Creativity and Innovation for Electrical and Computer Engineering Research

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Abstract

This paper introduces simple approaches to integrate creativity and innovation in the classroom. This in turn will help Electrical and Computer Engineering students to develop new ideas and to solve complex problems. The main objective of this paper is to help students and practicing engineers to improve their creativity and innovation skills, which will enhance their careers. Case studies and examples on how to produce new innovative ideas and patents are given.

1. Introduction

This paper is meant to be a hands-on opportunity for professors and students to experience and practice the creative problem solving process throughout all undergraduate and graduate courses in the Electrical and Computer Engineering curriculum. Certainly, the benefit of this paper can be extended and used in all engineering education disciplines including, but not limited to, mechanical, chemical, and civil engineering.

The framework of this paper is also very useful for practicing engineers, project managers, and executives. The ideas presented in this paper intend to enhance students' creativity and innovation for electrical and computer engineering research until they become comfortable with their own innate abilities to solve problems, come with new concepts, and design new systems. The instructor may implement this framework in all junior-level, senior-level, and graduate classes that he/she teaches. However, there are many required and elective courses in which education and research can effectively integrate. Such courses are the best candidates to introduce creative thinking and problem solving approaches. At Lawrence Technological University, the author introduces creativity and innovation in courses such as Electronics, Microprocessors, Digital Control Systems, Digital Electronics, Computer Vision, Digital Image Processing, Digital Communication, Very Large Scale Integration, and Integrated Circuits Design. Very favorable and highly gracious feedback from the students is usually received.

This paper is organized as follows. Section 2 describes background information regarding creativity and innovation integration in engineering education, definitions and procedures on how to introduce creativity in the classroom. Factors that boost creativity are introduced in Section 3, while factors that limit creativity are given in Section 4. Section 5 gives some techniques for creative thinking including applied imagination, checklists, random inputs, Ask

Questions, and TRIZ theory. A summary and conclusions are also given in Section 6, followed by a list of references and a brief author biography.

2. Background Information

The author often introduces creativity during the second or the third week of the semester. He usually gives one-hour lecture to talk about creativity and innovation techniques using PowerPoint presentation. The author also distributes to the students a copy of this presentation with a list of creative examples. Then he involves the students to solve these examples. The main advice given to the students is to make it simple when they solve these examples since often very complicated problem may have a very simple solution(s). In addition to regular teaching assignments, there are many informal teaching opportunities that arise in which creativity and innovation can be injected into the curriculum. Most notably, capstone design courses can be easily utilized for creative thinking to produce quality projects, provided that the instructor and the project advisor are willing to devote a significant amount of time to advising the student team members.

Creativity is a process of generating and manifesting a new idea[1]. This idea may come in seconds and goes with the winds in seconds unless it is recorded and explored. On the other hand, innovation is taking creative ideas into reality and implementation to produce a new product or system. Such product may use other ideas and concepts and may consist of many phases and may require days, years, or even a lifetime to utilize.

After this one-hour lecture about creativity and innovation, the author goes with his routine to teach the subject on hand with reference to the many creative thinking approaches that the students have learned in the creativity lecture. For instance, as a simple example when the design of an electronic amplifier circuit for a specific application is covered, one can ask many questions to produce a new and innovative design such as (a) How to put this amplifier to other uses or other applications? (b) How to modify it to make it better? (c) How to magnify its performance? (d) How to minify or simplify the circuit? (e) What if we substitute the bipolar transistor with a FET or MOSFET? (f) How to minify the amplifier circuit? (g) What to subtract? (h) How to make the circuit smaller and lighter? (i) What to adopt? (j) What could I copy? (k) What could I emulate from previous designs to produce a new and better amplifier circuit?

3. Factors That Boost Creativity

In the creativity lecture, the instructor may highlight the main factors that boost and enhance students' creativity including:

- Since creative ideas come in seconds and shall be lost unless recorded, always carry a small notebook and a pen or a mini cassette recorder to record your creative ideas.

- Take a walk. How many ideas have you had while walking, jogging, gardening, washing dishes and even driving?

- Travel helps to refresh your outlook and expose you to new ideas, people, customs, and ways of living.

- Listen to music; smooth easy listening, non-lyric music helps to enhance thinking.

- If you are stuck for an idea, open a dictionary, randomly select a word and then try to formulate ideas incorporating this word. You would be surprised how well this works. Similarly, you can choose one word out of 100 words placed in a bag to formulate your ideas incorporating the chosen word.

- Open a scientific journal, choose an article of interest then apply creative thinking approaches such as "applied imagination" or "ask questions" to formulate a new solution to accomplish the same goal.

- Go to www.uspto.gov or any other international patent site on the web and choose a patent of interest. Think how to apply creative thinking approaches to improve the patent or find another solution to accomplish the same goal.

- Define your problem, then ask six questions: What? Where? When? Why? Who? and How? You may find many positive ideas to solve your problem.

- Exercise your brain by talking to educated people, being a member in a scientific society, reading scientific papers and patents of interest, playing games and puzzles, and many others.

- Hobbies such as painting, drawing, sculpture, and cartooning can provide creative exercise.

- Writing; writing ability is considered to be a basic factor in creative aptitude and often utilizes all phases of the creative process.

- Be healthy; a healthy brain is embedded in a healthy body. Eating well and physical exercises are some important aspects to consider.

- Be happy; happiness is a vital necessity to creativity and innovation.

- Be confident; self-confidence is very necessary. If you fear failure, failure is what you shall get.

- Playing imagination games with your children may have a great contribution. Child mind is like a fresh intelligent computer.

- Brainstorming can help generate a stock of new ideas and enable you to decide which one is the best.

- Humor; humor means having fun and creativity needs a good dose of fun and play.

4. Factors That Limit Creativity

In the creativity lecture, the instructor may also highlight the main factors that limit and decrease students' creativity including:

- Avoid TV addiction; research shows that watching TV slows human thinking.
- Avoid drug addiction; drugs destroy human body and diminish creativity.
- Fear of criticism; fear always yields failure and hinders creativity.
- Lack of confidence; creative people are confident people, therefore self-confidence is a crucial factor in creativity and innovation. If you believe that you are not creative, then there is no need to learn how to be one.
- State of mind/body and general health; again you need to be in full health to be creative.
- Being too busy causes stress and reduces creativity.
- Conflicting goals and objectives reduce creativity.
- Stress; it is very bad for health and it drains most needed energy.
- Not allowing oneself enough time to relax.
- Ego; having a strong ego identity with a particular belief leads to defending this belief if it was wrong.
- Demands for quick production of results; deadlines often cause stress and reduction of creativity and good planning is the answer.
- Harsh words from others may destroy one's creativity; the instructor must be careful what he/she says to students.
- Routines and setting specific ways of doing things generate a rigid mind. Continuous exercise to human brains is necessary for creativity an innovation.
- Self-criticism; negative thinking and self-criticism are also limiting factors of one's creativity.
- Rigid rules and barriers limit creativity. Freedom is great for positive thinking.

5. Creative Thinking Techniques

This is the most important topic to teach in the creativity lecture hour. In the literature[1-6], there are many approaches and techniques for creative thinking which are all useful. However, some techniques explained here in particular are very rewarding in engineering research especially electrical and computer engineering research.

5.1 Applied Imagination

The author highly recommends this technique. Many students found it very useful for their research and capstone design projects as well. This technique generates a checklist for new ideas. A student can choose a scientific paper of interest, an electronic circuit, a mechanical system, a chemical formula, or a patent in the field of interest and ask the following questions to form and generate new ideas and solutions to accomplish the same goals or even other more complicated goals. This is the checklist for new ideas.

Put to other uses?
New ways to use as is? Other uses if modified?

Adapt?
What else is like this? What other idea does this suggest? Does the past offer parallel? What could I copy? Whom I could emulate?

Modify?
New twist? Change meaning, color, motion, sound, odor, form, and shape? Other shapes?

Magnify?
What to add? More time? Greater frequency? Stronger? Higher? Thicker? Extra value? Plus ingredient? Duplicate? Multiply? Exaggerate?

Minify?
What to subtract? Smaller? Condensed? Miniature? Lower? Shorter? Lighter? Omit? Streamline? Split up? Understate?

Substitute?
Who else instead? What else instead? Other ingredients? Other material? Other process? Other power? Other place? Other approach? Other tone of voice?

Rearrange?
Interchange components? Other pattern? Other layout? Other sequence? Transpose cause and effect? Change pace? Change schedule?

Reverse?
Transpose positive and negative? How about opposites? Turn it backward? Turn it upside down? Reverse rules? Change shoes? Turn tables? Turn other cheek?

Combine?
How about a blend, an alloy, assortment, an ensemble? Combine units? Combine purposes? Combine appeals? Combine ideas?

As an example, if one chooses a patent of an integrated circuit audio amplifier with limited frequency bandwidth to produce a new and innovative design of another integrated circuit amplifier used for other applications with different frequency and power requirements, the following checklist may be asked:

1. How to put this amplifier to other uses or other applications?
2. How to modify it to make it better?
3. How to magnify its performance, increase its frequency bandwidth, and increase its power gain?
4. How to minify or simplify the integrated circuit such that the fabrication will become easier and cheaper?
5. What if we substitute the bipolar transistor with a FET or MOSFET, or what if I change the biasing circuit of the amplifier to save energy and prolong battery lifetime?
6. How to minify the amplifier circuit? What to subtract? And how to make the integrated circuit smaller and lighter?
7. What to adopt? What could I copy? And what could I emulate from previous designs to produce a new and better integrated circuit?

Now you may have a new integrated circuit amplifier, and may be a new patent!

5.2 Ask Questions

This technique is very useful to solve problems in progress. A problem can be tucked in two different approaches. The **first** approach is based on "**ASK WHY FIVE TIMES**". In this approach, one can ask "Why" a problem is occurring and then ask "Why" four more time (or more if necessary) to solve the problem on hand.

As an example, if the problem is a nonworking electric machine. The questions and the corresponding answers may be as follows:

1. **Why** has the machine stopped?
   Answer: A fuse blew because of an overload.
2. **Why** was there an overload?
   Answer: There was not enough lubrication for the bearings.
3. **Why** was not there enough lubrication?
   Answer: The pump was not pumping enough.
4. **Why** was not lubricant being pumped?
   Answer: The pump shaft was vibrating as a result of abrasion.
5. **Why** was there abrasion?
   Answer: There was no filter, allowing chips of material into the pump.

Consequently a solution to this problem was found. Clean the chips and replace the filter.

The **second** approach of "Ask Questions" is the "**Six Universal Questions**". These questions are: **Who? What? Why? Where? How? and When?**

As an example, one can ask himself/herself to solve and generate a future career plan.

1. **Who** am I and who do I want to be?
2. **What** am I studying and what are my goals?
3. **Why** am I studying?
4. **Where** will I work after graduation?
5. **How** can I reach my goal?
6. **When** will I reach it?

Another example for the "Six Universal Questions" is to propose and plan a new project as follows:

1. **Who** should do the project?
2. **What** should be done?
3. **Why** is it necessary?
4. **Where** should it be done?
5. **How** should it be done?
6. **When** should it be done?

5.3 Brainstorming

The basis of brainstorming is a generating ideas process in a group of people, where other people's remarks would act to stimulate one's ideas in a sort of chain reaction of ideas without making any judgment. The generation phase of ideas is separate from the judgment phase.

Brainstorming works best with a group of people when you follow the following four rules.

1. Have a well-defined and clearly stated problem.
2. Have someone assigned to write down all the ideas as they occur.
3. Have the right number of people in the group.
4. Have someone in charge to help enforce the following guidelines:
    A. Suspend judgment
    B. Every idea is recorded and accepted
    C. Encourage people to build on ideas of others
    D. Encourage way out and odd ideas

The spirit of brainstorming is based on individual thinking such that individuals are much better at generating ideas and fresh directions. Once the idea has been born by an individual then a group may be better able to develop the idea and take it in more directions than can the individual originator.

5.4. TRIZ Theory

The author also introduces in the class TRIZ (The Theory of Inventive Problem Solving) to help students solve very complex problems systematically. TRIZ is the theory of inventive problem solving founded by Genrich Altshuller[7-8]. TRIZ provides a systematic methodology to solve engineering design problems. The theory is based on a tree search for a best solution by evaluating a best match function, D. This function is defined as

$$D = \frac{\sum Benefits}{\sum Expenses + \sum Harm}$$

An ideal solution will be reached once D approaches infinity. Therefore to increase the degree of approaching an ideal system, one may increase the benefits and reduce the expenses and the harm developed. Altshuller developed very extensive tables of a large number of alternative solutions once a problem arose.

5.5 Attribute Listing

This creative thinking technique is very useful to improve the quality of a circuit, system, or product. Attribute Listing is based on breaking down the problem into smaller bits then looking for a replacement for every bit to produce a new product or system.

As an example, if one seek to improve a torch. First you list the features and the attributes of the torch then you look for possible replacement for every feature, as follows:

Feature	Attribute (currently used)	Idea (replacement)
Casing	Plastic	Metal
Switch	ON/OFF	ON/OFF/DIM
Battery	Regular battery	Rechargeable battery
Bulb	Glass	Plastic
Weight	Heavy	Light

6. Summary and Conclusions

All people are creative to various extents and every student can be creative if educators stimulate his/her innate abilities. It’s just that some individuals act on their ideas and others ignore them. Inventers take action on their ideas. How many people have said, “I could have done that” when they see a new product. The response is “Well, why didn’t you?” That is the main objective of this paper and the whole purpose of creativity and education integration into the electrical and computer engineering curriculum.

Introducing creativity in the classroom has been a professionally satisfying task. Design-oriented courses, elective courses, capstone design courses, directed studies, and graduate courses have all been used as vehicles for creativity/education integration by the author. This integration has had a great impact on student projects and research assignments especially at the graduate level.

Much of the formal and informal student feedback regarding creativity and innovation integration in the classroom was very positive. This integration is also personally very satisfying, but it is also time consuming. The workload for both student and instructor is enormous. In retrospect, providing research opportunities to undergraduate and graduate students has been a valuable experience for both students and the author. At this essentially uncharted territory, we can only learn how to teach creativity and innovation to undergraduate students through experimentations, while at the same time not compromising their overall education.

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Author Biography

Hassan Hassan holds B.S. in Electrical Engineering, M.S. in Electronic Engineering, and M.S. and Ph.D. in Electrical and Computer Engineering from Wayne State University, Detroit, Michigan. He is the author of numerous numbers of refereed conference and journal papers. Dr. Hassan is an experienced educator at the undergraduate and graduate levels, taught at many universities including Kuwait University, Wayne State University, and presently at Lawrence Technological University, Southfield, Michigan. Due to his extensive education, Prof. Hassan taught almost every undergraduate course in the electrical and computer engineering curriculum and taught many graduate courses including: Engineering Analysis, Image Processing, Computer Vision, Artificial Intelligence, Very Large Scale Integration, Computer Aided Design of Integrated Circuits, Network Synthesis, Digital Control Systems, Digital Communications, and Optical Communications. Dr. Hassan is also serving as a consultant for local companies in these technical areas. He is a Senior Member of IEEE and IEEE Computer Society since 1993, member of Sigma Xi, Tau Beta Pi, Eta Kappa Nu, and a registered Professional Engineer in the State of Michigan since 1988.