Experienced Students' Errors in Electrical Engineering

Anca Miron
Faculty of Electrical Engineering
Technical University of Cluj-Napoca
Cluj-Napoca, Romania
anca.miron@enm.utcluj.ro

Elena Trotskovsky
Dept. of Electronic and Electrical Engineering
ORT Braude College of Engineering
Karmiel, Israel
elenatro@braude.ac.il

Andrei C. Cziker
Faculty of Electrical Engineering
Technical University of Cluj-Napoca
Cluj-Napoca, Romania
andrei.cziker@enm.utcluj.ro

***Abstract*— This Work-in-Progress (WIP) Research paper presents the results of the first stage of a study whose main goal is to understand the misconceptions of experienced students, consequently, to increase the efficiency of the teaching process. The support course for the study, "The use of electrical energy", is taught in the 3rd year of B.Sc., Faculty of Electrical Engineering, and it consists of lectures and laboratory lessons. Throughout the laboratory part the students learn how to realize simple electrical schemes, supply different types of loads and measure the main parameters of the electrical energy: voltage, current and active power. During the evaluation tests, the students have to draw and assemble electrical schemes that are combinations or simplifications of the ones already learned. Regardless of the test subject, all students were asked the question: "To measure active power one will obtain the same value using a voltmeter plus ammeter and a wattmeter?" The qualitative method was used for the study, so the main research tools were the observations on students' explanations during the practical exam. The results of the research show that many experienced students have a misconception regarding the measure of active power, and this fact is strongly connected with the lack of theoretical knowledge that they have.**

Keywords*— *B.Sc. students, electrical engineering, qualitative study approach, misconception

I. Introduction

The teaching and learning process is complex, and it is influenced by many factors that connect its two main actors: teacher and student. The teacher has to be knowledgeable about his/her course on one hand, and on the other hand, studies in the field underline that the teachers' knowledge about the students' errors is essential for the students' learning [1, 2]. Indeed, as the authors of [2] mention and demonstrate through their research, if the teachers know their students misconceptions, and understand how the students learn the scientific concepts, they can adjust their teaching methods accordingly. Thus, the efficiency of the teaching process would be increased. In engineering, these errors are the results of students' misconceptions and misunderstandings of the basic science and engineering concepts [3-6].

Classical learning approaches [7, 8] assert that the roots of students' misconceptions "are ideas derived from daily experience that students bring to their learning experience and that contradicts scientific understanding and are often resistant to change". Then again, an over-packed engineering curriculum can amplify students' difficulties in generation of strong theoretical base and correct understanding of fundamental engineering concepts [9-11].

The engineering educators who teach advanced courses of third – forth years of engineering program for B.Sc. degree usually suppose that their students already have basic conceptual knowledge required for their course. But during the lessons and even in the final exam they discover that the students make major errors that testify about serious lack of conceptual knowledge. These errors appear every year among the new students of the course.

An experienced lecturer with 14 years of pedagogical practice in the field of engineering education taught the course "The use of electrical energy" during the last six years – one course per year. The course consists of 2 hours of lectures each week and 4 hours of laboratory each two weeks. The course involves the issues related to illumination, heating, welding and protection of electrical devices. At the end of the semester the students have theoretical and practical exams. Throughout the laboratory part of the course the students use a book of lab assignments, which includes all learning materials: electrical schemes, operating instructions, formulas, tables, and requirements to draw graphs and conclude. At the practical exam, the students are required to create, draw and assemble a circuit of illumination and heating devices, containing specific types of lamps (and heating devices: microwave oven and infrared sources) and supplied from the AC power network. The circuit must include measurement instruments, such as ammeter, voltmeter and wattmeter. The exam assignments are a little different and more complicated than the standard assignments from the book. After the circuit assembling, the teacher checks it and asks questions that are specific to the student's exam subject but also common questions. The teacher paid attention that from year to year part of the students answer "Yes" on the common question "Is it possible to measure active power in your circuit using an ammeter and voltmeter?" The standard explanation was "Because power is the current multiplying by the voltage". In addition to this error, many other errors occur each year.

This typical error of the advanced students promoted the study. The proposed research aims at the understanding of the phenomenon, answer the question: "Why part of the advanced engineering students lacks basic conceptual knowledge?" and to help the students in overcoming the misunderstandings.

In comparison with other similar studies the paper brings contributions regarding the key topic of the research and the used approach.

In the process of teaching an electrical engineering course, the authors noticed a specific error, which is not described in the pedagogical literature. A survey of the literature does not show that the key topic of the research, i.e. misconception of students in active power measurement in AC power systems, has been discussed or investigated. The research's target group are the experienced (senior) students' as their errors during the practical exam are analyzed.

The study was conducted using the qualitative approach. The main research tools were the observations on the students' performances and interviews with them during the practical exam. Other studies use quantitative [3, 4, 13] or qualitative methods [3, 5, 6], e.g. interviews. The current study used both the interview and the observation.

The remainder of the paper is organized as follows:

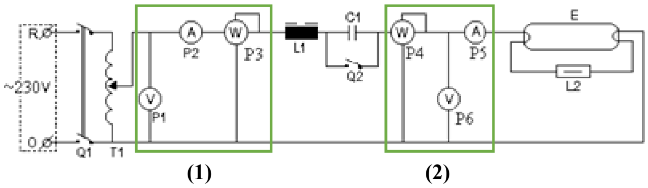
- Section 2 presents the main aspects about the support course, "The use of electrical energy" that are essential to understand the study;
- Section 3 describes the evaluation of the students;
- The results of the practical exam that show the students errors are described in Section 4;
- Discussions about the misconceptions are presented in Section 5;
- Section 6 enumerates the final remarks about the study and the next stage of the study.

II. Research's Background

The discipline "Use of electrical energy" is taught in the third year (Faculty of Electrical Engineering) that means the fifth semester of the four years B.Sc. schooling. The course consists of two hours of lectures every week and four hours of laboratory every two weeks, for 14 weeks. Through this period, the students learn about three major areas regarding the use of electricity: illumination, heating and welding, (IHW), and the protections that are made when using electrical energy. The lectures present the phenomenon, construction and functioning of the main devices used for IHW. During the laboratory classes the students learn how to supply from the main AC network different types of devices used for IHW, but also deepen the already acquired knowledge by measuring the parameters of the electrical energy (voltage, current and active power) and drawing the electric schemes for the circuits that are assembled in the lab. To support their study, the students have an assignments book where they can find all the electrical schemes and the description of the used devices. An example of one laboratory lesson is described further.

The study of the fluorescent lamp is realized using the electrical scheme from Fig.1. This is the usual supply circuit of a fluorescent lamp, as it needs a starter, L2, and a ballast, L1, to function properly. As the fluorescent lamp with the ballast have a low power factor, in the circuit a capacitor is introduced. The ballast with the inductor is called inductive ballast and the one with an inductor plus capacitor is called capacitive ballast.

During the laboratory, the students assemble the electrical scheme, supply the fluorescent lamp with different values of the supply voltage (180 V…250 V) and note the values obtained through the measurement apparatus in a table similar with the one illustrated in Fig. 2.



Legend
T_1 – autotransformer
Q_1 – automatic switcher
P_1, P_6 – voltmeter
P_2, P_5 – ammeter
Q_2 – simple switcher
L_1 – ballast (inductor)
L_2 – starter
E – fluorescent lamp
P_3, P_4 – wattmeter
C_1 - capacitor

Fig. 1. Electrical scheme for the study of a fluorescent lamp [14]

As it can be seen in the electrical scheme from Fig. 1, the students measure the voltage (voltmeter), current (ammeter) and active power (wattmeter) in two points of the circuit: the supply node **(1)** and connection point of the fluorescent lamp **(2)**. These values are measured for both cases: inductive and capacitive ballast.

At the end of the laboratory, the students make conclusions regarding the obtained values through measurement, after that draw graphs that illustrate the dependence of current, lamp voltage drop and active powers on supply voltage. If the students conclude wrongly, these aspects are further discussed with the help of the teacher.

U[V]	I [A]		$P1$ [W]		U_E [V]		P_E [W]		λ	
	ind.	cap.	ind.	cap.	ind.	cap.	ind.	cap.	ind.	cap.
170										
180										
190										
200										

Legend
U[V] – supply voltage
I [A] –current throught the circuit
P_1 [W] – active power of the entire circuit
U_E [V] – lamp's voltage drop
P_E [W] - active power of the lamp
λ – power factor

Fig. 2. Example of the table of laboratory lesson [14]

Regarding the active power, P [W], measurement, it is connected to the type of loads that compose the circuit. The loads can contain R (resistances), L (inductors), C (capacitors) or combinations between these three elements.

As it is well known, the formula of active power in an AC circuit is:

$$P = I \cdot U \cdot \cos\varphi \text{ [W]} \quad (1)$$

Consequently, in an AC circuit to measure the P, it is needed a wattmeter. There is an exception: for circuits that supply loads that consist only of resistances. As the phase shift between the voltage and current is 0, cos φ = 1, the mathematical relationship in this case is simplified, as in (2) and therefore it can be used a voltmeter and ammeter.

$$P = I \cdot U \text{ [W]} \quad (2)$$

The information about different AC circuit's components, mathematical relationships of AC quantities, and the measurement of electrical energy parameters are taught in the first two years of B.Sc., so the 3rd year students, the experienced ones should have the knowledge to perform the measurements and understand the circuits from the laboratory lessons.

III. Students Evaluation

The students' evaluation was realized using a theoretic exam and a practical exam. Further on are presented the practical exam and an example connected to the laboratory lesson from section II.

At the practical exam, the students get a subject, such as:

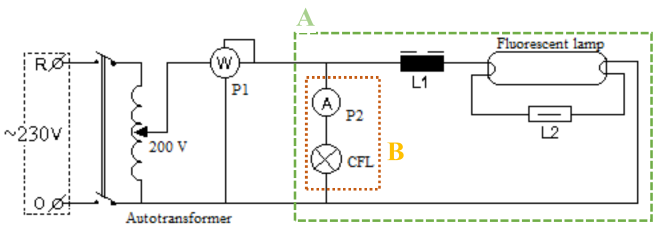
Subject x: "Realize a circuit that supplies at 200 V a fluorescent lamp and a CFL (compact fluorescent lamp). Measure the current through the CFL's sub-circuit and the active power of the entire circuit".

It can be seen that the subjects from the practical exam are more complex in comparison with the circuits realized during the semester, as the students have to combine and adept the learned circuits. A clearer picture about the difference between the laboratory and the practical exam can be drawn by relating the scheme from Fig. 1 with the one from Fig. 3.

To get the maximum grade, a student had to realize correctly the followings:

- to draw the electrical scheme;
- to assemble the circuit;
- to measure the electrical energy parameters.

It has to be mentioned that the students can use the laboratory support book.



Legend
P_1 – wattmeter P_2 – ammeter
A – circuit for which P_1 measures the active power
B – circuit for which P_2 measures the current

Fig. 3. Electrical scheme, solution to subject x

During their performance, the students were observed and at the end (when they were ready) they presented their scheme and circuit and had to answer the examiner's questions. Thus, the qualitative approach was used.

IV. Practical Exam Results

For the research, 132 students were evaluated during the practical exam, across a period of four days. The first two days were considered as the preliminary stage of the study and included the evaluation of 37 students. After this stage all details about the actual study were clarified, as the students' main errors were recognized and the proper questions and objectives were formulated.

For the next two days, the first stage of the research was perform, and included the analysis of the practical exam results for 95 students. Further, in the paper, all data that will be presented will be referred to the 95 students that participated in the actual study.

All students were questioned regarding their individual subject, plus the question "To measure the active power for your circuit, will you obtain the same result using a wattmeter or a voltmeter associated with an ammeter?"

Beside the answer to this question, other aspects were followed during the practical exam:

- How the students draw the electric scheme. Regarding this aspect it was observed that many students tend to copy the scheme from the book without adept it to their subject;
- If the students recognized the loads as R, L, C elements of a circuit. It was observed that even if the students know how to supply the load and how it functions, they cannot classify it as R, RL, RC or RLC load;
- How the students connected the measurement apparatus and assembled the circuit in order to determine the parameters correctly (accordingly to their exam subject – the right apparatus and in the correct position);
- If the students knew to assembly the circuit devices in compliance to the electrical scheme.

The results of the students' answers are presented in table I. It has to be underlined that only the most common errors are presented in the table. Analyzing the enumerated errors, it can be observed that all seven errors that were made by the students are connected to some degree with previous knowledge, namely, the information that was taught in the previous semesters.

TABLE I. Experienced Students Errors

No	Error	N_{st}^{a}	n_{st}^{b} [%]
1.	Confusion between wattmeter and voltmeter + ammeter	46	48.4
2.	Lack of the knowledge of the correct mathematical relationship for the active power in an AC circuit	37	39
3.	Copying the electrical scheme from the book	27	28.4
4.	Lack of understanding the difference between R, RL, RC and RLC circuits	25	26.3
5.	Wrong position of the measurement apparatus	18	19
6.	Confusing the series and parallel circuits	8	8.4
7.	Lack of skills to assembly the circuit accordingly to the scheme	4	4.2

a. Number of the students that made the error

b. Numeric percentage of the students that made the error

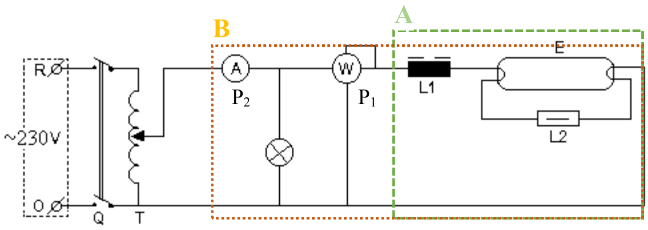
V. Occurred Misconception

The analysis of the errors made by the experienced students in addition to their answers shows that there is a misconception that they have regarding the *P* measurement: to measure the active power in a circuit, if one doesn't have a wattmeter, a voltmeter and ammeter can be used instead, and the same value will be obtained. When asked to explain their answer the most common replay among the students was: „Because power is the current multiplying by the voltage" – so the students forget/don't know about "cos φ", the phase shift between voltage and current that appear in AC circuits.

This misconception is strongly related with the fact that they lack theoretical knowledge about the mathematical relationship of the active power (error 2) on one hand, and on the other hand they don't understand the differences between the circuit's elements (error 4) and different types of circuits (error 6). This misconception and the lack of knowledge are connected with the previous courses where the students learn about the electromagnetic circuits.

The third error of the students can be explained as a misunderstanding about the exam's subject or insecurity regarding their knowledge, therefore they prefer to use a scheme that they know is right.

Other error that was made by 19% (error 5) of the students is regarding the fact that they don't know where to connect the apparatus in order to measure the quantities for the correct sub-circuit. An example of this error can be seen by comparing Fig. 3 with Fig. 4. The first picture illustrates the correct position of the wattmeter (to measure the active power for the entire circuit) and ammeter (to determine the current that flows through the CFL's sub-circuit) for "Subject x". The scheme from Fig. 4 shows a wrong solution for the locations of the measurement apparatus. This scheme was drawn by a student and assembled as a circuit. The student's scheme shows that the ammeter in this position will measure the value of the current that flows through the entire circuit, and the wattmeter the active power only for the circuit of the fluorescent lamp, respectively. So, the student used the appropriate measurement apparatus, but he/she was wrong in positioning the devices.



Legend

P_2 – ammeter P_1 – wattmeter

A – circuit for which P_1 measures the active power

B – circuit for which P_2 measures the current

Fig. 4. Electrical scheme, wrong solution to „Subject x"

The seventh error was observed at only at 5% of the students and was not considered a either a misconception or misunderstanding, but the lack of practical skills.

Related to the students misunderstanding of active power in AC circuits, during preliminary stage of the study it was found that many students who firstly answered wrong, after the examiners directed questions remembered the correct formula and answered partly properly. This fact allows to assume that the knowledge exists among these students, but in fragmental, not linked form. Maybe, in the exam they first time tried linking their "knowledge in pieces" to conceptual knowledge network [15]. Therefore, the aim of the educator will be to enhance this process during the course.

An answer to the above stated cause of the students' errors is that for many courses the curricula is over-packed, and in order to follow the schedule, often the teachers don't wait for all students to gain the necessary conceptual knowledge and the students learn for the exams and not knowledge. In this way, the students will build their scientific theoretical basis in a fragmented form.

VI. Conclusions and Future Work

Experienced students in electrical engineering make errors during the practical exams due to lack of knowledge or the ability to connect the new information with the previous knowledge. The errors observed during the study show that the misconception about the measurement of active power in AC circuits exists.

As it is known from pedagogical literature [16-18], active learning promotes the process of understanding and integrating fragmentary knowledge into the concept network. The learning process of the course must be directed to deeper students' understanding of conceptual knowledge. The follow pedagogical efforts may be proposed for this goal:

- To design a set of additional assignments during the course, which are different from the standard assignments described in the course book and exam assignment (more complicated than lab, but less complicated than exam assignments), and after the performing of standard laboratory work to offer the students to answer additional problems;
- Add homework which connect the theoretical material with the lab assignments;
- During the performance of the labs ask the students conceptual questions. The level of the questions must slightly increase during the course, they must become more complicate and professional to the end of the course.

After the assuming of the recommendations in the future course, next year the research will resume to determine the student's performances and their errors at the practical exam, so to verify the efficiency of the applied methods.

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