Development of a Problem Test Bank for Linear Circuits and Its Implications for Improving Learning and the Assessment of Student Learning

Charles F. Yokomoto, Maher E. Rizkalla
Department of Electrical and Computer Engineering

I. Introduction

In this paper, we describe an on-going project that is taking place in our department whose goals are to establish some uniformity in the assessment of student learning across sections in our introductory linear circuit analysis course, to promote an understanding in the culture of our department of the different levels of cognitive complexity of traditional textbook problems, and to develop a shared understanding of the relationship between traditional course letter grades and these levels. In order to facilitate this discussion, we have developed a large bank of exam problems that will serve several other purposes in addition to the facilitation of the discussions, such as (1) for creating exams for different sections by selecting problems that have been reviewed by a faculty committee for their effectiveness in assessing student learning for ABET assessment purposes, (2) for use in our assessment of problem solving skills and critical thinking for our campus general education assessment, and (3) for use in a coaching program to move students to higher levels of the cognitive skills that are essential for problem solving.

As part of the project, faculty members who have taught the course will review and rate them according to their level of overall difficulty and level of cognitive complexity according to taxonomy of problem solving based on the Dean and Plants problem solving taxonomy [1]. The involvement of the faculty committee in rating the problems is our first attempt at developing a level of shared understanding among faculty of the level of performance in problem solving and critical thinking that we expect of our students. Until the initiation of this project, instructors acted as autonomous agents in determining the difficulty of their exams.

II. Motivation For The Project

Currently, the traditional means for assessing student learning in textbook courses is the traditional pencil-and-paper problem-solving exam, and faculty have not incorporated the assessment of student learning on any scale of complexity such as the Dean and Plants taxonomy of problem solving [1] or Bloom's levels of cognitive complexity [2]. Faculty and part-time instructors teaching multiple sections of the same course were autonomous agents in writing problems and assigning grades. While autonomy will still be a principle that is followed in making exams and assigning grades, the faculty team agreed that the teaching/learning process as well as the fairness in the assignment of grades would be improved if we conducted faculty discussions that led to a common understanding of the levels of performance we expected from students, both for the attainment of a particular course grade and for the demonstration of learning at different levels of cognitive complexity.

III. Description Of The Project

The test bank of 120 problems was developed under a faculty development summer grant sponsored by our school. Faculty members who teach the course rate the problems according to difficulty and level of cognitive complexity to assess problem solving and critical thinking and to develop shared understanding of levels of difficulty. A description of the levels of cognitive complexity that we are using is the following:

Level 1. Problems that require only the memorization of basic formulas and rules.

Level 2: Problems that require the executing of basic procedures (step-by-step calculations) and techniques such as node-voltage analysis, mesh analysis, and superposition.

Level 3: Problems that require the selection of an appropriate procedure or technique from among several applicable ones, such as selecting node-voltage analysis over mesh analysis, superposition over node-voltage, etc.

Level 4: Problems that require the selection of an appropriate strategy or approach to a problem.

Level 5: Problems that require the application of basic principles in the development of a solution that is new to the student.

Using these levels, faculty members involved in the project will rate both the level of cognitive complexity and the letter grade that he/she would assign to that problem if it were solved correctly.

IV. Current Developments

In order to achieve the goals of the project, the faculty team developed a bank of 120 multiple-choice problems for the course that serves the dual purpose of creating exams with some degree of uniformity across sections of the course and promoting discussions on problem solving and assigning grades across the faculty who teach the course. A preliminary judgment of the level (see Section III) of each question and problem was made by the faculty team to be used as a catalyst for conversations among the faculty in the department who have taught the course.

IV.1 Sample Problems Written at Each of the Five Levels

The following examples demonstrate the interpretation of the five levels of problem solving that are being used for this project.

Level 1. Memorization of basic formula:

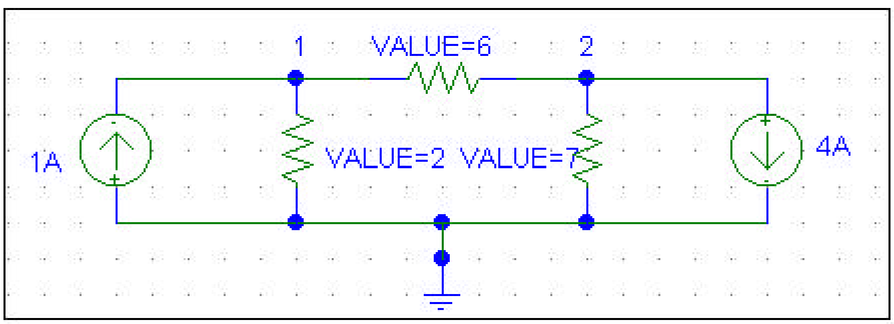
- The electric current is
  a) The time rate of change of charge
  b) The time rate of change of power
  c) The time rate of change of energy
  d) The time rate of change of voltage

- An energy source forces a constant current of 2 A to flow through a light bulb for 10 s. If 2.3 kJ is given off in the form of light and heat energy, the voltage drop across the bulb will be
  e) 230V
  f) 115V
  g) 110V
  h) None of the above

- A stove element draws 15A when connected to a 120 V line. In order to consume an energy of 30 kJ, the connection must last for:
  i) 33.3 s
  j) 66.6 s
  k) 16.67 s
  l) None of the above

Level 2. Problems that require the executing of a basic procedure.

- In the circuit shown below, which of the nodal equations are correct:



a) $V_1/2 + (V_1 - V_2)/6 = 1$ (1)
$V_2/7 + (V_2 - V1)/6 = -4$ (2)

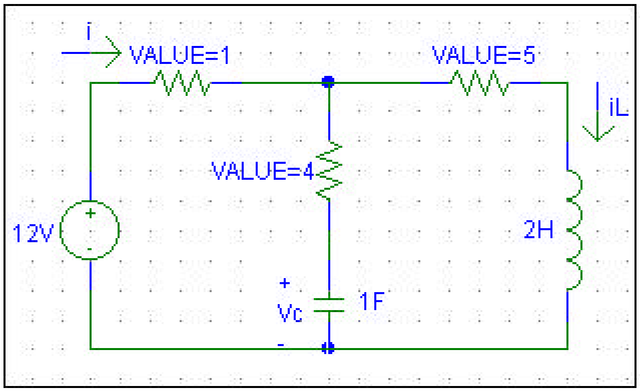
b) $V_1/2 + (V_1 - V_2)/6 = -1$ (1)
$V_2/7 + (V_2 - V1)/6 = 4$ (2)

c) $V_1/2 - (V_1 - V_2)/6 = 1$ (1)
$V_2/7 - (V_2 - V1)/6 = -4$ (2)

d) None of the above

Level 3. Problems that require the selection of an appropriate procedure or technique from among several applicable ones

- Consider the circuit shown. Under dc conditions, the current flowing in the inductance is

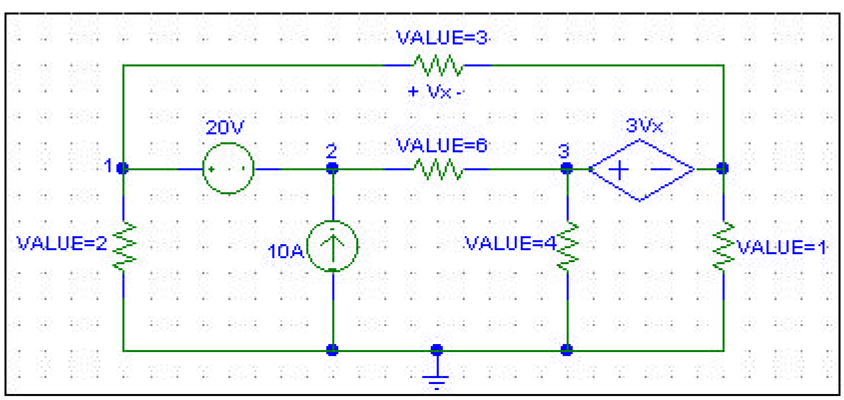


a) 2.4 A
b) 2 A
c) 4 A
d) 8 A

Level 4: Problems that require the selection of an appropriate strategy

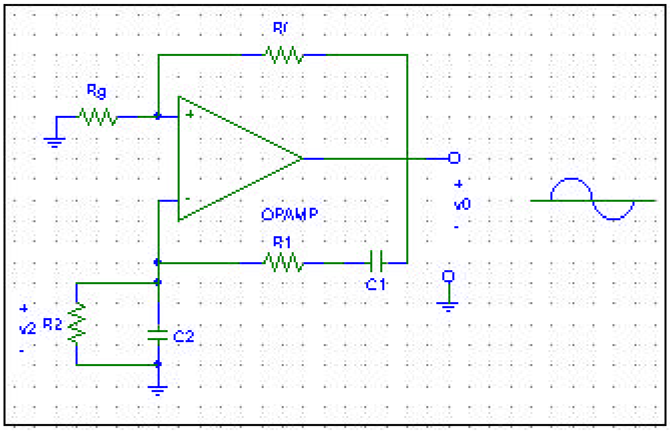
- Which of the following node-voltage equation is correct?

a) $V_2/8 + (V_2 - V_1)/2 = 5$
b) $V_2/8 + (V_2 - V_1)/2 = 15$
c) $V_2/8 + (V_2 - V_1)/2 = -5$
d) $V_2/8 + (V_2 - V_1)/2 + V3/6 + (V_3 - V_1)/4 = 0$



Level 5: Problems that require the application of basic principles in the development of a solution that is new to the student.

- The function of the following circuit is:



a) Integrator
b) Differentiator
c) Wien Bridge Oscillator
d) None of the above

V. The Next Step

During the spring and summer terms of 2002, the following activities will take place:

1. Faculty members who have taught the course will be asked to rate a cross section of problems from the database on their level of difficulty according to the five levels described earlier and the grade that they would assign to a student who solved it correctly, i.e., is it a "C" problem, a "B" problem, etc.?
2. After the ratings have been done on an individual basis, the faculty member will be brought together to discuss their individual ratings, thus beginning our first discussions on the subjects of problem solving, grading, and levels of cognitive complexity among our faculty.
3. Students will receive coaching in the taxonomy and their associated skills, and tracking will be performed to determine if students can improve the level at which they are able to solve problems.

At the same time that these conversations are taking place, problems from the test bank will be used for testing during the spring 2002 and summer 2002 terms, and data from student performance on the problems and the grades that they receive in the course will be analyzed for any significant relationships. Among the relationships that will be investigated are the following:

1. Are the five levels of problems described earlier a valid taxonomy of increasing levels of cognitive complexity or merely a typology of different kinds of problems.
2. Is there a relationship between the assignment of course grades and the level of cognitive complexity at which a student is able to demonstrate proficiency?

VI. Additional Uses For The Test Bank And Their Associated Levels

In addition to the two stated uses for the bank of problems, they will be used for several other purposes, including the following:

1. Faculty will be able to use problems from the test bank to create an assessment instrument for undergraduate transfer students who with to determine if they have the knowledge and skills to take subsequent courses that require the linear circuit analysis course as a prerequisite.
2. Faculty will be able to develop a test instrument for students who are returning for a graduate degree several years after taking a course in linear circuit analysis to help them determine any weaknesses in the area.
3. Instructors will also use the taxonomy as a coaching tool to help students develop their meta-cognitive problem solving skills. Furthermore, the use of the taxonomy will help unify the process of assigning grades in a course that often has multiple instructors, and our assessment of student learning will become more reliable. Scoring rubrics will be developed based on the taxonomy so that exams can be scored simultaneously for the purpose of giving course grades and for outcomes assessment. A part of the program was designed as training for students to become better students, and show how they progress next semester in EE 201 and become better problem solvers.

VII. Concluding Remarks

We have described a fairly complex project that is aimed at improving student performance on problems of higher and higher levels of cognitive complexity, to initiate faculty discussions on problem solving and related issues of grading and cognitive complexity, and to improve the reliability of the assignment of course grades across different sections of the same course. In order to accomplish this, a test bank of problems that will serve as a source of multiple-choice problems for our first course in linear circuit analysis was developed.

VIII. Bibliography

[1] H.L. Plants, R.K. Dean, J.T., Sears, and W.S. Venable, "A taxonomy of problem-solving activities and its implications for teaching, " *The Teaching of Elementary Problem Solving in Engineering and Related Fields, J.L. Lubkin (Ed), American* Society for Engineering Education, 1980, pp. 21-34.

[2] B.S. Bloom, *Taxonomy of Educational Objectives—Handbook I: Cognitive Domain,* David McKay Company, Inc., NY, 1956.

IX. Biographies

MAHER E. RIZKALLA

Maher E. Rizkalla is a Professor of Electrical and Computer Engineering at IUPUI. He received the Ph.D. degree in EE from Case Western Reserve University. His research interests include electromagnetics, VLSI design, electronic manufacturing, and applied engineering applications. He has developed two courses under separate FIPSE grants.

CHARLES F. YOKOMOTO

Charles F. Yokomoto is a Professor of Electrical and Computer Engineering at IUPUI. He received the Ph.D. degree in EE from Purdue University in 1970. His current interests are in the areas of assessment of learning outcomes for ABET accreditation, coaching, problem solving, and personal heuristics. He has been using the MBTI in research and classroom applications since 1980.