Reinforcement of Problem Solving Skills Using Exam Problems

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Abstract

Too many students think they understand how to solve problems, but rarely apply the necessary problem solving skills to these assignments. In other words, they are solving problem, not performing problem solving. This paper describes a process that can be utilized in many EET courses to reinforce concepts of problem solving.

In an upper-division EET course at New Jersey Institute of Technology, problem solving skills are reviewed and demonstrated as part of several lectures. This six- step approach to problem solving that was developed by the author is something that can be taught to the students, but need constant reinforcement for the students to understand how to apply these concepts. Even if students learned how to apply those skills during in-class examples or assigned homework, usually those skills are forgotten during exams, when the need to apply these skills is critical.

To help students understand the need for applying problem solving skills during tests, as well as reinforcing the concepts of problem solving, a specific series of questions were devised for the exam questions that both allowed the students to demonstrate an understanding of this approach, as well as provide the student with a framework to better reach the correct answer.

This approach consisted of requiring students to provide both a problem statement and alternative problem statements, depending on the nature of the problem. Students also were required to write down various other steps used in problem solving that will be detailed in this paper. In addition, the author will review preliminary assessments on the effectiveness of this methodology.

Introduction

For most technical professionals, problem solving is a primary job function.[1] According to Goldsmith[2], we must develop different skills -- the two most important being creativity and problem solving.

However, the concept of problem solving often is confused with the ability of students to solve problems. Student's skills in problem solving can be measured by examining the process followed to solve a problem rather than the actual solution found [3]. Considering that concept, students are really solving problem, not performing problem solving.

Several papers [4,5] and texts[6-7] have addressed the concepts of teaching problem solving techniques in the classroom. However, these concepts need to be reinforced in everything the student does, and one of the areas that traditionally are not addressed is reinforcing these concepts during exams. .

New Jersey Institute of Technology (NJIT) is an upper-division only ECET program, and in one of the first required circuit analysis courses, problem solving skills were reviewed and demonstrated as part of several lectures. This six- step approach to problem solving[4] that was developed by the author several years ago is something that can be taught to the students. However, upon reviewing tests from previous semesters, it became clear to the author that whatever the students learned was ignored during exams, and the main goal by the students during an exam was to just solve the problems. This was true even if students learned and demonstrated how to apply those skills during in-class examples or assigned homework.

To help students understand the need for applying problem solving skills during tests, as well as reinforcing the concepts of problem solving, a specific series of questions were devised for the exam questions that both allowed the students to demonstrate an understanding of this approach, as well as provide the student with a framework to better reach the correct answer. Before this could be implemented during the exam, this process was first developed for in-class discussions.

Background

ECET 303, called Introduction to Circuit Measurements, is one of the first courses that students take when they start the Electrical and Computer Engineering program at NJIT. This course consists of reviewing basic circuit laws and how they apply to circuit problems.

A major problem that the author observed over the last few years while teaching the course was that students didn't understand what circuit laws to apply to various problems, especially what laws would be easier to use for a given problem. This lack of approach, or lack of a problem-solving process, existed for homework, tests, and how they approached the lab assignments. Basically, students had a poor understanding of problem solving techniques.

The first attempt at trying to help these students was to develop a multi-step approach to problem solving for this course[5]. In this approach, students were taught a six step approach for laboratory based courses, where the six steps were discussed. These steps were: Understand the problem, define the variables, develop a hypothesis, pre-lab analysis, anticipate potential problems, and develop procedures. Students were required to write these steps as part of the pre-lab portion of their laboratory report.

At first, there was resistance by a number of students, who felt that all they wanted to do was "complete the lab". Eventually, those students who offered some resistance found that, contrary to initial beliefs, the laboratory assignments actually took less time to complete, if the procedures were followed. Some students told the instructor that they applied this problem solving approach to other laboratory based courses.

Toolbox concept

The next approach in helping to develop student's problem solving skills, and the method that lead to the concept of this paper, was to describe to the students how to use the various circuit laws that were covered in this course. Approximately nine weeks into the semester, all the basic circuit laws were covered. To help them understand the concepts of applying the correct laws to a particular problem, the author used the analogy of a toolbox during the first few weeks of the course, and continued using this analogy until week nine. For a particular repair or building task, the first need is to determine the proper tool. In some cases, more than one tool might be appropriate, so the question then becomes what tool would be the most efficient, or the most useful. That decision might also be based on what tool the user is most comfortable using.

Goldsmith[2] suggested that someone trying to solve a problem should imagine that the ***problem*** belongs to someone else. If this were true, what kind of advice would you give them? What would you say their first step should be? By having students imagining that they were trying to not only help themselves, but actually put themselves in the role of a teacher, perhaps they could develop better problem solving skills.

Students began to relate this concept to the use of circuit laws as tools to solve problems, and there was a lot of practice utilizing this process during class discussions. During these discussions, it became clear that students still had problems understanding how the various circuit laws related to one another, so the author divided all the laws into two groupings: those laws that helped simplify a circuit, and those laws that helped solve a circuit.

The laws that helped simplified a circuit included:

- Thevenin/Norton
- Source Tranformation
- Superposition

The laws that are used to solve the unknown for a circuit include:

- Ohm's Law
- Mesh and Nodal Analysis
- Voltage and Current Division

This concept was built upon from week's three to nine, and circuit problems that would illustrate various choices were presented and reviewed in class. During these exercises, the author asked various questions of the students:

1. What methods could you use to use to solve the problem, and list them all?
2. What choice are you are going to make from this list, and briefly describe why?
3. State what problems you could encounter solving this problem, and why you believe that these problems would exist?

The first question was meant to have students think about the list of laws that were covered, and determine all of them that were applicable. If there were circuits where nodal or mesh analysis didn't make sense to be used, but the students listed those laws, we reviewed why they weren't appropriate. The second question was directed to problem solving – why are you using that particular tool? Students were required to not only describe the method they were going to use, but also to defend it in class. In many cases, there were more than one "correct" answer, and the discussions then centered on what were the tradeoffs in the various approaches.

For example, in Figure 1, students could use mesh analysis, coupled with Ohm's Law, to solve the circuit. However, students would have to solve three simultaneous equations. Alternatively, you could simplify the circuit, utilizing either Source Transformation or Thevenin, and then use voltage division to find the answer. Rather than discuss the solution to this problem, we discussed the process on how to arrive at a solution. Therefore, the major discussion in this particular circuit centered on the various alternative methods and the positives and negatives associated with each method.

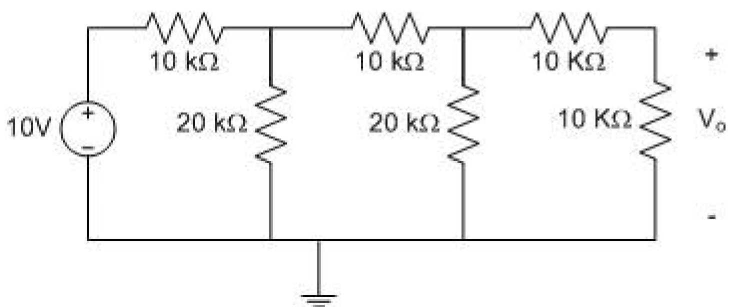

Figure 1. Circuit used to identify alternative methods for obtaining the output voltage.

Applying Problem Solving Concepts to Exams

However, the author was concerned that when students took exams, the concepts of problem solving were forgotten in the quest to get the correct answer. If students were able to think a problem through using the problem solving techniques that were discussed in class, then they could possibly improve their grades.

To help students utilize problem solving skills during the exam, several of the questions on the second and subsequent exams required that they first answer the questions that were discussed on the previous page. These questions - what methods could be used, what method are you going to use, why, and what potential problems would the student expect to encounter - were intended to help focus the students on the best method for the problem. To encourage students to answer these "process" questions, points were assigned to these "process" questions as part of the overall score for the specific problems.

In the following semester, this process concept was introduced starting with the first exam. An example of a circuit from this exam is shown in Figure 2. At this point in the course, students were taught mesh and nodal analysis, along with other basic circuit laws, but were not taught Thevenin or source transformation. Students listed the laws they were taught, and were asked to eliminate those laws that weren't pertinent, select one or two laws that might be applicable, and justify the choice of the method they finally chose to solve the problem. While both mesh and nodal analysis could be used, nodal analysis would require only two simultaneous equations, while mesh requires three equations. In addition, nodal analysis would give the voltage answer directly, while mesh would require students to also apply Ohm's law to find the output voltage.

Some students solved it with mesh analysis, stating they were more comfortable with that type of analysis. That reason is acceptable – many times we decide to solve a problem with a method that is more comfortable, even if it is not the most efficient method. However, when the author reviewed this test, he went the process of why nodal analysis might be more efficient.

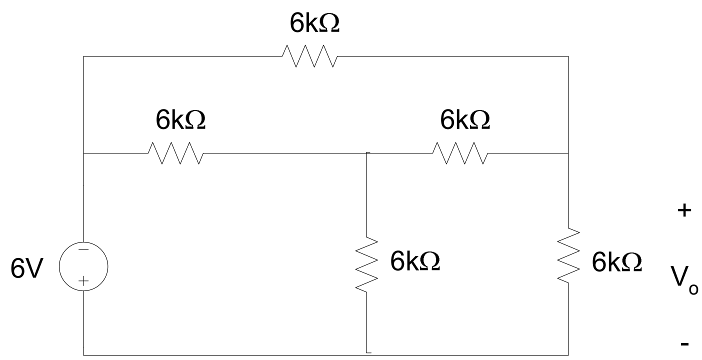

Figure 2. Circuit from exam question requiring problem solving statements

Student Assessment

The author reviewed the results of test questions that incorporated the problem solving preliminary questions given this semester with similar questions from the last two semesters. There are insufficient numbers of students this semester to have any reasonable statistical analysis, and problems existed in trying to match comparable students (in terms of GPA from community colleges). Over the next two semesters, the author will develop a means to match students, as well as have enough students for a statistical analysis.

However, in comparing three specific questions from this semester to the two prior times the author taught this course (over the last 18 months), there was a 15% increase in grades for these problems. This increase did not take into account points given to students for answering the "process" questions prior to solving the problems.

Moreover, student evaluations were favorable in terms of this method, and several students said that this method helped them focus and achieve the correct answer. The first semester this method was introduced, the author decided not to require these types of questions on the final, in order to see how many students would use this method on their own. Over 1/3 of the students used this method in their final.

Conclusion

While teaching problem solving skills are an important part of a student's education, these concepts need to be reinforced throughout the course material. This paper presented a method of reinforcing these techniques during student examinations. Because there can be a perception, by the students, that this method helped their grades, there could be a perceived value to the students in utilizing problem solving techniques.

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Biography

Ronald H. Rockland, received the B.S.E.E. and M.S.E.E. degree from New York University in 1963 and 1967, respectively, and his Ph.D. in bioengineering and electrical engineering from New York University in 1972. He also received an M.B.A. in marketing from the University of St. Thomas, St. Paul, MN in 1977. He is currently an Associate Dean of Engineering and Associate Professor of Electrical and Computer Engineering Technology at New Jersey Institute of Technology, Newark, NJ. He also has over 20 years of industrial experience in research, engineering, marketing and sales management with several high technology corporations. His current research areas are application of computers to the technical learning process and biomedical signal analysis, and he has received numerous teaching awards, including the F.J. Berger Award and being named Master Teacher at NJIT.