Assessing the Demand of Problems in an Undergraduate Electrical Engineering Course

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Abstract— **This paper describes a study to assess the demand of problems posed in undergraduate electrical engineering courses. This is part of a larger study to examine the gap between the demand of problems and the types of reasoning students use when attempting to solve them. The analysis uses a two-dimensional taxonomy table consisting of rows and columns that define cognitive processes and categories of knowledge, respectively. The cognitive process dimension (i.e., the rows of the table) contains six categories: *remember*, *understand*, *apply*, *analyze*, *evaluate*, and *create*. The knowledge dimension (i.e., the columns of the table) contains four categories: *factual*, *conceptual*, *procedural*, and *metacognitive*. Preliminary results suggest that the proposed two-dimension analysis can be successfully used to characterize the demand of electrical engineering problems.**

***Index terms*—abstraction, demand of problems, electrical engineering, problem solving, undergraduate research.**

I. Introduction

Electrical engineering demands high levels of knowledge and expertise and undergraduate electrical engineering curricula must provide students with extensive problem-solving skills. The National Academy of Engineering highlights problem solving as one of the essential attributes for future engineers [1]. To be successful problem solvers, students must build engineering frameworks that they can use to solve complex problems that have conflicting goals and undefined system constraints [2]. At the upper levels of a typical undergraduate electrical engineering curriculum, problem solving is often complex because students are required to abstract a specific problem to a more generalized problem or knowledge representation, interpret the results from the generalized problem and then transfer the results back to the specific problem being solved. It is sometimes the case that this capacity for abstraction is not matched to the complexity of the problems being posed. There then exists a gap in reasoning ability, on the part of the students, to reach the demand of the problems. In earlier work [3], students' attempts at solving electrical engineering problems were analyzed using the representation mapping framework of Hahn and Chatter.

The goal of this paper is to assess the demand of problems in several undergraduate electrical engineering courses and to compare this with the analysis of the instructors' solution attempts [3][4]. The demand of a problem may be defined as the level of thinking required (by students) in order to successfully engage with and solve a specific problem [5]. In this paper, the results of a preliminary study to assess the demand of the problems posed in sophomore and junior electrical engineering courses are discussed. These courses were selected because research has shown that a high percentage of cognitive abilities that students gain in math, science, and theorizing concepts take place in the sophomore and junior years [6][7]. The demand of a problem is assessed using a two-dimensional taxonomy table by analyzing the problem statement, the task complexity, possible paths in the solution, and the solutions that instructors expected students to develop when solving the problem.

II. Framework

In order to assess the demand of a given problem, the two-dimensional taxonomy table was chosen for this study. The two-dimensional table is a revised version of the original Taxonomy of Education Objectives (Bloom's taxonomy) proposed by Krathwohl [8]. The original taxonomy was created by Benjamin Bloom as a framework for classifying statements of what educators were expecting students to learn based on different categories in the cognitive domain [9]. It consisted of a one-dimensional taxonomy with the following categories: *knowledge, comprehension, application, analysis, synthesis, and evaluation.* Krathwohl proposed a modification of Bloom's taxonomy by suggesting that the *knowledge* category might be intrinsic in nature and different in each of the other taxonomy categories. He eliminated the *knowledge* category in his revised taxonomy by allowing a separate dimension including different categories of knowledge [9]. At the same time, he proposed to reorganize and rename the cognitive process dimension in verb form to match the way that it is used in student learning objectives. The original *knowledge* category was renamed as *remember*. Comprehension was renamed as *understand* because this verb is a widespread synonym for comprehending. *Application*, *analysis*, and *evaluation* were retained, but in the verb form as *apply*, *analyze*, and *evaluate*. *Synthesis* changed place with *evaluation* and was renamed *create*. All of these categories are called "cognitive processes" [9].

Table I shows the two-dimensional taxonomy table. The rows and columns of the table contain precisely defined cognitive processes and types of knowledge, respectively. The cognitive process dimension contains six categories: *remember*, *understand*, *apply*, *analyze*, *evaluate*, and *create*. The knowledge dimension contains four types: *factual*, *conceptual, procedural*, and *metacognitive*. The cells of the table are where the cognitive process and knowledge intersect [8]. Therefore, problems can be placed in the cells of the table. If a problem involves the use of various cognitive processes or various types of knowledge, it should be placed in more than one cell [6].

TABLE I. THE TWO-DIMENSIONAL TAXONOMY TABLE [8]

The Knowledge Dimension	**The Cognitive Process Dimension**					
	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual						
Conceptual						
Procedural						
Metacognitive						

a) The Cognitive Process Dimension: Krathwohl described the categories in the cognitive process dimension from simple to complex and from concrete to abstract. It is assumed that each category is a prerequisite to the mastery of the next, more complex, category. Each category represents a scheme of educational goals, objectives, and standards [8]. Consequently, for every category a specific type of problem might be assigned according to the demand of the educational goals and objectives of the course [8][9]. Table II shows a discussion of the cognitive processes within each of the six categories in detail, a definition of the category, as well as examples in the context of electrical engineering [8]. For example, the first category of this dimension is *remember* which involves retrieving relevant knowledge from long term-memory. There are two associated names, *identifying* and *retrieving*, and an example related to electrical engineering. The explanation is similar for the subsequent categories.

b) The Knowledge Dimension: The categories of this dimension range from concrete (*factual*) to abstract (*metacognitive*). The *conceptual* and *procedural* categories overlap in terms of abstractness, with some *procedural* knowledge being more concrete than the most abstract *conceptual* knowledge [8]. Table III shows the four types of knowledge along with their associated subtypes. *Factual* refers to discrete, concrete, isolated "bits of information" including knowledge of terminology, and knowledge of specific details and elements. It exists at a relatively low level of abstraction [8] because it implies the knowledge of basic terms students must know to be prepared to solve a problem [10]. In contrast, *conceptual* is knowledge of "more complex, organized knowledge forms" [8]. It comprises knowledge that is rich in relationships, a network in which the linking relationships are as prominent as the discrete pieces of information [11]. It includes classifications and categories, principles and generalizations, theories, models, and structures. *Procedural* refers to "knowledge of how to do something" [8]. It includes knowledge of skills and algorithms, techniques, and methods, as well as knowledge of the criteria used to determine and /or justify "when to do what" within specific domains and disciplines [11]. Finally, *metacognitive* refers to "knowledge about cognition in general as well as awareness of and knowledge about one's own cognition" [8]. It encompasses strategic knowledge, knowledge about cognitive tasks, including contextual and conditional knowledge, and self-knowledge [8][9][12].

TABLE II. SUMMARY OF THE STRUCTURE OF THE COGNITIVE PROCESS DIMENSION [8]

Categories	**Definition and Examples**
Remember	Retrieve relevant knowledge from long-term memory: identifying and retrieving (e.g., recognize the units for voltage, current, and resistance)
Understand	Construct meaning from instructional messages, including oral, written, and graphic communication: interpreting, exemplifying, classifying, summarizing, inferring, comparing and explaining (e.g., based on resistance-capacitor circuits, infer voltage-current behavior across the capacitor after five constant times)
Apply	Carry out or use a procedure in a given situation: executing and implementing (e.g., apply node-voltage analysis to find currents)
Analyze	Break material into its constituent parts and determine how the parts relate to one another and to an overall structure or purpose: differentiation, organizing, attributing (e.g., distinguish between relevant and irrelevant information in calculating the capacitors when adjusting the power factor in a three-phase configuration circuit)
Evaluate	Make judgments based on criteria and standards: checking and critiquing (e.g., checking with Kirchhoff's voltage law if the numerical value of voltage found applying Ohm's law across a resistor is correct)
Create	Put elements together to form a coherent or functional whole; reorganize elements into a new pattern or structure: generating, planning and producing (e.g., generate hypothesis of how build a filter with specific characteristics

We believe that Bloom's taxonomy table may be useful to classify the demand that a problem makes of on student attempting to solve it. Bloom's taxonomy is one of the most widely accepted and applied taxonomies in educational research. This is consistent with research developed by Davila & Talanquer and Momsen et al., that classified assignment problems in different categories of the cognitive process in courses of chemistry and biology [13] [14]. If the two-dimensional taxonomy table can be used successfully to categorize the demand of a given problem, it could be useful in our larger research study that seeks to understand the reasoning students use to solve different types of problems.

TABLE III. SUMMARY OF THE STRUCTURE OF THE KNOWLEDGE DIMENSION [8]

Types of Knowledge	**Definition and Subtypes**
Factual	The basic elements students must know to be acquainted with a discipline or solve problems in it: i. Knowledge of terminology ii. Knowledge of specific details and elements
Conceptual	The interrelationships among the basic elements within a larger structure that enable them to function together: i. Knowledge of classification and categories ii. Knowledge of principles and generalizations iii. Knowledge of theories, models, and structures

Procedural	How to do something, methods of inquiry, and criteria for using skills, algorithms, techniques, and methods: i. Knowledge of subject-specific skills and algorithms ii. Knowledge of subject-specific techniques and methods iii. Knowledge of criteria for determining when to use appropriate procedures
Metacognitive	Knowledge of cognition in general as well as awareness and knowledge of one's own cognition: i. Strategic knowledge ii. Knowledge about cognitive tasks, including appropriate contextual and conditional knowledge iii. Self-knowledge

III. Research Method

The purpose of this paper is to describe a preliminary study to assess the demand of electrical engineering problems. This includes defining the operations students must perform when solving the problem. For this purpose, we asked instructors assigned to different electrical engineering courses to provide the two most representative problems from their course exams and one additional representative problem not on the exam. We used the two-dimensional taxonomy table to analyze these problems. We also interviewed instructors and asked them to describe their expectations of how students should solve the problems. A summary of these interviews was also part of the analysis to strengthen the consistency of the analysis. Engaging an additional source of data led a more reliable analysis [15]. Interviews were audio recorded and the instructor's description of their expectations of how students have to solve problems were recorded using a smart-pen.

A. Course Selection

Three courses were selected for this study: *Electronics and Electrical Circuits I* (*Circuits I*), *Electronics and Circuits II* (*Circuits II*), and *Signals and Systems.* These courses are part of the undergraduate electrical engineering degree program at the institutions where the study took place. *Circuits I* and *II* are sophomore courses and *Signals and Systems* is a junior level course. The purpose of *Circuits I* and *II* is to introduce students to electrical circuit theory: Kirchhoff's law, circuit analysis theorems, transients in circuits with resistors, capacitors and inductors, and sinusoidal steady-state circuits. The *Signals and Systems* course is related to the representation and analysis of linear time-invariant systems through input-output relations and convolution. We selected these courses because our experience teaching them suggests that there is a significance difference in the demand of the problems students are asked to solve in them.

B. Data Collection

A total of 54 problems from 18 interviews of 4 instructors were collected for this study. Table IV describes the distribution of the quantity of problems and number of interviews for each one of the selected courses. Problems were collected between the fall 2013 and spring 2016. The instructors interviewed have taught the selected courses at least twice during the period of data collection. Instructors were recruited from two universities: a traditional large public institution and a non-traditional medium-sized institution, both in the United States. Participants were informed in detail of the purpose of the study during the recruitment process, and they signed the IRB-approved informed consent form before starting the interview.

TABLE IV. Number of Participants and Problems

Course	Number of Problems to Analyze	Number of Interviews
Electric Circuits I	12	4
Electric Circuits II	18	6
Signals and Systems	24	8
Total	54	18

The study consisted of analyzing problems of *Circuits I, Circuits II,* and *Signals and Systems.* These problems were collected during the interview of the instructor assigned to each course. Instructors who agreed to participate in the study were requested to select two problems from their course exams and one additional problem not used on any exam that best represented the assessment of the students' understanding of the material covered throughout the class. During the interview, we also asked them to discuss the major ideas and concepts involved in each of the selected problems and to provide their expectations of how a proficient student would solve these problems. Instructors were interviewed before students took the exam, and the interviews were audio recorded using a LiveScribe smart-pen to simultaneously capture spoken explanations and hand-written notes.

Semi-structured interviews were conducted with the instructors. This approach allows the researcher to clarify vague statements and to pursue emerging ideas and thoughts [16]. The instructor interview protocol included the following questions:

a) What is the main material you expect students should master for this part of the course?

b) Walk me through the exam and tell me briefly about each of the problems and what the problems assess.

c) Please pick two problems that you believe best assess whether a student's understanding of the main material covered for the exam. Show me how you expect a proficient student to solve these problems.

d) Finally, please provide me with a problem that was not on the exam, but is something that you could have put on the exam to assess material that was core to this section of the course. Please walk me through how you would expect a proficient student to solve this problem.

C. Analysis and Findings

The demand of the problem was assessed by analyzing the statement of the problem, what the problem was asking, and possible paths to finding the solution(s) using the two-dimensional table. We also analyzed the transcripts of the instructor interviews so that we could take into consideration the instructor's expectations of how students should solve these problems.

Here, we present the results of the analysis of three problems from *Circuits I*, *Circuits II*, and *Signals and Systems*. The analysis of the problems involved four steps. First, we wrote a summary of the steps to be considered when solving the problem based on the statement of the problem and the textbook of the course. Second, we identified the associated type of cognitive process and type of knowledge using the two-dimensional table. Third, we wrote a summary of the interview to identify ideas and actions expected by the instructor. Lastly, we decided if there was consistency between the analysis using the two-dimensional table and the instructor's expectations.

Circuits I Problems

The instructor of this course selected problems related to the application of different techniques for the analysis of electric circuits. The first problem consisted of finding the output voltage in an ideal amplifier, the second problem involved the use of the superposition theorem to find a specific voltage in a circuit, and the third problem involved the application of nodal analysis to find an output voltage and branch currents in a circuit. We chose the third problem, shown in Figure 1, as part of our study.

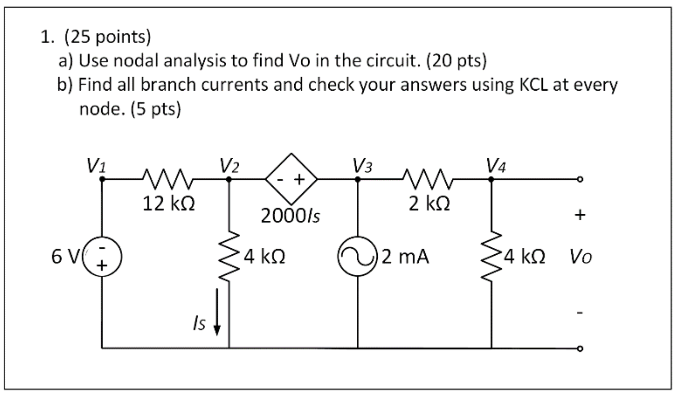

Figure 1. Problem Provided by the Instructor of *Circuits I*.

Below is the list of steps that a student must perform to solve this problem, the type of cognitive process used, and the type of knowledge associated with each step (Table V). We developed the list of steps based on the course textbook for *Circuits I* [17] and determined the type of cognitive process and type of knowledge based on the definitions of Krathwohl [8].

TABLE V. LIST OF STEPS, COGNITIVE PROCESS, AND KNOWLEDGE APPLIED TO SOLVE CIRCUITS I PROBLEM

List of Steps	**Type of Cognitive Process**	**Type of Knowledge**
a) Identify the nodes V_1, V_2, V_3, and V_4.	Remember, Apply	Factual, Procedural
b) State the nodal equation at V_1, identifying that V_1 is the numerical value of voltage source, but with inverse polarity.	Apply	Procedural
c) Identify that V_2 and V_3 compose a super-node, and state the constraint equation.	Apply	Conceptual, Procedural
d) State the nodal equation at V_4.	Apply	Procedural
e) State the algebraic manipulation to solve for the voltage V_4.	Apply	Procedural
f) State the first answer indicating that V_4 is the same output voltage.	Apply	Procedural
g) Solve for the rest of voltages V_1, V_2, and V_3.	Apply	Procedural
h) State the equations for the branch currents I_1, I_X, I_2, I_3, and I_4.	Apply	Procedural
i) Solve for each one of the branch currents.	Apply	Procedural
j) Calculate the value of *Vo* applying Ohms' law.	Apply	Procedural
k) Check if the numerical values of the branch currents were correct in applying Kirchhoff's Current Law at node 3 (V_3).	Apply	Procedural

In Table V, we noticed that *remember* and *apply* were the type of cognitive process involved in this problem, but it was more often the use of the *apply* process. Although *factual* and *procedural* knowledge were involved because of the formulas, theorems, and principles, *procedural* knowledge was predominant in this problem. Therefore, we located this problem in the cell intersecting *apply* and *procedural* knowledge. Regarding the complexity, we posited that this problem contains only one path that yield a well-defined solution (numerical value of *Vo*). This is consistent with the two-dimensional table analysis indicating that this problem implies low complexity (*remember*, *apply*) [8] with only one type of knowledge (*procedural*).

Regarding the interview and the notes provided by the instructor (Figure 2), we found that the instructor expected students to solve the problem using the steps involved in nodal analysis. At different moments in the interview, the instructor expressed his expectation that the students would follow the steps that were taught in the classroom:

"I would expect them to work through those steps, they might be in a different order where they might come up with a constraining equation first and then a KCL equation… "

"I expect most the students to follow the same steps that I have but they, they could be out of order…"

The instructor also mentioned that he was expecting students to be proficient in algebra because much of the solution involved mathematical operations:

"I expect them to have enough background in algebra, I guess to solve this problem and it's all basic algebra on this problem…"

"And so, it was designed so they could basically plug everything in to one equation and then solve, and then there's other problems in the exam where they have to come up with simultaneous equations… "

Based on our analysis of the problem, the instructor intends to engage students at the cognitive level of *apply* within the cognitive process dimension. The instructor matches the problem to the proper procedure, and then discusses how to execute and implement the procedure to solve the problem. Moreover, the instructor determines a sequence of steps as a procedure: to apply algorithms for solving the nodal equations and to have a set of skills in performing the algebraic expressions. These are characteristics of *procedural knowledge* and are consistent with the analysis performed with the two-dimensional table.

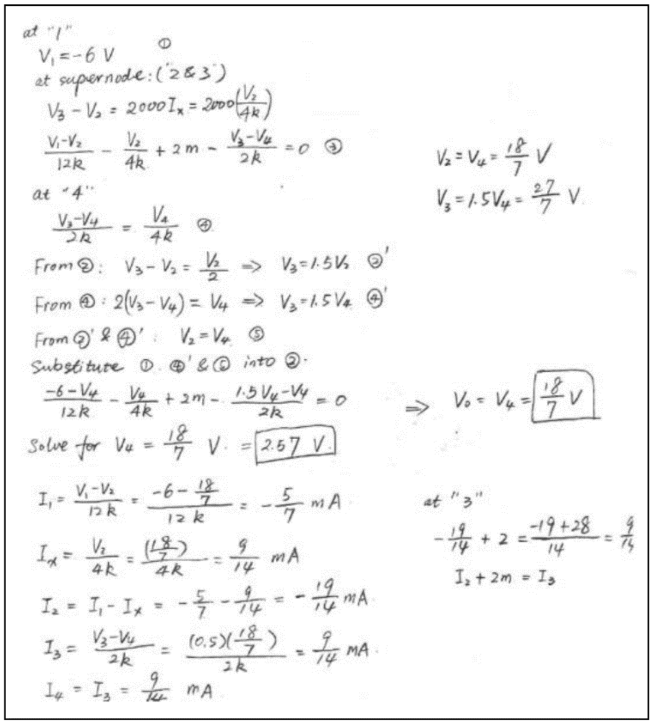

Figure 2. Notes Provided by the Instructor of *Circuits I.*

Circuits II Problems

The instructor was interested in two topics: a) how students could relate the voltage induced in the secondary circuit by the primary circuit by mutual inductance, and b) identify operational characteristics of diodes. The first problem asked students to find the average complex power provided by the power supply. When solving this problem, the instructor was expecting students to apply mesh analysis techniques and the concept of mutual inductance. The second problem asked to find the voltage source of the primary circuit given the output voltage of the secondary circuit. This problem was similar to the first one in using the concept of mutual inductance. The last problem covered diodes and their properties. The problem asked for the value of the built-in junction voltage giving the reverse biased value of voltage. We chose to analyze the first problem (Figure 3).

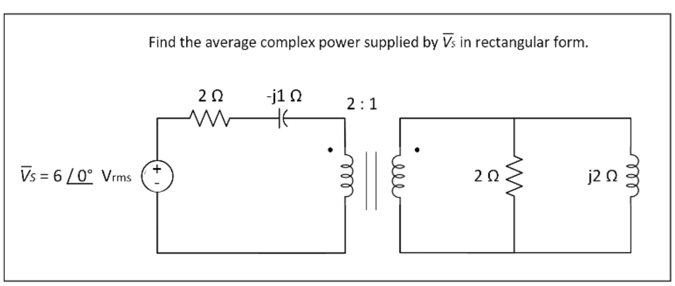

Figure 3. Problem Provided by the Instructor of *Circuits II.*

Table VI shows the list of steps that a student must perform to solve the chosen problem. Like previous problem, we developed the list through analyzing the course textbook for *Circuits II* [17] and we identified the types of cognitive processes and types of knowledge for every step.

TABLE VI. LIST OF STEPS, COGNITIVE PROCESS, AND KNOWLEDGE APPLIED TO SOLVE CIRCUITS II PROBLEM

List of Steps	**Type of Cognitive Process**	**Type of Knowledge**
a) Identify that the problem is asking to find the complex power, real, and imaginary that are supplied by the power source.	Remember	Factual
b) Calculate the equivalent impedance in the secondary by combining the two parallel impedances 2 Ω and j2 Ω.	Apply	Procedural
c) Using the ratio of mutual inductances 2:1, instructor simplifies the circuit reflecting the secondary impedance in the primary.	Apply	Conceptual, Procedural
d) Perform algebraic operations to find the equivalent impedance and substitute in the primary side of the circuit.	Apply	Procedural
e) Perform algebraic operations to find the total impedance of the circuit.	Apply	Procedural
f) Calculate the value of the current applying Ohm's law.	Apply	Procedural
g) Calculate the complex power applying the formula that relates voltage and the conjugate of the current.	Apply	Procedural
h) Perform math operations to find the real and imaginary power.	Apply	Procedural

As shown in Table VI, *apply* was the most common cognitive process involved in the solution of this problem. It is evident that *factual*, *conceptual* and *procedural* knowledge are involved in this solution. However, the predominant type of knowledge was *procedural* because there were many procedures required to solve the problem. We categorized this problem in the cell intersecting *apply* and *procedural* knowledge. As in the problem in *Circuits I*, there was just one solution path to find the average complex power. However, it was possible a second path to find the solution by calculating the total impedance and relate this value to the power. Then, find the average power as requested in the problem. At the end, this second option also needed to apply the same concepts related to the steps described in Table VI. For that reason, the presumption of one path might be valid. Like the previous problem, this is consistent with the two-dimensional table analysis indicating that this is problem that requires relatively low levels of cognitive processes (*remember*, *apply*) and one type of knowledge (*procedural*).

During the interview, the instructor discussed the steps needed to find the average complex power (Figure 4). The instructor explained that the primary and secondary components of the circuit must be simplified into just one circuit. In the interview, the instructor said:

"This is a problem that tests at least a couple of different concepts, probably three. I'll go ahead and sketch this circuit that they're given. So, there's a transformer in it. It's a fairly simple circuit."

Then, the instructor mentioned that the students just have to follow the procedure taught in the class to find the solution:

"They can do it any way they want as long as they follow a procedure that's correct and they show their work so I can tell what they're doing."

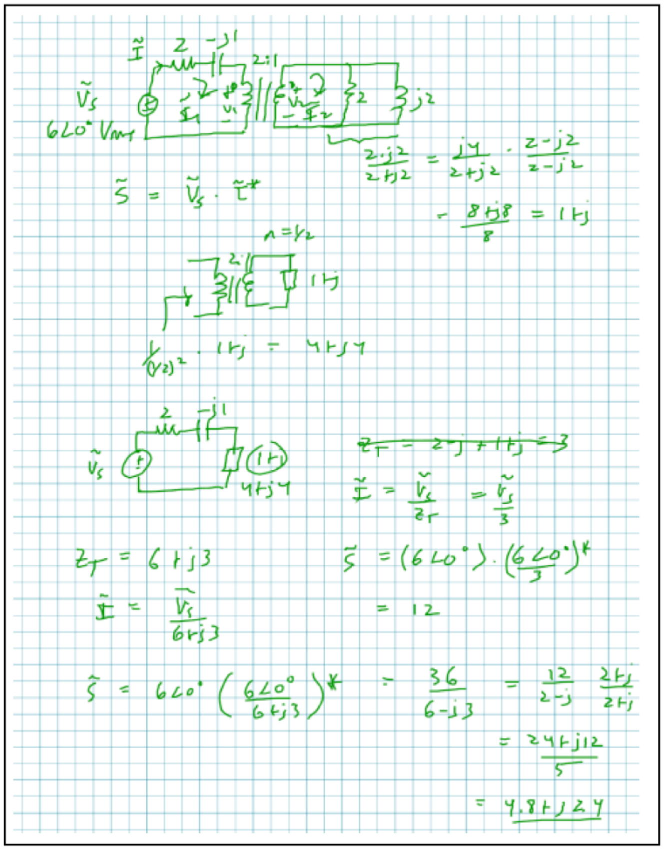

Figure 4. Notes Provided by the Instructor of *Circuits II*.

Similar to the previous problem, the instructor expects students to solve this problem using the procedure taught in the classroom. We can see that the cognitive process in this problem is at the level of *apply*. The instructor also anticipates that students will try to match the problem with a similar problem, and then apply the rules, techniques, or methods related to the analysis of mutual inductance in electrical circuits (*procedural* knowledge). This interpretation of the interview is consistent with the findings based on the two-dimensional table.

In both the *Circuits I* and *Circuits II* problems, the instructors expect students to solve the problem by performing a sequence of steps, applying formulas, and performing algebraic operations.

Signals and Systems Problem

During the interview, the instructor discussed three problems that covered the following topics: a) the Laplace transform, b) the *z*-transform, and c) the region of convergence. The first problem included a transfer function in the frequency domain, and asked students to determine if the system is stable by applying the region of convergence stability criterion. The second problem consisted of the *z*-transform that relates the input and the output of a discrete-time signal. The third problem provided an impulse response and its Laplace transform. This problem required plotting the poles and zeroes, finding the region of convergence, and determining the stability and causality properties. We chose the second problem for our analysis (Figure 5).

6. (4 pts) A linear time invariant discrete-time system has an impulse response

$$h[n] = (0.9)^n\, u[n]$$

Find the difference equation relating the input $x[n]$ and the output $y[n]$.

Figure 5. Problem Provided by the Instructor of *Signals and Systems*.

Below is the list of steps that a student must perform to solve the problem (Table VII). We completed the list based on the textbook of the course of *Signals and Systems* [18]. Similar to the previous problems, the type of cognitive process and type of knowledge were identified according to their definitions given by Krathwohl [9][19].

TABLE VII. LIST OF STEPS, COGNITIVE PROCESS, AND KNOWLEDGE APPLIED TO SOLVE SIGNALS AND SYSTEMS PROBLEM

List of Steps	**Type of Cognitive Process**	**Type of Knowledge**
a) Identify the problem is related to *z* domain.	Remember, Understand	Factual, Conceptual
b) Transform the impulse response $h[n]$ to *z* domain.	Understand, Apply	Conceptual, Procedural
c) State the formula of convolution: $Y(z) = X(z) \times H(z)$.	Apply	Procedural
d) Expand the equation for $Y(z)$ and $X(z)$.	Apply	Procedural
e) Apply the inverse *z*-transform.	Understand, Apply	Conceptual, Procedural
f) Simplify the expression to get the difference equation that relates the input and the output.	Apply	Procedural

According to Table VII, *remember*, *understand*, and *apply* were the types of cognitive process involved in the solving this problem. As shown in the table, *understand* and *apply* appeared approximately the same number of times. The problem was requesting students to use *factual*, *conceptual*, and *procedural* knowledge because of the need to recall formulas, to identify implicit concepts involved in the problem, and to perform algebraic operations. In comparison with the problems of *Circuits I* and *II*, more *conceptual* knowledge was required to solve this problem. This is as expected because the solution to this problem requires the student to identify a schema or mental model related to the problem, and then determine how specific aspects or features of this model are related to the stated problem. This problem could be located in more than one cell of the two-dimensional table, intersecting *understand-conceptual* knowledge and *apply-procedural* knowledge. It is also worth noting that this problem required more than following a prescribed sequence of steps to find the solution. This is evident in steps d) and e) where the problem required expanding the equation for $Y(z)$ and $X(z)$ and then applying the inverse z-transform.

During the interview, the instructor expected several steps from the students in the following order: 1) identify the problem as stated in time domain, 2) make the connection between discrete-time signals and the z domain, 3) determine that this problem is related to convolution of the impulse response, and 4) work in the z domain by applying the z-transform (Figure 6):

"If they thought only in the time domain, they would say the output is a convolution of the impulse response and the input. But that's almost impossible to solve for in--especially in a classroom situation. So what they have to do is find the z-transform of this and go into the z domain."

We found that the instructor wanted students to infer how to manipulate the final expression in the z domain to make possible the conversion to the time domain (inverse z-transform):

"I can expand this out, so I get $Y(z) - (.9z\text{-}1)Y(z) = X(z)$ *and then I can just take the inverse z transform. So that goes to y[n]. That goes to 0.9 y[n-1] is equal to x[n]. And we have the difference equation that relates the input and the output."*

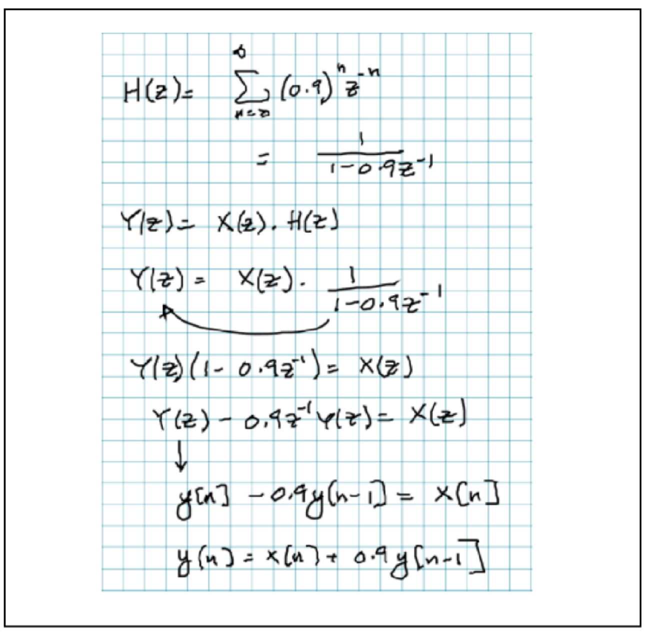

Figure 6. Notes Provided by the Instructor of *Signals and Systems.*

The instructor expects the students to think at the level of *analyze* in the cognitive process dimension, by determining the relevant implicit information given in the problem and how that information is related to the overall structure of the problem. The instructor considers how students understand and manage the components of the problems in the time and frequency domains, and how the domains are interrelated. The instructor starts by stating the components of the problem, and then analyzing the way the components of the problem are organized and interrelated. These results are consistent with the analysis performed using the two-dimensional table.

IV. Discussion and Future Work

Bloom's taxonomy is widely accepted by the engineering education research community as a useful tool to evaluate the difficulty of material and for curriculum development [9]. In this paper, we described a preliminary study to determine the demand of electrical engineering problems. The preliminary results suggest that the two-dimensional table can be successfully used to characterize the demand of problems. In the original proposal for this study, the use of the single dimension of Bloom's taxonomy was suggested as a measure of the demand of the problem. However, the revised two-dimensional table interrelates cognitive processes with the knowledge dimension, (from *factual* to *metacognitive* knowledge). This provides a richer method for determining the demand of the problems.

Instructors of *Circuits I* and *Circuits II* expected students to solve problems in the categories of *apply* and *procedural* knowledge of the cognitive and knowledge dimensions, respectively. The instructor of *Signals and Systems* expected students to solve the problem in the categories of *understand*, *apply* and *conceptual* knowledge. Thus, solving the *Signals and Systems* problem required a high level within the cognitive dimension because the instructor expected the problem to be solved with *conceptual* knowledge while identifying implicit aspects. The demand of the problems in *Circuits I* and *Circuits II* were lower than the demand of the problem in *Signals and System*. This is consistent with our experience in teaching electrical engineering course, in which problem solving is fundamentally more complicated in upper level courses. This increased demand of problems in the upper levels of electrical engineering curricula might have some implications for instructors' practice particularly when one considers the cognitive development of typical undergraduate students.

Future work includes conducting interrater reliability by asking two more researchers to collaborate on the analysis of the demand of problems. This should strengthen the overall research methodology. It also remains to determine if the demand analysis presented here is correlated in any way to the previous analysis of students' episodes of reasoning when solving the problems.

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