Using Creative Problem Solving to Engage Non-electrical-engineering Majors in a Required Circuit Theory Course

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Abstract

It can be challenging to engage non-electrical-engineering students in a required course on electrical circuit theory. Such students may lack interest and curiosity in circuit theory based on a perceived lack of applicability to their respective disciplines. To address this, an extra-credit group project was designed to allow the students to practice the creative problem-solving (CPS) method and to discover the pervasive applicability of circuit theory in modern systems designed by the students themselves. A lecture is devoted to presenting the fundamental concepts of the CPS method and outlining the extra-credit group assignment, in which students creatively consider applications of circuits. Each group is to brainstorm processes that are performed manually, and then to select one process to be performed by an automated system designed by the group. The group must identify functional subsystems required, and as many electrical components as possible within each functional subsystem. The students are instructed to explain the circuit theory underlying several of the individual electrical components the group identified. The goal of this project is for the students to creatively connect circuit theory to problems that interest them. This project also has the potential to yield novel, patentable inventions. Pre- and post-project surveys are conducted to assess the effectiveness of this project. This project is found to successfully engage the students and to foster creative thinking in the project groups.

Keywords

The Creative Problem Solving (CPS) technique; circuit theory; engaging non-major students in required courses

Introduction

One challenge facing professors is that of engaging engineering students in an out-of-major required engineering course. The students may perceive that the course is simply a requirement they must fulfill, and that the principles from this course will be minimally applicable in their future careers; or, they may perceive that the subject matter is beyond them, because they do not have the interest, aptitude, or background in the material.

An extra-credit project was designed to creatively engage just such an engineering student.[1] The primary objective for this project is to engage the students by allowing them to establish for themselves the connections between theory presented in the course and a potentially novel system designed by the learners. A secondary objective is to foster and encourage creative

[1] This project was conceived after the syllabus was disseminated, so it was presented as optional, for extra-credit. A future course offering may have it as a mandatory assignment.

thinking in the students by introducing and practicing tools from the creative problem-solving (CPS) method.

The following discussion describes an in-class module designed to introduce the concepts and tools behind the CPS technique, describes the extra-credit group assignment, outlines assessment techniques for the module and project outcomes, and presents the results of the pilot run of the project. The context for this discussion is a course on electrical circuit theory for mechanical engineering students, and the project is found successful in getting the students to practice CPS tools and encouraging the students to establish for themselves connections between the principles of circuit theory and real-world systems of interest to the student.

Project Introduction and Definition

This project is introduced using a 50-minute in-class module. The module presents the CPS technique and tools, and it includes an in-class group exercise, which models the early stages of the project. Upon module completion, the students are instructed to form project teams, use CPS tools to design their own automated system, and describe the electrical components involved.

The module's CPS discussion is based on the method outlined by Osborn, developed by Parnes, and presented by the Creative Education Foundation. [1] It presents the fundamental CPS postulates that all people possess some level of creative ability; and that creative skills may be taught, developed, and improved. The module also presents creative thinking skills, including the generation of multiple potential solutions using divergent thinking (brainstorming), and narrowing an array of candidate solutions using convergent thinking. Additionally, concepts are introduced such as psychological creativity (P-creativity), in which conceived ideas are novel to the individual; and historical creativity (H-creativity), in which conceived ideas are not only P-creative, but also are novel to all humans everywhere. [2] It was anticipated that the student groups would do P-creative work, but no expectation was set for H-creative results.

Next, the assignment is outlined in the module. The participating students are instructed to form groups of no more than five students and perform the following tasks:

1. Use divergent thinking to generate a list of processes that are performed manually.
2. Use convergent thinking to select one process that the group intends to automate.
3. Design a mechanical system to automate the process, considering:
    a. The functional units required to automate the process.
    b. The mechanical and electrical subcomponents comprising each functional unit.
    c. The circuit theory behind the operation of the electrical subcomponents.
4. Write a report describing the group's design process, including:
    a. A listing of the candidate processes considered
    b. For the selected system, a description of functional units; electrical and mechanical subcomponents of those functional units; and, a description of at least five electrical subcomponents, including illustrations, equations, graphs, and text clearly explaining the circuit theory behind the subcomponent's operation.

A functional unit—a subsystem of the automated system which performs a specific task—is comprised of electrical, mechanical, and electromechanical subcomponents. The relationship between the automated system, functional units, and subcomponents is illustrated in Figure 1.

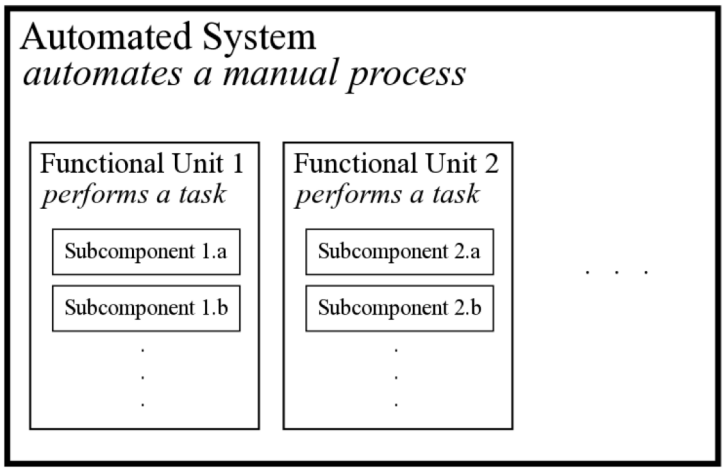


Figure 1. Relationships between the automated system, functional units, and subcomponents. The process may be divided into tasks, each of which is performed by a functional unit. Functional units are comprised of various mechanical, electrical, or electromechanical subcomponents. The students earn project credit by explaining the circuit theory behind several subcomponents of their automated system.

Finally, the early stages of the project are modeled in class. The instructor will lead the class in a live brainstorming exercise to generate a list of manual processes. An instructor-prepared discussion on an automated system for one manual process is presented immediately after the brainstorm, so the instructor must ensure that this process is listed during the brainstorm. The instructor's prepared analysis of the desired automated system includes the identification and descriptions of its functional units and their electrical or electromechanical subcomponents. Subcomponent operating principles are discussed, connecting class theory to application.

The in-class module was presented at the end of the eleventh week of class, with the project due 31 calendar days later (on the last day of class). To motivate at least a majority of the class to undertake the optional project, extra credit was offered worth up to five percent of the total possible course grade. Additionally, to prevent groups from procrastinating until the last week of class and then discovering that they did not have the time to accomplish their project, a mid-project brainstorm was due two weeks after the in-class module presentation.

In the specific example chosen for the in-class module, an automated fuel vending system (AFVS) for automobiles was designed. Here, a user would park an automobile alongside the AFVS and open the fuel door. The AFVS must then fully open the fuel door, unscrew the fuel cap, and then insert the end of the fuel line into the fuel tank opening. The AFVS must pump fuel until the tank is full or a pre-programmed amount of fuel is dispensed.

Functional units were defined for the students as subsystems that must achieve a certain task for the overall automated system. Functional units for the AFVS include, but are not limited to: a robotic hand for manipulating the door and fuel tank cap; a robotic arm or armature for positioning the end of the fuel line into the tank opening; flow-sensing technology with temperature monitoring to determine the amount of fuel dispensed; and electrically-operated valves for flow control.

Electrical or electromechanical subcomponents were defined for the students as components of the functional units which enable them to operate. For the AVFS, electrical subcomponents identified in class included: servomotors, comprised of an electrical machine and a potentiometer-based positioning system (for the robotic arm and hand); a four-piston flow meter with an electrical pick-up and Resistive Temperature Detector (RTD) circuits (for the flow-sensing system with temperature detection); and solenoid valves (for flow control). Discussion on these components highlighted: the application of Ohm's Law in rheostat devices integrated into servomotors; electromagnetic induction in flow detection devices; RTDs and their negative temperature coefficient in temperature monitoring; electrical machine theory (also in the discussion of servomotors); and magnetic machinery in the solenoid valves. This discussion also highlighted the fact that computer logic and control systems were a necessary part of the system, but that a treatment of these systems was beyond the scope of the class and this project.

Project Assessment Techniques

This effectiveness of this project was assessed using pre-discussion and post-project surveys. Pre-discussion surveys were given to the entire class just prior to the presentation of the introductory module, and post-project surveys were completed by all project participants upon submission of the group report. The students were asked to provide descriptions of terms in their own words, to provide agreement ratings for particular statements, and, in the post-project survey, to provide feedback on the project itself. When an agreement rating was solicited, a numbering scale from 0 (complete disagreement) to 10 (complete agreement) was used.

To assess the how well the students received the fundamental CPS concepts and skills, the students were asked in the pre-discussion and post-project surveys to rate their agreement with each the following foundational postulates of the CPS technique:

A. All people have some creative potential.
B. Creative thinking and problem solving can be taught, developed, and improved.

Also, both surveys tested the student's understanding of CPS tools by asking them to define *divergent thinking* and *convergent thinking* in their own words.

The students also were asked in the post-project survey to assess how effectively the project fostered creative thinking by rating their agreement with the statements:

C. Our group generated ideas novel to me (project-related P-creative activity).
D. Our group generated historically novel ideas (project-related H-creative activity).

These statements are related to the secondary project objective.

To measure how effectively the project helped them connect the circuit theory presented in class to interesting applications, the students were asked to rate their agreement with the statement:

E. This exercise helped me draw connections between theories from our class to interesting real-world applications.

Statement E is designed to assess the effectiveness of the project in achieving its primary aim.

Results

Prior to the in-class module, 39 pre-discussion surveys were administered, and 29 students chose to participate in one of seven project groups. This majority participation rate indicates that the students were sufficiently motivated to participate.

The students gained familiarity with the tools of the CPS method through the course of the project. Prior to the in-class discussion, ten students correctly identified divergent thinking as a process by which multiple ideas are generated, and nine correctly identified convergent thinking as a narrowing of the field of ideas or options. After the project, the number of students who could properly describe the CPS tools of divergent thinking and convergent thinking more than doubled from the previous counts (see Figure 2).

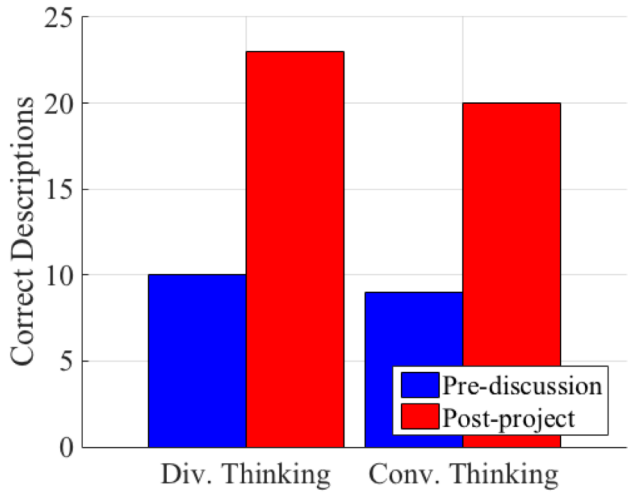
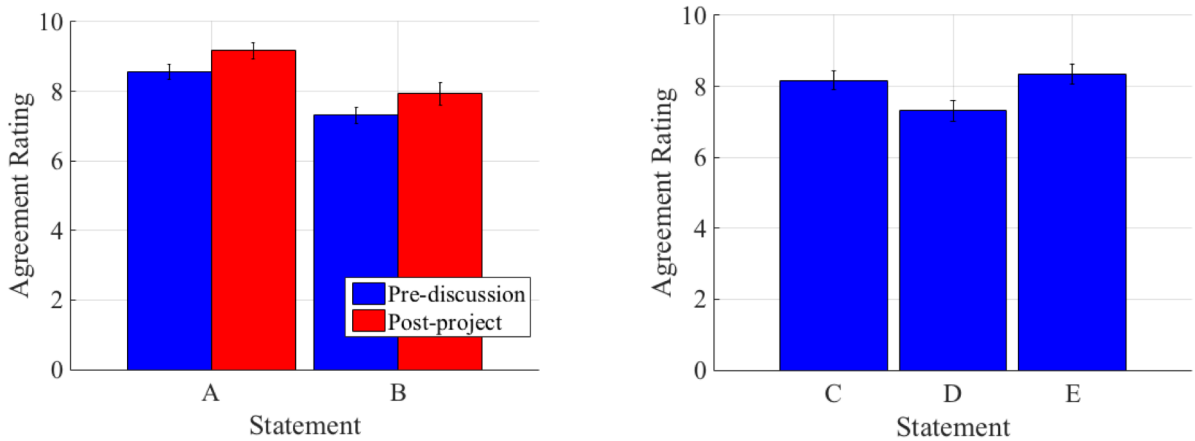


Figure 2. Number of students to correctly identify the CPS tools of divergent thinking ("Div. Thinking") and convergent thinking ("Conv. Thinking"), both prior to the discussion presented in the in-class module, and after project submission.

As shown in Figure 3(a), student agreement with the postulates of the CPS technique (statements A and B) was higher among those students who completed the project than in the class at large



(a) (b)

Figure 3. Average agreement ratings from student surveys for statements A-E presented in the Project Assessment Techniques section. Standard error bars are provided with each data point. In (a), the statements included are only those posed in both pre-discussion survey and the post-project surveys regarding the fundamental postulates of the CPS technique. Subfigure (b) shows agreement ratings ratings for the statements related to project outcomes posed only in the post-project survey.

before the introductory module was presented. Figure 3(b) shows students thought their group's automated system was novel to themselves as individuals (statement C); but, they also recognized that their work was not as novel in the context of all human thought and history (statement D). Finally, students agreed strongly that the project helped them connect theory presented in class to interesting applications (statement E).

Notable comments and quotes from the student free-form project feedback solicited included the following:

- The project should be introduced earlier in the semester.
- An example of a project should be provided, with clearer guidelines on what should be discussed, and what is beyond the scope of class discussion.
- "I like being able to work with and learn from my peers."
- "[I liked] meeting with [my] group and trying to solve a problem."
- "… it was a lot of fun and helped me to learn about brainstorming and practical implementation of things we learned."
- "[This was] one of the first group assignments [in which] I have designed a product or created an idea with a group of people in college."
- "I liked that we had the freedom to create whatever we wanted."
- "It made class not seem like a class as much, and it made problem-solving seem like it had more of a purpose than just a right answer."

The results presented here omit any discussion of the actual student work in order to maximize the potential for students to obtain intellectual property rights as they desire.

Conclusion

Students became increasingly familiar with the CPS tools of divergent thinking and convergent thinking because of the module and the project. On the other hand, it is difficult to say whether the module and project increased student agreement levels with the postulates of the CPS technique. While post-project survey agreement with statements A and B was higher than pre-discussion survey agreement levels, it may be that a higher percentage of students who agreed with the postulates participated in the project. To clarify this in the future, every student taking the pre-discussion survey should also provide post-project survey agreement ratings for statements A and B. This can be achieved if future iterations of the course integrate the project as a mandatory one for all students, or if the post-project survey is administered to all students, with the portion discussing project outcomes reserved only for project participants.

Both the primary and secondary objectives of the project were met. Students agreed fairly strongly that the project helped them to establish connections between the circuit theory in class and interesting, real-world application (statement E). The free-form written feedback also

reflected the success of this project in achieving this primary objective. The project also was successful in stimulating creative group thought and activity. The students felt that their work was P-creative, but not necessarily H-creative. Nonetheless, creative thought occurred.

While the project successfully achieved both its primary and secondary objectives, future iterations of the project can be improved. Based on student feedback, future iterations of the project should be introduced earlier in the semester, perhaps as early as the third or fourth week of class. It is anticipated that this will have the desirable effects of (a) engaging the students earlier in the class as they search for the connections between the theory and their automated system, and (b) giving the students more time to get instructor feedback and to prepare their report. Additionally, it will be helpful to the students for the instructor to provide an example report on the example system discussed during the in-class exercise. This will help define expectations for the project. Next, more guidelines will be provided, with a discussion on what is beyond the scope of the project. If incorporated as a required course project, it also may be very successful, and the assessment of the module's introduction the principles and tools of the CPS method will be improved. Finally, a supplementary discussion on intellectual property will be helpful. This can serve as motivation for the students to be creative, and it may help them to safeguard their ideas or even achieve a patent.

This project was successful and is worth repeating. While readily reproducible in a circuit theory course, this project may also be adapted to other engineering courses.

References

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