# A Problem-Solving Approach to Teaching Creativity for Engineering and Other Disciplines


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## ABSTRACT

Creativity is an integral part in the careers of every professional, including artists, actors, as well as businessmen and engineers. Engineers, the focus of this effort, are traditionally considered to be systematic thinkers and implementers of constrained procedures and algorithms. In order to challenge this perception, ECE490DI is a class designed to show engineering students that their majors and future careers will not only use creativity, but be fully immersed in it. Once the students realize this fact, the next step is to help them discover their own creativity skills and show them that creativity, like other talents, can be nurtured and strengthened through repetitive use.

To accomplish these goals, students in ECE490DI take a class trip to renowned theme parks in Orlando, FL, where they attend multiple workshops in the areas of leadership, teamwork, and creativity. The workshops allow students to exercise their leadership, teamwork, and creativity and show them several tools to expand and further improve their abilities in those areas. Students are also given the chance to meet and interact with theme parks' engineers, also known as "Imagineers," to see the practical applications of creativity in a hands-on creative work environment.

While the objectives of ECE490DI were successfully met in previous semesters, the class was redesigned to have a broader scope and a multidisciplinary nature. The multidisciplinary version of the class builds on the assessment results of the previous offerings as well as feedback from participating students, faculty members, and theme parks staff members. The new version of the class includes more meetings throughout the semester to further reinforce the ideas and concepts from the workshops.



**Keywords**: Creativity, Professional Skills, Engineering Education, Multidisciplinary.


## 1. INTRODUCTION

The National Academy of Engineering established a steering committee to envision the state of engineering in 2020 and develop a framework for the future of undergraduate engineering education in the United States. *The Engineer of 2020 – Visions of Engineering in the New Century* [1] was published to present the Academy's aspirations describing the attributes required for engineering in 2020.

As expected, strong analytical skills and the ability to work under increasing economic, legal, and political constraints were highlighted. However, the text is overwhelmingly dedicated to identifying a number of professional skills as essential attributes of the 2020 engineer: practical ingenuity, creativity, communication, business management, and leadership [1].

Engineering students are often most challenged to develop and hone their creativity. Despite their training in designing systems and components, many engineering students do not consider themselves to be creative individuals [2]. Moreover, many engineering students believe that creativity is a talent that they may have (or have not) been born with. The research findings in [3] and [4] totally refute this misconception and shows that creativity is a skill that can be taught through practice just like other skills. Unfortunately, teaching engineering students a disciplined approach to the creative process has eluded academia [5]. While students and professors alike have may have an increased interest in creativity, engineering curricula, due to time and resource limitations, are still overwhelmingly focused on mathematics, sciences, and engineering fundamentals [6]. Therefore, a need exists for instructing engineering students in the creative process to complement existing engineering, math, and science classes.

In the fall semesters of 2011, 2012, and 2013, engineering undergraduates from the Valparaiso University College of Engineering (Valparaiso, Indiana, USA) participated in a four-day off-site course focused on creativity, innovation, teamwork, and leading the creative process [7-10]. The course was taught by members of the College's engineering faculty and included sessions and on-location tours that were led by instructors from an external training organization (ETO) near Orlando, Florida. Assessment shows a significant improvement in the students' understanding of the roles of creativity, innovation, and the roles of leadership, communication, and teamwork in the creative process. A detailed description of the class as well as the assessment results can be found in [10].

This paper describes the organization of the previous offerings of the class in section 2. Section 3 discusses the motivations to improve the class and broaden its scope in 2014 and thereafter. The improvements to the class are listed and discussed in section 4. Section 5 is summarizes our conclusions.

## 2. PAST WORK

Some courses at various universities are constructed to explicitly include lessons on creativity and the creative process [11]. However, many of these classes are not taught within the context of engineering [2, 12, 13].

To address the development of students' professional skills (including creativity), Valparaiso University's College of Engineering began in 2001 to incorporate lessons encouraging their development in its senior design class [14]. Specific lessons on creativity were progressively embedded into additional classes in the following years [15].

However, engineering students have been found to be better prepared for problem solving by introducing concepts like creativity outside of traditional classrooms [16]. Therefore, after reviewing the National Academy of Engineering's *The Engineer of 2020*, a separate Creative Engineering course was conceived in April, 2011 [9]. The course would introduce engineering students to the creative process and challenge students to define and explore the topic of creativity in engineering. The objectives for the class are shown in Table 1.

**TABLE 1:** Objectives for Creative Engineering Course

| | |
|---|---|
| 1. | Students will be able to give examples of creativity in engineering. |
| 2. | Students will be able to use tools and processes that help them to be more creative. |
| 3. | Students will be able to explain how individuals can be more creative. |
| 4. | Students will be able to explain the role of a leader in the creative process. |

When designing this Creative Engineering course, the College of Engineering at Valparaiso University decided to partner with an ETO to develop the class for three reasons. First, it would allow professors to serve as facilitators and guides for the class. Second, working with an ETO would help reduce the faculty load required for developing and implementing the course. Finally, partnering with an internationally recognized creative organization would make the course a hands-on, real-life experience and bring a certain amount of prestige to it [8, 9].

In the Creative Engineering course, a team-teaching approach was used. The course was facilitated by Valparaiso University College of Engineering faculty, while specific on-location classes, tours, and workshops were be led by instructors from the ETO. In addition, faculty served administrative roles in course development and implementation, handling all the logistics related to traveling to and from the ETO's location in Lake Buena Vista, Florida (near Orlando).

There are many ways to evaluate creativity, including testing, interviews, observations, and self-assessments. However, for topics like creativity where confidence levels impact an individual's performance, there is evidence that self-efficacy is a reliable predictor [17]. Therefore, students enrolled in the various offerings of the course were asked to self-evaluate if they were creative and to assess their ability to meet the four objectives in Table 1 using a Likert scale. The self-assessment included both a pre-course and a post-course assessment. The results for the two assessments in each of the three offerings of the course are shown in Figure 1. (Note the data for the Control Group and the 2011 course were calculated to two significant digits. This was changed to three significant digits in 2012 and 2013.)

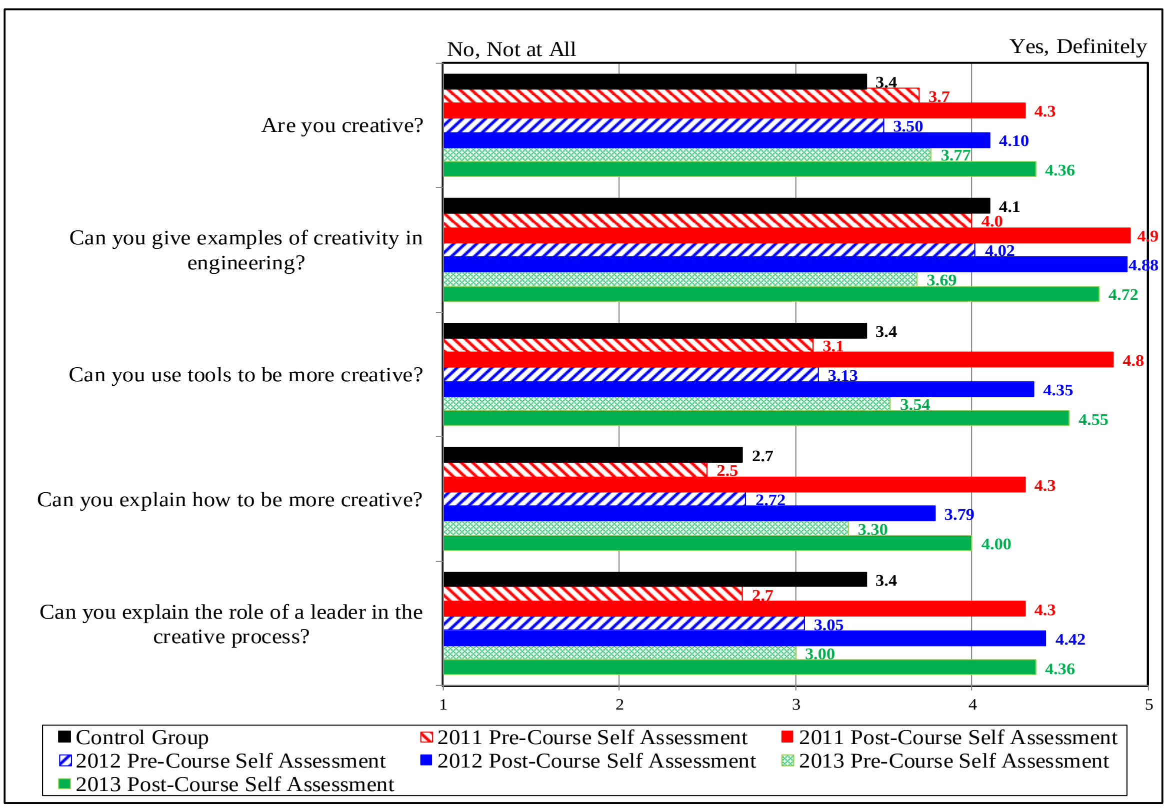


**FIGURE 1**. Averages of student self-assessments performed before and after the 2011, 2012, and 2013 Creative Engineering course using a Likert scale (1 being "No, Not At All" and 5 being "Yes, Definitely"). Data is also provided for a control group of students that did not participate in the class.

## 3. MOTIVATION FOR CHANGE

The 2011 - 2013 offerings of the class achieved remarkable success that is documented in [10]. However, it was still obvious that a higher ceiling can be reached and that there are ways to improve the students' learning experience. As a result, an overall class evaluation including students, College of Engineering faculty members, and members of the ETO was performed. The outcome of the evaluation was a decision to make some changes in the fall, 2014, class.

The motivation for change was two-fold. First, there was the desire to teach creativity more effectively and thoroughly. Second, there was a consistent theme from past participants wanting to extend the duration of the class trip to the ETO and see additional examples of applying creativity to real-world problems. While in the near future, time and resource limitations prohibit any significant extension of the trip to the ETO, it was feasible to improve the course by addressing the following motivations:

### a. More in-depth discussions

During the first three years of the ECE490DI course, various participants have identified the need for more in-depth discussions, especially on the subjects of teamwork, creativity, and leadership. The general feeling was that students were getting a broad overview of these topics but were not having enough time to fully delve into and deeply comprehend them. The short workshops, already in place, provide the students with a way to improve their leadership, creativity, and teamwork skills. However, due to the time limitations of the workshops, students needed other opportunities to absorb and reuse these skills in a practical way.

### b. Greater problem-solving focus

Because the majority of students participating in ECE490DI had been engineering majors, both the students and the faculty members expressed a desire to have a greater focus on problem-solving. This focus would allow students to observe how problem-solving is approached in the real world with real life examples.

### c. Broader scope

It was strongly believed that diversifying the enrollment in ECE490DI to include students from a broad range of majors would further the development of all the students' creativity. The diversity in the discussions, case studies, workshops would better prepare all of the students for their professional lives. For example, students that are studying in the fields of business or engineering would be able to discuss the marketing or sales aspects of a specific design. Other disciplines such as art and music could press the engineering students to find better solutions. In turn, non-technical majors could receive an introduction to the technical trade-offs of their design requests.

## 4. PROPOSED IMPROVEMENTS

### a. Additional class meetings

One way to help students fully develop and implement their creative skills would be to increase the number of meetings before and after the trip to the ETO. The "pre-trip" meetings would feature ice-breaking and team-forming activities. This made the students more comfortable around each other and improved their communication and teamwork skills. The "post-trip" class meetings would review the materials from the trip's workshops. However, the majority of the post-trip meetings would illustrate additional examples and scenarios where these skills could be applied. This would allow the students to understand the importance of these skills, and how to better put them into practice. The pre-trip and post-trip meetings were held once per week. The duration of each meeting would be 75 minutes. A brief outline of the pre-trip and post-trip classes is shown in **TABLE 2.**

**TABLE 2:** A Tentative outline of the pre-trip and post-trip class meetings

| Week | Meeting Topics |
|---|---|
| 1 | The Design Process<br>• DVD on the design process (by ETO)<br>• Defining creativity<br>• Identifying problems and needs<br>• Case study |
| 2 | Identifying Requirements and Constraints<br>• What are requirements and constraints<br>• How do requirements and constraints help define and refine design problems<br>• Case study |
| 3 | Brainstorming Solutions<br>• What is brainstorming<br>• What are the rules of brainstorming<br>• Role of a leader in brainstorming<br>• Role of research in brainstorming<br>• Case study |
| 4 | Creating a Brainstorming Tool Portfolio<br>• Storyboarding<br>• "Tried and true" brainstorming tips<br>• Case study |
| 5 | Innovation and Improving the Creative Process<br>• How does innovation improve creativity<br>• Using innovation to predict the future<br>• Case study |
| 6 | Examples of Creativity<br>• DVD on creative/innovative individuals (ETO) |
| 7 | Examples of Creativity<br>• DVD on theme parks (ETO) |
| 8 | Class trip to ETO |
| 9 | Storyboarding Final Project<br>• Review of design process<br>• Review of creative process<br>• Building storyboards for final projects |
| 10 | Building Models of Final Project<br>• Definition of models<br>• Case study of model building<br>• Begin models of final projects |
| 11 | Refining Models of Final Project<br>• Review role of models<br>• Presentation of models to peers<br>• Peer review of models |
| 12 | Submission of Final Project<br>• Presentation of final projects to peers<br>• Peer review of final projects<br>• Submission of final projects to ETO |

### b. More problem-solving

One of the things that could be done to increase the focus on problem-solving would be to include problem-solving activities throughout the course. This included activities taking place both during the trip and on-campus class meetings before and after the trip.

Within the course, it was important to help students realize that their ways of solving problems were also examples of expressing their creativity - especially with real world engineering design problems where the problem is open ended and can have a myriad of acceptable solutions. Students would be encouraged to consider both non-traditional solutions and solutions other than their own. Students would also be encouraged through confidence building exercises that reinforce the concept that there are no bad ideas during brainstorming. "Bad ideas" often serve as the eccentric foundation of tomorrow's engineering breakthroughs.

To provide adequate practice opportunities, several in-class activities, homework assignments, and case studies were developed for use prior to and after the trip to the ETO. These activities ranged from fifteen minute brainstorming exercises to extended case studies. To encourage students to push their creative limits, requirements and constraints would be added. One sample project was a classroom that needed to be re-designed to accommodate additional students. The classroom dimensions needed to remain the same, and the students could not be crowded to an extent that compromised the quality of education. Students were not be allowed to self-select their teams. Rather, teams were assigned by the faculty to promote a diverse group of individuals to work together and learn from each other. This project was worked on in intervals of a few minutes for a total time of 15 minutes. Between intervals, faculty would present additional tips and tricks for student to use. When time was up, students would present their solutions to their peers to discuss and constructively critique the ideas.

Additional problem-solving activities were incorporated during the visit to the ETO. For example, students would see a mediocre attraction (ride). Following the attraction, in groups, students would discuss for two or three minutes what they liked and did not like about the attraction. The groups would then present their thoughts to the class. Next, students would regroup for five minutes to brainstorm potential improvements to the attraction. These ideas would then be presented again to the class. This activity would improve problem solving skills along with communication skills since students need to speak in front of their peers with a relatively short time constraint during the trip. Another example that can be used for an extended period of time during the trip is addressing a significant empty space within one of the theme parks. Students were asked to develop a proposal for how the space could be used while reflecting the culture of ETO and the surrounding theming.

### c. Broader scope of discussions/problems

To broaden the scope of the class and further enhance inputs to the creative process, ECE490DI was opened to all majors, not just students majoring in engineering. In addition, by bringing different disciplines to the creative process, the faculty intended to better simulate real-world, problem-solving scenarios. This would give students from different majors a chance to work together on short-term and long-term assignments. The engineering students could learn about the financial impacts from the business students and aesthetics from the fine arts students. Chemistry students could propose the use of a new material, while a political science student could have the opportunity to point out some socio-political issues with a particular solution.

For example, prior to the class trip, students participated in an extended activity to analyze what the ETO does best and apply it to a transportation system within a major city. The problem statement included a few more details: the transportation system would need to be energy friendly, accessible, and reflect the diversity of the city. By dissecting the problem statement and eliciting from the statement constraints and requirements, the students were able to better appreciate the breadth and depth of the problem before them before moving on to the brainstorming process.

When the students eventually moved on to brainstorming solutions to the above transportation problem, they were asked to perform some word association. First, they wrote down words that came to mind when they heard the word, "transportation." Next, they repeated the word association activity with the name of the ETO. The class was then given a homework assignment to record the word association of eight peers not taking the class with both transportation and the name of the ETO. The results were collected and over 1,000 words were generated. This quick introduction to research allowed students to see other people's perspectives when given the same prompt as well as help them build confidence in their own creative talents. It also helped students realize that all ideas can be useful, even "off-the-wall ideas," which could lead to new solutions.

Next, students were given modified constraints and scenarios to ascertain potential solutions to the transportation problem. These modified constraint situations included scenarios such as having unlimited resources, developing a low-cost/no-cost solution, considering solutions from a child's perspective and from an "expert's" perspective, and thinking first of the end-in-mind goal. Through this activity, students were encouraged through the different constraints to approach the problems with different perspectives to see how different people might solve a problem.

Once at the ETO site, the first step to broadening the scope was repeated, short discussions highlighting different concerns that an attraction went through, from conception to final implementation. On previous trips to the ETO, these discussions focused on the engineering aspects of the attraction. Now, the content of these talks could be expanded to include things such as the value of features and add-ons to the attraction. Design trade-offs in the artwork, music, theming, and hardware/software of the attraction now had to be considered. This would help students appreciate the importance of working on an interdisciplinary team.

After each attraction discussion, the students would be challenged to modify the experience given various constraints. This would involve an exercise similar to the in-class activity, with the students being given a constraint and then asked to brainstorm ideas to make the attraction better. Again, students would be assigned to teams to diversify each team's membership. Results would be shared with the class through informal presentations in the theme parks themselves.

A final activity to broaden the scope that occurred at the ETO was to challenge students to decide between several of the presented solutions to improve an existing attraction to increase its utilization without making significant engineering changes. For example, students would be asked to redesign an attraction featuring a well-known character from the 1970s that is dwindling in popularity. Students were told that the management wants to increase the attraction's popularity without spending a substantial amount of money. Teams would identify potential improvements and brainstorm how they would assess which solutions would be best. This gives students a chance to practice using creativity within a real world context with real world constraints. Through this activity, the scope would be broadened more than in the previously mentioned activities, showing how different ideas are important to different areas of a corporation. This activity would also provide the benefit of allowing students to work on an interdisciplinary team, giving them practice at compromising so that everyone gets to be heard and the best idea comes forward.

## 5. CONCLUSIONS

An off-site, creativity in engineering course has been offered in the College of Engineering at Valparaiso University for the last 3 years. While the class has been a great success, a 3-year review was performed to further improve the class including feedback obtained from students, faculty members, and members of an external training organization. The recommendations led to increasing the amount of time on activities and case studies both before and after a class field trip to the external training organization. Additionally, a greater focus on creativity in the problem-solving process and the diversification of the students' majors provided a richer, more robust experience for all students.

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