many assignments in each course is orchestrated to support an heuristic approach to critical thinking.

I. Introduction

"Industry wants students from engineering and engineering technology programs to be proficient in problem solving skills. During their educational process, these students are faced with solving a myriad of technical problems. However, are they just learning how to solve problems, or are they being taught how to approach the concept of problem solving?" This is a fundamental question posed by New Jersey Institute of Technology's Ronald Rockland.[1]

Indeed, it is very easy to fall prey to teaching students how to simply solve specific problems in their courses. However, this fatal flaw can be avoided if the approach to problem solving is centered on a pedagogy of Critical Thinking and Heuristic-based Problem Solving. This is the philosophy underpinning the Freshman Year Initiative (FYI) at the Irving, TX (Dallas) campus of the DeVry Institute of Technology. The goal for the collaborative teaching and cooperative learning approach is for students to understand and apply a problem-solving heuristic to any situation s/he may face in their academic, personal and professional lives. To use the biblical metaphor, we strive to feed our students by teaching them how to fish for solutions, not just how to 'eat the problem of the day'.

II. How do you define Critical Thinking?

Before attempting to teach the concept of problem solving, it is important to understand its roots in one of the three main streams in Critical Thinking.

One day, a student ran into class with great glee holding forth a business card that his employer, a major hotel chain, had handed out to employees. On the card, to be carried around on the job, was the problem-solving heuristic we were studying in class. While it was affirming to see the immediate relevancy of the course objectives, "relevance" or "what industry desires" is not sufficient justification for an academic course at a post-secondary institution. Our efforts must be firmly rooted in pedagogical outcomes, as well as what employees deem to be "the software flavor of the month."

But, be warned, the term "Critical Thinking" has become a veritable cliché. It has come to mean so much in the academic community that that it ends up meaning nothing. "Agreement about teaching critical thinking persists only so long as theorists remain at the level of abstract discussion and permit their use of the term to remain vague."[2]
My colleagues and I – all teaching first-year technical, business, communication and social sciences courses – have embraced a complementary understanding of three main streams in the the pedagogical history of Critical Thinking:

1) The Critical Thinking movement, advocated by Richard Paul, Edward deBono and others
2) Classical Rhetoric, developed by the Ancient Greek philosophers
3) Industrial and Business Heuristics, articulated by Fogler, Kepner and others

1) The Critical Thinking theorist, who actually coined the phrase "thinking about our thinking", is Richard Paul. In his pedagogical theory, he urges students to probe the **Eight Elements of Reasoning**: [3]

1. Purpose of the Thinking
2. Assumptions
3. Evidence
4. Implications and Consequences
5. Points of View
6. Concepts
7. Interpretation and Inferences
8. Question at Issue of the Problem[3]

According to Paul, educators need to engage students in various "Reasoning Abilities" such as:

- Evaluating evidence
- Comparing analogous situations
- Refining generalizations and avoiding oversimplifications
- Analyzing issues, problems or beliefs
- Clarifying values and standards

- Questioning deeply
- Analyzing actions
- Exploring significant similarities and differences
- Developing one's perspective
- Exploring and Evaluating solutions
- Analyzing and Evaluating arguments, interpretations or beliefs
- Synthesizing subject-matter insights and knowledge[4]

The acclaimed "father of lateral thinking" Edward deBono, who was credited with helping Peter Ubberoth turn the 1984 Olympic Games into a profitable venture, defines the use of Intelligence in Thinking as:

- Not making stupid mistakes
- Defending your point of view
- Being right most of the time
- Coping adequately[5]

Furthermore, deBono calls upon people to extend their thinking skills to "lateral thinking" beyond our "natural" or vertical thinking approach. The basic principle of lateral thinking is that any particular way of looking at a situation is only one from among many possible ways. It may appear to people that their search for alternative methods is a natural search. However, the lateral search for alternatives stretches far beyond the normal search.

In a natural search, one is looking for the best possible approach and considers only reasonable alternatives. In the lateral search for solutions, the problem solver is trying to generate as many alternatives as possible, and they do not have to be reasonable.[6]

To summarize the differences: [7]

Natural or Vertical Thinking	**Lateral Thinking**
Is selective	Is generative
Moves only if there is a direction in which to move	Moves in order to generate a direction
Is sequential	Can make jumps
Must be correct at every step	Does not have to always be correct
Uses the negative to block certain pathways	There is no negative
Excludes what is irrelevant	Chance intrusions are welcomed
Fixed categories, labels, classifications	Categories, labels, classifications are not fixed
Follows the most likely paths to a solution	Explores the least likely paths to a solution
Is a finite process	Is a probablistic process

DeBono has also articulated the "Six Thinking Hats" taxonomy. He calls upon creative thinkers to wear as many different hats as possible when confronting a problem. [8]

The White Hat -- Neutral Objectivity

Like paper, the White Hat is neutral. It is for objective facts and figures without any argument. "White Hat thinking" also covers listening, questioning and defining the information you would like to obtain.

The Red Hat -- Emotional View

The Red Hat covers emotions, hunches, intuitions and feelings. Normally, we only put forward our feelings twisted in amongst our logic, and we create various reason for supporting our feelings. "Red Hat thinking" gives us permission to use our hunches without having to justify them.

The Black Hat -- Logical Negative

The Black Hat is probably the most important of all 6 hats. It is caution and judgment, and its use prevents us from making mistakes. "Black Hat thinking" makes us consider the reason why a potential solution might not work, why it is illegal, or why it's not worth pursuing.

The Yellow Hat -- Logical Positive

The Yellow Hat is optimistic, covering hope and positive thinking. It provides all the reasons why a potential solution will work -- the advantages, benefits, savings. "Yellow Hat thinking" can look forward and recall previous successes.

The Green Hat -- Creativity

The Green Hat suggests energy, growth and fertility. "Green Hat thinking" covers proposals, suggestions, ideas, alternatives and provocations, and it makes time and space available for creative thinking.is neutral.

The Blue Hat -- Process Control

The Blue Hat is concerned with the organization, or control, of the thinking process and the use of the other hats. "Blue Hat thinking" looks not at the subject of our thinking but at the thinking itself.

To reap the fruits of lateral thinking, deBono urges people to acknowledge and "wear" as many of the hats as possible when confronting a problem.

2) The second approach to Critical Thinking, common in composition courses at the college level, is Rhetoric. In its true sense, it deals with Argumentation and persuasive communication. These are the main components:

- Ethos (credibility)
- Pathos (emotion)
- Logos (logic)
- Clearly defined terms
- Fair use of information, e.g. current, representative, accurate
- Logical Arguments, i.e. no logical fallacies such as red herrings, faulty cause and effect, *ad hominem*

"Rules of correct reasoning were first extracted by Aristotle, yet men knew how to avoid and detect fallacies before they learned his lessons." (*Ryle, 1963*)

Rhetoric is well-covered in any English course dealing with persuasive communication, so we found it more beneficial to engage students in a less common approach to Critical Thinking – the Heuristic.

Interestingly, "heuristic" (pronounced "your-wris-tick") comes from the Greek word for "discovering". The Greek rhetoricians, for example, used heuristics to "discover" what to say in their speeches."[9]

Today, we know a Heuristic as a systematic process or procedure to define and resolve a problem. Heuristics are typically used in situations where there is more than one good answer, i.e. more than one solution. They increase the chance that the solution chosen is the best possible solution among the many solutions possible.

3) What is a Problem-solving heuristic?

Every day we solve personal, academic and professional problems, from the complex to the simple. When we wake up, we must decide how to dress ourselves for the day. During the day, we must find solutions to eliminate our pangs of hunger. More important obstacles we must overcome are where to further our education, which career path to pursue, and with whom to enter into relationships.

Most of the time, we use our "gut feelings", while others credit their "common sense" for guiding their problem-solving efforts. However, these adhoc, often uneven and intangible instincts cannot serve us as well as a systematic problem-solving process, or heuristic, to guide people through the problem scenario to a successful solution.

Smart people can and do make mistakes. This often occurs when they do not define the real or root problem correctly or by not logically working towards possible options and deciding on one solution to implement. Sometimes, disaster can strike when the real problem is not defined or when there is no organized approach to solving problems.

However, there are no guarantees. The adherence to a systematic method to guide people through a problem scenario to a successful solution cannot always prevent mistakes. But, it can maximize the potential for success more than an adhoc, casual, disordered approach to problems.

There are many heuristics or systematic approaches to confront and resolve problems.
While the *Quality Improvement Systems Thinking* heuristic has been used to improve industrial production by viewing the problem as part of a layer of a system, our First Year Initiative faculty saw greater value in three other Heuristics

- *D.R. Woods -- McMaster Five-Point Strategy*
  Define, Explore, Plan, Act, Reflect
- *C.H. Kepner & B.B. Tregoe -- The Rational Manager*
  Situation Analysis, Problem Analysis, Decision Analysis, Potential Problem Analysis
- *Fogler & LeBlanc -- The Five Building Blocks*
  Define, Generate, Decide, Implement, Evaluate

Prof. D.R. Woods of the Department of Chemical Engineering at McMaster University in Ontario, Canada has articulated the "McMaster Five-Point Strategy" (1985). In it, he calls upon problem-solvers to Define, Explore, Plan, Act and Reflect. In each stage, there are required tasks to complete. They include: [10]

1. **Define:** Identify the unknown or stated objective.
   Isolate the system and identify the knowns and unknowns (inputs, laws, assumptions, criteria, and constraints) stated in the problem.
   List the inferred constraints and the inferred criteria.
   Identify the stated criteria.

2. **Explore:** Identify tentative pertinent relationships among inputs, outputs and unknowns.
   Recall past related problems or experiences, pertinent theories and fundamentals.
   Hypothesize, visualize, idealize, generalize.
   Discover what the real problem and the real constraints are.
   Consider both short-time and long-time implications.
   Identify meaningful criteria.
   Choose a basis or a reference set of conditions.
   Collect missing information, resources, or data.
   Guess the answer or result.
   Simplify the problem to obtain an "order-of-magnitude" result.
   If you cannot solve the proposed problem, first solve some related problems or solve part of the problem.

3. **Plan** Identify the problem type and select among heuristic tactics.
   Generate alternative ways to achieve the objective.
   Map out the solution procedure (algorithm) to be used.
   Assemble resources needed.

4. **Act:** Follow the procedure developed under the plan phase; use the resources available.
   Evaluate and compare alternatives.
   Eliminate alternatives that do not meet all the objectives or fulfill all the constraints.
   Select the best alternative of those remaining.

5. **Reflect:** Check that the solution is blunder-free.
Check reasonableness of results.
Check procedure and logic of your arguments.
Communicate results.

H. Scott Fogler of the College of Engineering at the University of Michigan, together with Steven E. LeBlanc of the College of Engineering at the University of Toledo, have pioneered their own problem-solving approach: The Five Building Blocks of the Heuristic (1995). Their methodology features various techniques the problem solver can employ at each stage of the heuristic, as follows: [11]

Stage	Techniques
Problem Definition:	Finding Out Where the Problem Came From
	Exploring the Problem
	Present State/Desired State
	The Duncker Diagram
	Statement-Restatement
	Evaluation
Generating Solutions:	Blockbusting
	Brainstorming
	Osborne’s Checklist
	Random Stimulation
	Other People’s Views
	Futuring
	The Fishbone Diagram
	Analogy and Cross-Fertilization
Deciding the Course of Action:	The Kepner-Tregoe Analyses:
	Situation Analysis
	Problem Analysis
	Decision Analysis
	Potential Problem Analysis
Implementing the Solution:	Seek approval
	Planning
	Carry Through
	Follow Up
	Experimental Projects
Evaluation:	Evaluation Checklist
	Ethics Checklist

Safety Considerations
The Five P's -- Purpose, Pride, Patience, Persistence, Perspective

In The Rational Manager and The New Rational Manager, C.H. Kepner and B.B. Tregoe present a series of four inter-related analyses to help problem solvers. [11]

The Kepner-Tregoe (K.T.) Approach begins with a Situation Analysis to determine which problem within a scenario to tackle first by measuring the Timing, Trend and Impact of each problem. After the Situation Analysis of "Where are We?" is answered, problem solvers are directed to perform one of all of the following analyses:
Problem Analysis: What is the fault or problem?
Decision Analysis: Which solution should be used to correct the fault or problem?
Potential Problem Analysis: How can possible future faults or problems be prevented?

In conclusion, we found this heuristic approach to Critical Thinking to be the most viable stream for our students. "Critical thinking means that you *take in* information, *question it*, and then *use it* to create new ideas, solve problems, make decisions, construct arguments, make plans, and refine your view of the world." (Carter, 1999)

III. DeVry Dallas First Year Initiative (FYI)

To learn, and from time to time apply what one has learned – isn't that a pleasure?
– Confucius, 500 B.C.

The context for our FYI must be noted. The integration of Critical Thinking has been tried – successfully and unsuccessfully – in higher education for many years. Among General Education (GenEd) faculty at DeVry, we have experienced three models to promote critical thinking across the curriculum.

1. Persuade faculty to incorporate Critical Thinking in every course.
This can be achieved by:
- Getting students to answer in complete sentences on labs, quizzes, exams
- Avoiding regurgitative multiple-choice questions that only assess memory not thinking or problem-solving
- Giving students problems to trouble-shoot individually and in groups
- Encouraging substantiated debating about concepts and applications explored in class and in lab
- Pushing students to analyze, evaluate and synthesize concepts and applications
- Assigning Critiques

2. Formalize the Promotion & Evaluation of Critical Thinking.

This can be achieved by:

- Creating Joint Assignments among Technical/Specialty & GenEd courses
- Requiring GenEd faculty to create assignments exploring technical/business issues
- Urging Technical faculty to emphasize communication and critical thinking skills
- Building a "communication & thinking" grade into all quizzes, exams, e.g. 80% for correct answers, 20% for thinking and expressing

However, DeVry Dallas faculty pursued a far more invasive model:

3. Restructure the curriculum delivery around CT & CW objectives

Born out of a synthesis of cross-curricular experiments and experiences of DeVry's Phoenix, Scarborough and Dallas campuses, the DeVry Dallas' Freshman Year Initiative (FYI) was launched in the Spring 2000 term.

It featured:

- Faculty Teams of 5 professors were formed and assigned to the same first-term class group.
- These Teams were led by new associate FYI deans and, most often, the professor teaching the general education course, Critical Thinking & Problem Solving.
- This course served as the "pedagogical hub".
- Faculty met before and during the term to plan a cross-curricular scope and sequence integration of courses
- Students were scheduled into cohort classes
- Faculty Teams planned and delivered 2-hour labs each week where all members of the Faculty Team would meet with the students.
- Students were assigned 1-2 cross-curricular Team Projects designed with terminal course objectives from all five first-term courses. For example, in the Electronics Engineering Technology program, these courses were Math, Psychology, Digital Electronics, and Computer Applications, as well as the Critical Thinking & Problem-Solving course.
- ¨Together with program advisors and associate deans, Faculty Teams monitor attendance and achievement of students each week

Here is the Course Description for the Critical Thinking & Problem-Solving Course:

"Appropriate knowledge, skills and attitude are three essential ingredients in an equation for academic success and personal development. This first-term course equips students with a foundation for academic success at DeVry Institute of Technology by focusing on critical thinking and problem-solving strategies, as well as study skills and personal development methods.

This course serves as the hub for the integration of concepts and applications from other first-term courses. During the two-hour lab time each week, collaborative teaching and team learning models will be embraced to help students understand and master the physical and mental resources that can enhance the success and satisfaction of a DeVry education."

The initial outcomes of this FYI experiment for our campus were:

- ➢ Application of Critical Thinking and Problem-solving theory in design, delivery and implementation of curricula and team projects
- ➢ Greater cross-departmental faculty collegiality
- ➢ Greater cross-curricular awareness and relevance among students and faculty
- ➢ Exposure to benefits and pitfalls of teamwork
- ➢ Cohesive focus on attendance and achievement of students by faculty, program advisor, and deans
- ➢ Promising positive affect on retention

In their collective reflection upon the first Team Projects, a class of Electronics Engineering Technology students identified the following major weaknesses of the Team Project process:

- A very difficult process of identifying meeting times and then getting everyone to attend in the midst of conflicting work schedules
- Team members dropping out and the necessary re-distribution of tasks among remaining members
- Social loafing by some members of certain teams
- Team Members with irregular schedules

The students identified the following major strengths of the Mini Project process:

- A demonstration of an entrepreneurial spirit and business acumen
- Team cohesion, even harmony, and smooth operation for some teams
- Getting to know fellow team members better

At many times during this first term, Faculty Teams felt as if they were "Grouping in the Dark", to use the name of a study of collaborative learning among students at several universities. However, we took comfort in the findings of that study: "Participation in group projects improved communication, conflict management, and problem solving skills even when students received minimal guidance about how to work together." [13.]

IV. Here is a Team Project for our first-term Electronics Engineering Technology students as developed by a Faculty Team. We believed this cross-curricular project called upon our students to demonstrate their ability to understand and apply the concept of problem solving.

TECHNICAL REQUIREMENTS:

1. The objective of this project is to **design, build** and **test** a four-bit Adder Circuit that:
   a. Adds Hexadecimal and Binary Numbers
   b. Displays the results in Decimal
   c. Indicates when the Output of the Hex addition is at overflow
   d. Indicates when the Binary addition has produced an overflow
2. Search the Internet to:
   a. find the data specifications for all the IC chips your Team uses.
   b. find Digital information on computer addition and subtraction.
   c. Simulate the design of the circuit before building it at http://www.cis.ufl.edu/~fishwick/dig/DigSim.html

   Provide your findings in the Report.
   As well, each Team must demonstrate the simulation during its Presentation.
3. The wires should be colored, flat and right-angle bends.
4. No looped wires will be accepted.
5. Test the circuit at various stages of construction to be sure it is working properly. Remember that the I/O board is your input and output for the circuit.
6. In your Report, explain why you decided to use the method you selected to subtract from the A (4-bit binary number) the B (4-bit binary number) and display the number in Decimal form (the seven-segment display).
   If you want to make an "A" on this project, you must complete this design part.

DOCUMENT REQUIREMENTS:

1. The report will be at least 1,500 words of written and graphic explanations, using the following format:
   a. Cover sheet
   b. Table of contents with page numbers
   c. Page numbers on every page
   d. Parenthetical references in the document
   e. Works cited or References sheet with at least three ideas, facts or statistics borrowed from sources of information, e.g. people, web sites, articles, books.

2. The report must provide a full explanation of the team's application of the problem-solving heuristic to the Design, Building and Testing of the Adder Circuit, specifically

a. Two Problem Definition techniques
b. Two Solution Generation techniques
c. The Kepner-Tregoe Decision Analysis
d. The Gantt, Deployment and Critical Path Management Implementation charts
e. Two Evaluation techniques

3. On the Technical side, the report must also provide:
   (i) A Complete Parts List
   (ii) A Detailed, neatly drawn schematic, using ORCAD, EWB, or Visio
   (iii) A Theory of operation section explaining how Adder Circuit operates.

PRESENTATION REQUIREMENTS:

1. Each team will demonstrate its project using Power Point software to the class in the COLL Lab during Weeks 13 and 14.
   (A 10% bonus will be given to teams that present in the first week.)
2. Everyone will participate in the presentation and speak at least five (3-5) minutes each on a portion of the entire project for a minimum of 15 minutes.
   The team members will then subject themselves to scrutiny from the audience during a 5-minute Question-and-Answer session.
3. Presentation format:
   a. Introduction of team members and the subject
   b. Preview the main points to be discussed
   c. Go through the information and steps performed to have a successful conclusion of the project – demonstrations and presentation of final product may be included

   Remember to include a demonstration of your circuit's simulation from the web site listed in the Technical Requirements above.

   d. Conclusions and Recommendations
   e. "Are there any questions?"

NOTE: A Sample speech evaluation form was provided to students.

PEER & SELF-EVALUATION PROCESS:

1) All team members will be asked to confidentially evaluate each other's participation in the process of completing the Team Project.
2) The peer evaluation will be factored into the overall project grades (both report and presentation) in the COLL course and possibly other courses.
3) Students will also be required to reflect on their own participation in the Team project, along the theme of "What I learned from my Experience." The evaluation will ascertain situations of perseverance in dealing with team obstacles.

V. Conclusion

"Having a technical background is important, but it's also important to realize that the technology is in a constant state of flux," writes IT analyst Lawrence Magid. [14] "When thinking about future jobs, it's important to focus on the basic skills of reading, writing and math, as well as increasingly important skills such as critical thinking and public speaking."

"Thinking about our Thinking," or a pursuit of Critical Thinking through a Problem-Solving Heuristic, can provide our students with the necessary tools to effectively confront and resolve any academic, personal or professional problem they will encounter in their lives.

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