Hands-on Activities for Innovative Problem Solving*

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Abstract

This paper describes team-based, interpersonal, and individual hands-on activities that enhance out-of-the-box creative thinking. The activities are designed to be inquiry-based, and to allow for self-exploration of problems and solutions. Some of them encourage work in a self-paced mode, and other promote group competitions, thinking and discussions. Students are encouraged to find multiple, imaginative, intuitive and common sense solutions and not "one right answer" to a problem.

The activities are part of an undergraduate course at Florida Atlantic University titled: "Introduction to Inventive Problem Solving in Engineering". The goal of this "elective" is to enhance innovative and inventive thinking abilities of undergraduate students resulting in skills that can be used in science, math, engineering and technology. The different activities are introduced in specific contexts to enhance learning and understanding of the material.
The activities help students to:
-discover and explore problems and solutions
-learn new concepts in thinking
-become more creative/inventive
-become more open-minded and learn how to avoid mental blocks
-appreciate diversity and discover self
-use intuition and common sense in problem solving
-experience design basics and exercise the "more than one solution" approach
-deal with peer pressure
-enjoy learning.
In addition, the activities help to:
-boost teaming skills
-increase interaction and cooperation
-improve communication between students
Some of the activities are well known, but others are new. They help a great deal to achieve the goals of the course. Observations of students "in action" clearly indicate positive attitudes, persistence, openness and willingness to take risks in an enjoyable learning environment.

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1. Introduction

This paper shares some individual and group activities that have been used to enhance innovative thinking skills of undergraduate students in a 3-credit "elective" course at FAU titled "Introduction to Inventive Problem Solving in Engineering". They include 3-D mechanical puzzles, games, brain-teasers, LEGO® Mindstorms competitions, and design projects. These activities allow for self-paced, semi-guided exploration, and lead to out-of-the-box thinking, imagination, intuition, common sense, and teamwork. (For class syllabus, please refer to http://www.ee.fau.edu/faculty/raviv/EGN4040_SP2003_Syllabus.htm.)

The activities help the students understand concepts of the Eight-Dimensional Methodology for Innovative Problem Solving[6,7] that has been developed and taught by the author at FAU. It is a systematic and unified approach that stimulates innovation by effectively using "both sides" of the brain. It builds on comprehensive problem solving knowledge gathered from industry, business, marketing, math, science, engineering, technology, and daily life, and helps to quickly generate many unique "out-of-the-box" unexpected and high-quality solutions. The dimensions, namely *Uniqueness, Dimensionality, Directionality, Consolidation, Segmentation, Modification, Similarity, and Experimentation* provide problem solvers of different professions with new insights and thinking strategies to solve day-to-day problems that they face in the workplace.

The next section is divided into 12 subsections that explain the different goals of the activities followed by specific examples. Note that some activities may "belong" to more than one category, especially those that involve teaming and communication.

2. The activities

A) Activities for stimulating the mind; discovering and exploring problems and solutions; learning new concepts in thinking

3D Puzzles. Almost every class starts with solving 3-D mechanical puzzles. The purpose of this 5-minute activity is to stimulate the students' minds and to help introduce an upcoming concept in problem solving. A few times per semester the students meet in a laboratory with more than 250 different 3-D puzzles where they simply play. In a way it is a "playground for the mind" where they explore problems and solutions at their own pace. An example for a book from which puzzles may be designed and built is[8]. Puzzlebusters[1] and brainteasers are part of their homework assignments.

Figure 1: 3-D mechanical puzzle

What bothers you? This is an exercise that helps students think about problems. The instructor asks them to simply write down answers to the "what bothers you?" question, i.e., find problems that require solutions. This activity leads to a long list of problems that later can be redefined and solved. An example that I give the students on "what bothers me" is what I call the "speed bumps problem". Every working day I experience at least 14 speed bumps on my way to and from work, and feel that there is a "problem".

In a multi-group brainstorming session students are asked to identify/clarify/define (not to solve yet) the "**Speed Bump Problem**." In a typical session they find more that 20 problems that are related or caused by speed bumps. The following is a "sample" categorized list of student responses.

Driving/Traffic:
- Cause Traffic Jams/ backups
- Slow-down traffic
- Cause tailgate and other accidents
- Cars drive in bike-lanes to avoid them
- Not convenient for bicycles

Driver:
- Sometimes invisible/ confusing (weather conditions, reflections)
- May surprise drivers
- Annoying and frustrating
- Bad for the body
- Tall drivers may hit their heads
- Blind on-coming traffic (at night)
- Cause drink spills
- Reward fast drivers (cars with excellent shock-absorbers are not affected much at high speeds)

Punish slow drivers (they still have to feel the bumps)

Cost:

May be too expensive to build/maintain

Causes traffic delays when built/ maintained

Environment:

More noise and pollution due to deceleration/ acceleration

Animals may not like the noise made by decelerating/accelerating cars

Car damage:

Cause CD to skip; damage fragile items

Damage suspension/ bottom of car/ alignment

Wear brakes/ clutch

Emergency:

Slow down ambulances/ fire trucks

May injure patients inside ambulances

Law enforcement:

Slow them down in emergency situations

Less tickets given out (… a "good problem" for drivers)

This particular exercise only defines the problem. In some classes, student teams were asked to find solutions to the speed bumps problem, choose one solution, build, test and demonstrate it.

Another example that I share with the students is when I try to get into my car in a rainy day, I get wet despite the fact that I have an umbrella. It happens at the time when the car door is open and the umbrella needs to be folded and put in the car.

Measure the height of a building. Students are given a 12" ruler, 8"x8" mirror, paper, and a pencil. Their task is to explore ways to measure an unreachable height in a building. This team-based activity takes about 15 minutes, and helps students find solutions for ordinary problems in not-so-ordinary ways. Groups include 2-3 students.

B) Activities for learning new concepts in thinking

The following activities help to understand the so-called "out-of-the-box" concept and to get into "unexpected thinking" mode.

Use 6 popsicle sticks to make 4 equilateral triangles. To teach the eight-dimensional methodology we use many hands-on activities. For example, the concept of solving problems by adding a dimension is illustrated using a well known problem: use 6 popsicle sticks to make 4 equilateral triangles. Students discover that by looking for a 3-D solution, the problem can be easily solved by constructing a pyramid[4].

The nine-dot problem. The well known "nine dots" problem[3] is used to explore unexpected "out-of-the-box" solutions to a problem. In this problem the students are asked to first connect the three rows of three dots in each row with five connected straight lines, then with four, then with three, and finally with one. Folding the paper (adding a dimension) provides multiple solutions to the last part of the problem.

Problems with little or no data or information. These kind of problems help introduce the "no right answer" to a problem. For example, students are shown the following 5 numbers: 2, 3, 5, 10, 24 and asked to use all the five numbers and any mathematical operations that they choose to make up the number 120. The problem has many solutions, for example: (10-5)*24/(3-2)=120, or $(10-5)^{(3-2)}*24=120$.

Solutions of many problems depend on initial assumptions made by the students. For example, the group-based problem: "Estimate the number of dentists in Los Angeles, California" leads students to generate their own estimated-data for the problem.

C) An activity for thinking logically and strategically

Quarto. One of the greatest two-player logic games is quarto. It has a 4x4 board and 16 different pieces. Each piece has a square or circular horizontal section, is tall or short, has either dark or light color, and is solid or has a hole in it (total of 2*2*2*2=16 combinations for pieces). Players take turns and hand to their opponent one piece at a time to be placed on an empty board square. The first player to line up four pieces that share the same feature, horizontally, vertically or diagonally, is the winner. (Feature is one of the following: tall, short, dark, light, square, circular, hole, no-hole.)

D) Activities for enhancing imagination and becoming more creative/inventive

What is it? Students are shown an invention, and asked to "figure out" what it is.
For example:

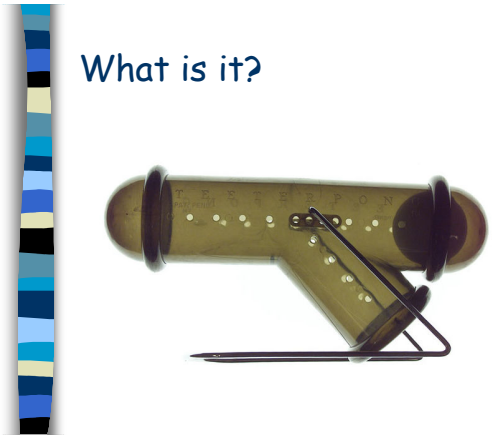

Figure 2: Imagination exercise: mouse trap

After a few minutes of guessing and discussing (usually with some hints) they discover that it is a mousetrap. The following is the patent abstract of "Mousetrap for catching mice live."[10]:

A "Y" shaped mousetrap lures a mouse into an open end of the "Y" by means of smelly bait located at a closed end of the bottom of the "Y". The "Y" is pivotally supported horizontally by a stand. As the mouse walks past the pivot point, a ping pong ball rolls from the opposite short "Y" tube member and down to the entrance of the open ended tube member. The mouse is trapped alive and can be drowned by immersing the mousetrap.

Darwin's approach. After a class discussion regarding the effect of changes in technology and environment on humans in the past decades, students are asked to draw a next generation of the human being as they perceive it. This drawing exercise usually results in drawings of strange-looking computerized robot-like people with huge air-filter-like nose. In addition to enhancing thinking and imagination, this exercise helps to reduce the "I am not an artist" attitude of many students, since they have been specifically instructed not to write their names, and not to limit their imagination.

What can you do with coat hanger? Students are shown a coat hanger and asked to individually list different possible uses. They are given the freedom to use any material, size or shape of a hanger; they may imagine cutting it, shrinking it, using many of them, etc. Amazingly, in a short period of time each student writes many ideas. The students take turns to mention their ideas. Usually one idea mentioned by each student is suitable time-wise and fun-wise to complete the exercise.
(The coat hanger may be substituted with any other basic familiar object such as a book or a mailbox.)

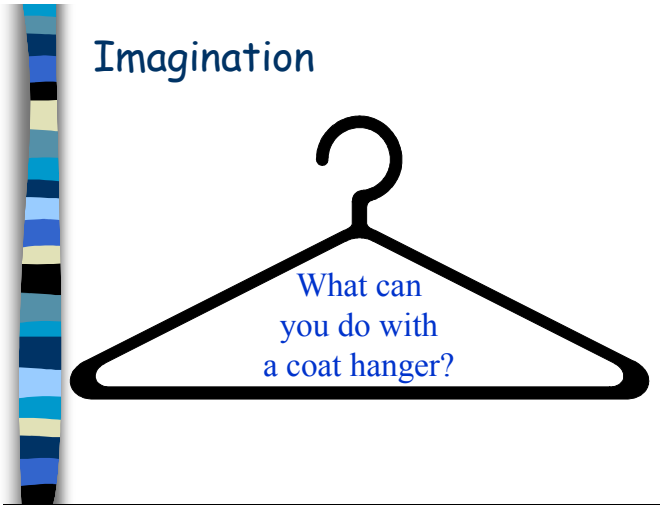

Figure 3: Multiple solution question: what can you do with a coat hanger?

E) An activity for making people more open-minded and for learning how to avoid mental blocks

Shape division and "stuck" mind exercise. This exercise was suggested by[2]. Students are introduced to several different 2D geometrical shapes, one at a time. First they are asked to divide an equilateral triangle into 4 identical pieces. After quickly solving it, they are introduced to more difficult questions. For example, divide an L-shape into four identical pieces, then divide a symmetrical trapezoid to four identical pieces, then a hexagon into eight identical pieces, and finally divide a rectangle into seven identical pieces. Despite the fact that the last question is the easiest one, most students can't solve it. Their minds simply "get stuck" due to their expectation for difficult question.

This activity helps to explain to the students that each time they approach a new problem they must have a "fresh look," and avoid mental blocks, in this case making unnecessary assumptions.

F) Activities for appreciating diversity and discovering self

Describe yourself using three adjectives. To help appreciate diversity in thinking, students are asked to describe themselves using three adjectives. Obviously the adjectives vary from one student to another.
This exercise is followed by an open discussion for the need of different kinds of thinkers, choosing different kinds of team members in a group, and appreciation of each other's thinking.

The Diversity Game. A fun way to introduce diversity in thinking styles is by using the Diversity Game, a four-color card game created by The Nedd Herrmann Group[9]. The facilitator distributes 5 cards to each student. Participants are asked to arrange their 5 cards in order, starting with the card that best describes them and ending with the card that is least like them. The participants are allowed to move around and to improve their hands by trading cards with their peers. They discard two least preferred cards, and continue to exchange cards using the leftover cards. Later the participants display the cards. The different steps are introduced with discussions and explanations. At the end, the meaning of each color is explained in group and individual contexts, referring to Nedd Herrmann's four quadrants approach.

G) Activities for using intuition and common sense in problem solving

I always remind my students to use common sense and intuition when they solve problems. At the same time I mention to them not to over-rely on their intuition. The following well known problems are examples for counter intuitive solutions to problems:

Fold a paper. Imagine folding a paper in half once; then take the result and fold it in half again; and so on. How many times can you do that?
6-7 is the maximum number of times that this can be practically done. In class, answers by students varied from one to infinity.

Helium balloon. Joe attached a helium filled balloon by a string to his seat. After driving for a while at a constant speed, he braked the car. Question: Relative to the seat, did the balloon move forward backwards, or not at all? (The answer is …. backwards.)

Students are asked to list things that do not make sense. An example that I share with my students is "Exit Seating Instructions" written by a well known airline:

> *"If you cannot read or understand the information on this form, please advise the (name of airline) agent or flight attendant. U.S. government regulations prohibit an individual from sitting in a designated exit seat if they cannot speak, read or understand the instructions."*

H) Activities for experiencing design basics and exercising the "more than one solution" approach

Transportation projects. Several teams are formed to solve specific real-life multidisciplinary problems in intelligent vehicles. Each team (also called "E-Team") is assigned a task. The teams use problem solving strategies to generate ideas, choose the best solution, complete comprehensive patent and marketability searches, and design prototypes. Examples for E-Team tasks that were suggested to the students:
- Sensor fusion system for detecting obstacles
- Smart bumpers to minimize collision effects
- Advanced collision-warning system
- Radar-based system for controlling traffic lights
- Alternatives to speed bumps

How to say no. On a separate piece of paper , without writing their names, the students are asked to write down as many possible ways for "how people say 'no'". Here are some examples for what they write:
-We would love to do it, but…
-You know, something came up, …
-We are going to do it, aren't we?
-We could, but, …
-May be another time
-Whatever
-I'll call you about it

The actual lists made by the students are surprisingly long. Collectively they listed more than 200 different ways. This activity doesn't only show the "no unique solution" concept but adds to the fun and enjoyable element of the class.

I) An activity for adding joy and fun to learning and for dealing with peer pressure

Tower of Babylon (students prefer to call it "Giant Jenga"). 18 layers of four colorful 1.5"x1.5"x6" blocks are organized in a tower-like shape. Students take turns to pull pieces (one at a time) from lower layers, and put them on top (similar to the Jenga game, except that they are allowed to use both hands). At some point the tower collapses and the game ends. This game is normally played at the last meeting of the class. Beyond the fun of it, students must use judgment under peer pressure, gain some focusing skills and practice hands-on coordination.

Figure 4: "Giant Jenga" team activity

J) Activities for boosting teaming skills

Lego®. LegoMindstorm robots are used in different team competitions. The most difficult task is introduced to the students as follows:

> *"Design and build an autonomous robot that will get out of a maze. First robot to complete the task is the winner. Note: The starting locations of the robots in the maze are kept confidential until the beginning of the race."*

Most solutions include robots that use tactile sensors. Some robots managed to exit the maze by applying a non-linear rotational motion to the robots. Recently, groups have been literally applying "out-of-the-box" solutions by building robots that move above the maze walls.

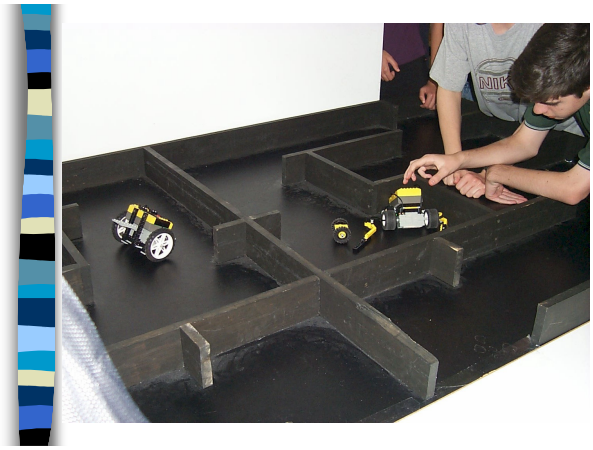

Figure 5: Maze for LegoMindstorm robots

Crossing the river. This is an out-of-classroom team activity. The class is divided into groups with the same number of students (about 10) in each group. Each group is given two 4 feet 2"x 4" wooden shelves, two ropes and a chair. The competition starts five minutes after the instructions are given, allowing them to think and set a strategy for accomplishing the task.

The Task: Each group with the provided material has to cross a 30'ft wide imaginary river. The material may touch the river but the participants may not. If, while crossing the river a student touches the river he/she must walk back to the starting position. The first group to accomplish the task is the winner.

K) An activity for increasing interaction and cooperation between students

Name Game. This is a version of the name game suggested by[5]. Many students recognize each other by face but not by name, and this game helps to change that. In the beginning of the first few classes the students are asked to, one at a time, say their names, and something interesting about themselves. In addition, they are asked to state the first names of the students that spoke before them. (This of course does not apply to the first two students.)

L) An activity for improving communication between students

Line up according to your birthday. The instructor asks a simple question: "If you know the month of your birthday, raise your hand." This seemingly strange question is followed by a task: "Without talking, and with no questions asked, in 30 seconds, line up according to the month of your birthday." After lining up, the participants are allowed to talk and mention loudly, one by one, the month of their birthday. (I have been through this exercise several years ago, but can't find the original source.)

Figure 6: Power Point slide for a communication exercise

Conclusion

This paper presents hands-on, teaming and communication activities that are used as part of a problem solving course at FAU. They help the students to use new concepts in thinking and problem solving, to think differently, to use imagination, intuition and common sense, to appreciate others' points of view, and to have fun in the process. The exercises contribute to the development of a more innovative and creative classroom environment, and help a great deal in introducing students to problem solving topics, such as "exploring more than one solution", "changing points of view", appreciating diversity in thinking, and using the "Eight Dimensional Methodology for Innovative Problem Solving." As reported in previous papers by the author, at the end of the course students consistently generated many more solutions to given problems than at the beginning of the class (usually more than twice as many solutions). Assessing the benefits and drawbacks of each activity is a tough issue, and still needs to be worked on. In addition, for some students some of the activities may not be as fun as for others. In these special cases the instructor should be ready to intervene, help and share some hints to minimize the development of "mental blocks."

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Biography

Dr. Daniel Raviv received his Ph.D. from Case Western Reserve University in 1987, and M.Sc. and B.Sc. degrees from the Technion, Israel Institute of Technology in 1982 and 1980, respectively. He is currently a professor of Electrical Engineering at Florida Atlantic University (FAU) in Boca Raton, Florida. His major research interests are in autonomous driving and innovative thinking.