# Teaching Inventive Thinking*

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## Abstract

This paper reports on a new undergraduate course at Florida Atlantic University titled: "Introduction to Inventive Problem Solving in Engineering". The goal is to enhance inventive thinking abilities of undergraduate students resulting in skills that can be used in science, math, engineering and technology. The course is focused on developing thinking skills that stay with the students, and is based on: a) well established systematic and non-systematic approaches to inventive problem solving, b) results from NSF support to FAU on unified frame for inventive problem solving strategies, and c) proven successful methods that have been used in high-tech innovative industries.

The new course uses hands-on problem-based learning and emphasizes expanding creativity and thinking skills of students. The activities include 3-D mechanical puzzles, games, mind teasers, and design projects. It emphasizes out-of-the-box inventive thinking, imagination, intuition, common sense, and elements of teamwork.

## 1. Introduction

In today's global marketplace, the pace of competition, the increasing demands of customers, and the explosion of knowledge and technology all contribute to the need for innovative "out-of-the-box" thinkers and approaches.

There is a growing concern that students are not being encouraged to think and are losing some basic skills for defining, understanding and solving problems. Many have a difficult time thinking logically and critically towards obtaining desired solutions.

Thinking is a skill that can be developed, and the earlier the better. In order to get students who can think critically and solve problems, we must address the need for development and implementation of courses in innovation and inventiveness in different disciplines, especially engineering and technology.

The goal of the course reported in this paper is to enhance inventive thinking abilities of undergraduate students resulting in skills that can be used in science, math, engineering and technology. In this course there is no "right or wrong", and no "unique solution". Trying,

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inquiring and questioning is what counts. It emphasizes out-of-the-box inventive thinking, imagination, intuition, common sense, and elements of teamwork. The course is focused on developing thinking skills that stay with the students, and is based on: a) well established systematic and non-systematic approaches to inventive problem solving, b) results from NSF support to FAU on unified approach for inventive problem solving strategies, and c) proven successful methods that have been used in high-tech innovative industries.

The new course uses hands-on problem-based learning for introducing undergraduate engineering students to concepts and principles of inventive problem solving. It emphasizes expanding creativity and thinking of students as they relate to engineering and technology. The course allows for self-paced, semi-guided exploration that improve self-esteem and encourage questioning and daring. These activities include 3-D mechanical puzzles, games, mind teasers, and design projects, each of which illustrates principles and strategies in inventive problem solving.

## 2. Related work

The literature on creativity and problem solving is quite rich. Some books focus on creativity in general [7,8,17,18,20,22,29,30,44], some on general methods for problem solving [9-14, 23], and others deal with specific methods [19,21,25,45]. Some emphasize mental blocks and how to overcome them [1,42,43]. Many books focus on business and industry [6,32,39]. Some books are more engineering and technology oriented [2-4,16,24,27,34,35,38], and others are math specific [31]. Some are invention specific [33] and many are intended for K-12 [28]. Puzzles and games [5,15,26,36,37,40,41] are the subjects of many books.

Most books are not suitable or not meant to be textbooks, and to teach these topics one has to use bits and pieces from many books. A major drawback of the literature when it comes to teaching the material is that even in cases where real-life examples exist, interactivity is sometimes missing, not to mention hands-on, fun activities that allow for first-hand experience of principles and strategies. When it comes to dealing with specific strategies for understanding the problem and obtaining ideas, the methods used are usually general and not specific enough.

## 3. The Course

We place high priority on the “Creativity in problem solving” portion of the class. In other words, we put more emphasis on the material of the course that deals with problem definition, pattern breaking, general strategies, using math and science, unified approach to strategies of inventive thinking, and systematic inventive thinking.

This part of the material includes theoretical and hands-on activities, specifically puzzles, games, mind teasers, and design activities for:

**A.** Problem understanding, representing, and defining the real problem.

**B.** Pattern breaking, specifically out-of-the-box thinking, changing the point of view, challenging conventional wisdom, and mind stimulation.

**C.** General strategies, for example a) DeBono Methods, in particular the Lateral Thinking, PMI, and the Six Thinking Hats [9-14], b) Buzon Methods such as Mind Mapping [7,45], and c) Other Methods such as Metaphoric Thinking and SCAMPER [29].

**D.** Using math and science, specifically systematic logical thinking, geometrical and scientific principles.

**E**. Unified approach to strategies, based on the multi-dimensional strategy scheme developed as part of a NSF grant, i.e., *uniqueness, dimensionality, directionality, consolidation, segmentation, modification, similarity,* and *experimentation*.
**F.** Systematic Inventive Thinking (SIT) for technical innovations, based on the TRIZ (Russian acronym for Theory of the Solution of Inventive Problems) methodology.

<u>The TRIZ methodology.</u> Genrikh Altshuller [2-4] and his colleagues studied over two million patents and identified the main principles and knowledge that define the process for solving inventive problems. TRIZ makes use of the global patent collection and the known effects of science (physics, chemistry and geometry) as a database that supports the needs of problem solvers.

TRIZ helps in some significant ways. It details how to define a problem and how to generate ideas. It solves technical conflicts (contradictions) by applying inventive principles. Once the class of conflict is identified, TRIZ directs the problem solver to the class of principles leading to solutions while avoiding compromises. It leads to scientific effects that can be used to conceive solutions, inventions and next-generation designs.

Among the tools and concepts that TRIZ provides are: 40 inventive principles, the contradiction matrix, application of scientific effects, S-Field analysis, separation principles, levels of innovation, ideality, and pattern of evolution of technical systems.

TRIZ is currently being used internationally leading to a substantial increase in the number of patents by its users. It is being successfully used by many corporations including Motorola, Proctor and Gamble, Xerox, Kodak, McDonnell Douglas, Hughes, Eli Lilly, AT&T, General Motors, General Electric, and Ford [24].

<u>Du Pont successful program on innovation and creativity</u>. David Tanner, the director of the Center for Creativity and Innovation at Du Pont summarized the creativity success of Du Pont in a book titled: Total Creativity [39]. He showed how Du Pont recognized six dimensions of creativity, and how they successfully implemented them in the company. The approach taken at Du Pont can be partially used to teach engineering students topics in inventive problem solving.

<u>The unified approach to problem solving.</u> After several years of research in the area of inventive thinking and recently with support from NSF, we unified many approaches that exist in the literature as well as his own under an eight-strategy approach. Each strategy contains many sub-strategies, each of which can be used to solve engineering problems.

Most of the following topics are covered in the class.

## <u>4. Topics</u>

**I. Introduction**
Making a case for creativity
Creative thinking as a skill
The multi-dimensional approach to creative thinking
Creativity and inventiveness
**II. Valuing diversity in thinking**
Thinking preferences

Creativity styles
Behavior patterns

**III. Setting the stage for success**

Basic philosophy
Having a vision
Setting the right attitude
Recognizing and avoiding mental blocks
Avoiding mind sets
Risk taking
Paradigm shift and paradigm paralysis
Individual and team work

**IV. Creativity in problem solving**

**A. Problem Definition**

Type of problems
Understanding
Representing
Current state, desired state
Defining the real problem

**B. Pattern Breaking**

Out of the box
Thinking differently
Changing your point of view
Watching for paradigm shift
Dreaming and day dream
Challenging conventional wisdom
Lateral thinking and random words
Morphology
Mind stimulation: games, brain-twisters and puzzles
Always listen to your mind and body

**C. General Strategies**

Idea-collection processes

- Brainstorming and Brainwriting
- The SCAMPER methods
- Metaphoric thinking
- Outrageous thinking
- Mapping thoughts
- Talking and listening
- Other (new approaches)

**D. Using Math and Science**

Systematic logical thinking
Using math concepts
Geometry
Science

**E. Unified Approach to Strategies**

1 Uniqueness
2 Dimensionality

3 Directionality
4 Consolidation
5 Segmentation
6 Modification
7 Similarity
8 Experimentation

**F. Systematic Inventive Thinking**

Systematic inventive thinking
- The TRIZ methodology
- The problem/function
- Levels of inventions
- Evolution of technical systems
- Ideality and the ideal final result (IFR)
- Stating contradictions and the contradiction table
- 39 standards features and 40 inventive principles
- Separation in time and space

Use physical effects
Use geometrical effects
Use chemical effects
Use fields
Substance-field method
ARIZ

**V. Decision and Evaluation**

Focused thinking framework
- Listing and checking solutions
- Six thinking hats
- PMI
- Matrix
- Synectics

Other criteria
Ethical considerations
Generalizing solutions
Identifying potential problems

**VI. Implementation**

Planning
Carrying through
Following up

**VII. Ideas to market**

**VIII. Intellectual Property**

Introduction to intellectual property: Patents, Copyrights ©, Trademarks ®, Trade Secret, Unfair Competition.

* Patents
  - What is a patent? Types of patents
  - Patentability
  - Patent application; patent claims
  - Disclosure Document Program (DDP)

Provisional Patent Application (PPA)
* Copyrights ©
* Trademarks ®
* Trade Secrets
* Unfair competition
* Relationships between Trademarks, Trade secrets, Copyrights and Patents

**IX. Creativity and the organization**
Organizational support
Setting an inventive environment
Supporting inventive individuals

## 5. Conclusion and Future Work

In this paper we reported on a class that attempts to enhance inventive thinking skills of undergraduate students that can be used in science, math, engineering and technology. It is based both scientific and educational merits that expose students to hands-on inventive problem solving. It is based on: a) well established systematic and non-systematic approaches to inventive problem solving, b) results from NSF support to FAU on unified frame for inventive problem solving strategies, and c) proven successful methods that are currently being used in high-tech innovative industries.

Currently, we are focusing on expansion of the course to include more hands-on and design activities, and on formative as well as summative evaluation.

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Teaching Inventive Thinking. Editor | On 15, Feb 2000. By: Daniel Raviv. Note: This paper was first published as â€œTeaching Inventive Thinkingâ€, Recent Advances in Robotics Conference http://cimar.me.ufl.edu/FLA99/papers.html University of Florida, April 29-30, 1999. After a brief introduction of the method, students become very fruitful in generating many good and useful ideas quickly! Even those who thought they were â€œnot very creativeâ€. The author is Daniel Raviv, Florida Atlantic University.