Application of Bloom's taxonomy for increasing teaching efficiency – case study

Authors:

Jerzy Rutkowski, Katarzyna Moscinska, Piotr Jantos, Silesian University of Technology, Gliwice, Poland
Jerzy.Rutkowski@polsl.pl, Katarzyna.Moscinska@polsl.pl, Piotr.Jantos@polsl.pl

Abstract — *In this paper we present a method for increasing teaching efficiency of a basic engineering course. Circuit Theory is an obligatory, two semester course delivered to all students of the Faculty of Automatic Control, Electronics and Computer Science, Gliwice, Poland. Since 2005, the course is delivered in the blended e-learning version. In the last few years we observe increasing problems with the laboratory work - students neither possess theoretical background of an exercise, nor can perform successfully measurements and interpret obtained results. The goal of our study was to identify main reasons of students' poor performance in the laboratory. We have verified whether all course components enable sufficient preparation for the laboratory work. We have also analysed the contents of laboratory exercises and pre-lab short tests in order to find out which levels of knowledge they address. Bloom's taxonomy of learning outcomes has been applied in order to classify questions and problems into categories. In general, disregarding of the Bloom's pyramid structure was found out as the leading source of laboratory failure - lack of lower level knowledge components inhibits application of medium level elements and therefore prevents successful execution of laboratory exercises. The authors have suggested modification of the laboratory program so that all practical work was preceded by obligatory calculations (calculate – assemble exercises). Moreover, we have decided to introduce weekly obligatory computer quizzes, to be solved before attending laboratory exercises. We have focused on graded difficulty of problems, in order to represent particular levels of Bloom's pyramid. Such form of formative assessment lets students gain more experience and build self-confidence. Majority of students confirms that the introduction of quizzes enable better preparation for the laboratory as well as gradation of difficulty level helps to understand the course. Adequate difficulty level of pre-lab tests (including lower level cognitive categories – knowledge, comprehension) and focusing on practical issues is necessary in order to decrease students' failure rate and improve students' attitude to the Circuit Theory course .*

Index Terms — *Bloom's taxonomy, Circuit Theory, course content modification, blended learning.*

INTRODUCTION

Circuit Theory course is an obligatory, two semester course delivered to all the students of the Faculty of Automatic Control, Electronics and Computer Science. Except from non-obligatory lecture, students attend obligatory classroom tutorials and laboratory exercises. In order to get the final grade students have to pass the written test at the end of the classroom tutorials, perform all the exercises in the laboratory and pass the final exam, in form of computer test. Students are not allowed to take the final exam unless they finish classroom tutorials and laboratory exercises.

In 2005, we have initiated transformation of CT course into blended e-learning version [1]. Knowledge delivery is performed in a face-to-face manner, whereas Moodle-based Learning Management System is applied for the coursework presentation, students' work collection, formative and summative assessment and communication.

Circuit Theory is a difficult course, with an average examination pass rate of 40% in each round. Formative assessment, carried out during the semester, gives even worse results. In order to improve learning efficiency many options of non-obligatory formative assessment were introduced [2]. These activities were focused mostly on lecture issue or classroom tutorial problems.

Recently, we observe significant problems with the laboratory work. Many students are not prepared to do the exercise – they either do not possess required knowledge (theory), which is verified by an introductory test, or cannot perform the exercise and interpret its results. Students who fail the laboratory introductory test are not admitted to do the exercise, which causes severe delays in the laboratory work. The goal of our study was to identify these reasons of students' poor performance in the laboratory, which can be eliminated by modification of teaching method. The following issues were taken into account:

1. Do other course components prepare students properly to the laboratory exercises?
2. Is difficulty level of introductory tests and exercises appropriate?
3. Which reasons of failures are indicated by students? What is students attitude to laboratory exercises?

In order to analyze problems 1 and 2, the authors have examined thoroughly course syllabus and studied the contents of the lecture, topics of classroom tutorials as well as laboratory exercises. Bloom's taxonomy of learning outcomes has been applied in order to classify questions and problems into categories [3,4]. Moreover, a survey was performed for second year Electronics Department students in order to find their opinion with respect to all the issues. As the result, some modification of both laboratory introductory tests and exercises were proposed.

CATEGORIZATION OF LEARNING OUTCOMES

There have been many attempts over time to categorize learning outcomes. These are broadly referred to as taxonomies of learning and can be useful ways of stating what students are expected to achieve. The taxonomies of learning objectives begin at the lowest level with the simplest activities and progress upward through stages with increasing complexity. For students to progress up the hierarchy, they must function at lower levels firstly, incorporating that level of activity, and then proceed up through each level to more complex functioning [5]. The most widely applied are Blooms and SOLO taxonomies, and their modifications.

Bloom's taxonomy was first described as a hierarchical model for the cognitive domain in 1956 [3]. Work of Bloom was inspired by the fact that over 95% of the test questions investigates students' knowledge at the lowest possible level – recall of information. In his study, Bloom identified six levels within the cognitive domain, from the simple recall or recognition of facts, as the lowest level, through increasingly more complex and abstract mental levels, to the highest order which is classified as evaluation. The categories and the choice of equivalent key words are listed below:

1. ***Knowledge:*** define, list, name, order, recognize, relate, recall, repeat,
2. ***Comprehension***: classify, discuss, explain, identify, indicate, report, review, select,
3. ***Application***: apply, choose, demonstrate, sketch, solve, use, write,
4. ***Analysis***: analyze, calculate, compare, contrast, discriminate, examine, experiment,
5. ***Synthesis***: assemble, construct, create, design, develop, formulate, prepare, propose, write,
6. ***Evaluation***: assess, attach, choose, compare, predict, rate, select, evaluate.

The categories should be considered as degrees of difficulties, i.e. the lower level category must be mastered, before the next one can take place. This model was revisited in 2001 by Anderson [6]. As a result, a number of significant changes were made to the terminology and structure of the taxonomy [6,7].

There are numerous examples of questions that can be easily assigned to one of Bloom's categories, for example: *comprehension*: retell in own words..., *application*: use a manual to calculate.... , *analysis*: what evidence can you list for... etc. The classification is much more difficult in case of most technical courses. For example, Thompson et al. [7] noticed that in case of Computer Science course there is a significant disagreement between academics in assigning questions into categories. Similar observations have been made by the authors while teaching Circuit Theory and Signals and Systems courses. For example, typical classroom tutorial problem is 'to calculate'. However, depending on the task, such problem could fall into *understanding, application* or *synthesis* category. Sometimes effective calculation requires careful choice of the proper method – in such case even the highest category (*evaluation*) may be considered. Nevertheless, usually laboratory work and calculation tasks are intended to assess medium levels of understanding [8].

CIRCUIT THEORY COURSE – REVISION OF COMPONENTS

Contribution of the lecture and the classroom tutorials

The Circuit Theory course syllabus was created according to the regulation of Polish Main Board of Higher Education, which defines standards and minimum contents to be delivered. The course fulfils all the standards and requirements, which has been verified by internal Quality Assessment procedure as well as external National Evaluation Board. The lecture is delivered by an experienced lecturer based on modern facilities, e.g. PowerPoint presentation. The lecture material is available on the LMS course page and consists of lecture updated program and conspectus, main definitions, terms and concepts, as well as drill problems.

The classroom tutorials enable to understand theoretical concept delivered by the lecture and prepare students to the laboratory exercises. Tutors explain the most difficult issues and solve numerous calculation problems. Various forms of formative assessment are offered during the semester in order to let the students get experience. Students solve paper work or computer tests, get feedback from the tutors and can master their skills. However, we observe that when formative assessment is non-obligatory, or does not contribute to final grade, the students' interest is rather poor.

The course program is complete, consistent and gives sufficient background for laboratory practical work. Unfortunately, the classroom tutorials which are extremely helpful for understanding difficult theoretical ideas, are sometimes delayed with respect to laboratory, as was indicated by comments of many students in the survey.

Revision of laboratory exercises

We have analysed the contents of laboratory exercises in order to find out which levels of knowledge they address. During most exercises students need to assemble simple circuits according to schematics prepared by the tutors, or sometimes just use simple boards, which may be configured with a set of switches. Depending on the exercises, students carry out measurements and/or perform oscilloscope observations. In some cases the goal of the exercise is to verify theoretical calculations, prepared by students beforehand. When there is no match between calculations and measurements, the exercise has to be repeated with a new configuration of the board. Most of exercises require medium levels of understanding - *application* and *analysis*. As Circuit Theory is delivered to the first and second year students, all the exercises are fully designed by tutors and do not include elements of students' creativity, which are assigned to highest level – *synthesis* and *evaluation*. Figure 2 presents an exemplary stand of Circuit Theory exercise.

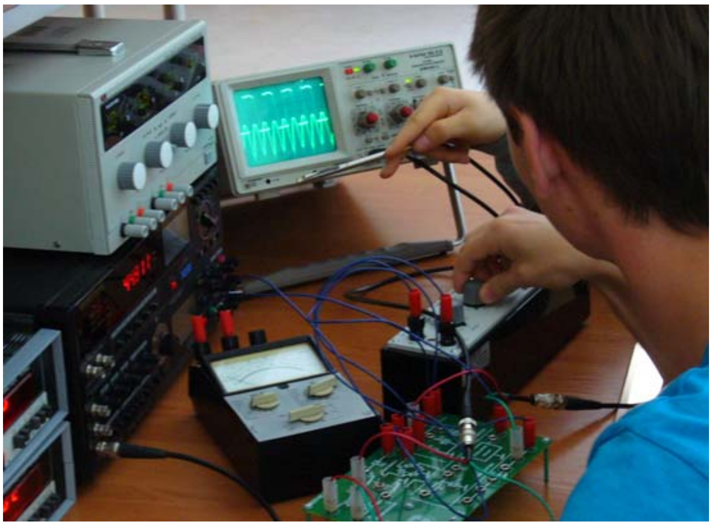

FIGURE 2
AN EXEMPLARY STAND OF LABORATORY EXERCISE

Source of laboratory failures

Our observations and analysis, confirmed by the result of students' survey, allow us to indicate the following reasons of students' failures in the laboratory:

1. lack of understanding of theoretical issues that are necessary to perform the exercise and analyse its results,
2. lack of experience with practical work (problems with assembling electric circuits).
3. discouraging rate of failure in the laboratory.

There are many reasons of insufficient theoretical knowledge of students attending the laboratory. The course is difficult; it requires very good mathematical background, technical skills and metdhodical studying. Unfortunately, many students lack mathematical background from the high school. Obviously, many students neither attend the lecture, nor study enough on their own. Nevertheless, as we have already stated, some modifications of teaching method may help to eliminate these barriers.

Our experience shows that in many cases students are unaware which part of the course is necessary to perform the exercise. It seems that they need dedicated pre-lab tasks, to verify whether they posess required knowledge.

We have observed that in case of exercises that verify students calculations, students perform better both during introductory tests and practical work. The structure of the exercise prevents students from attending laboratory classes without studying corresponding theoretical background. This type of exercise will be called *calculate-assemble* type, as opposite to classical *assemble* exercise.

Students' lack of practice is quite common in case of the undergraduate students and cannot be easily compensated. There is a limit for laboratory hours that cannot be increased, and there are rarely extra stands available for volunteers. However, the laboratory exercises are carried out either by a single student or teams of two students, so they are able to gain their experience quickly. Usually, this obstacle disappears in the second semester of Circuit Theory course.

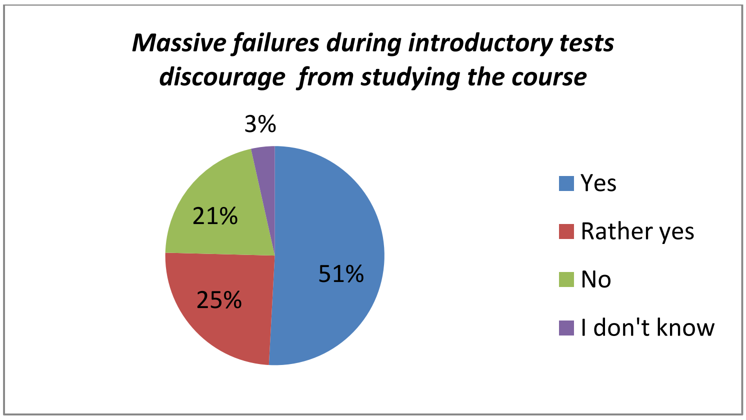

FIGURE 3
INFLUENCE OF FAILURE RATE ON STUDENT ATTITUDE TO THE COURSE

Massive failures during introductory tests discourage students from studying the course, as shown in the Figure 3. The tests are necessary, as students who are not prepared and do not expect correct results usually waste their times watching irrelevant signals, measuring noise instead of meaningful information, etc. However, it seems that both the subject of the introductory test and its difficulty level should be verified.

In general, disregarding of the Bloom's pyramid structure is the leading source of laboratory failure - lack of lower level knowledge components inhibits the application of medium level elements and therefore prevents successful execution of laboratory exercises. The authors have suggested the following modification to the laboratory program:

1. more *calculate – assemble* exercises,
2. more obligatory pre-laboratory tasks; graded task difficulty,
3. practice – oriented introductory tests; adequate difficulty level.

Some of the listed modifications have already been introduced and the obtained results are promising.

MODIFICATION OF THE CIRCUIT THEORY LABORATORY

Conversion of the laboratory exercises into calculate-assemble form

Verification and modification of the laboratory program must be performed according to the quality assurance standards and requires approval of the Head of the Division. This procedure will take place next semester. We are going to start with a discussion of the new concepts within the Division. Once the new exercises are approved, new stands will be successively placed in the laboratory. The stands must be designed so as to enable measurements in numerous personalised configurations.

Introduction of obligatory, pre-laboratory computer quizzes

We decided to introduce weekly obligatory computer quizzes to be solved before attending laboratory exercises. Such form of formative assessment enables students to get more experience and build self-confidence. The difficulty level of the most demanding task is chosen so that the students who pass this quiz have no problems with the theoretical aspects of the laboratory exercise. The feedback available after completing the test lets the students verify whether their answers were correct. The quiz includes both open-ended (numerical) and multiple choice question. As there are no descriptive questions, instead of asking students for definitions, etc., we want them to chose the correct one. In particular, we focused on the proper sequence of questions: firstly, the lower order, then the higher order questions [9]. This refers to the lower level (*knowledge*, *understanding*) and the medium level (*application*, *analysis*) of Blooms taxonomy.

An example of created quiz structure is given below. The subject of the quiz is application of Thevenin's Theorem for simplification of linear circuits.

Q1 Chose the proper definition of Thevenin's theorem (*knowledge*),
Q2 Chose the proper definition of Thevenin's equivalent resistance (*knowledge*),
Q3 Chose the proper schematics for the measurement of Thevenin's equivalent resistance (*understanding*),
Q4-Q6 Calculate Thevenin's equivalent for the given circuit (*application*, *analysis*),
Q7 What method should support calculation of Thevenin's equivalent for the given complex circuit? (*analysis*),
Q8 Calculate Thevenin's equivalent for the circuit of Q7 question (*application/analysis*).

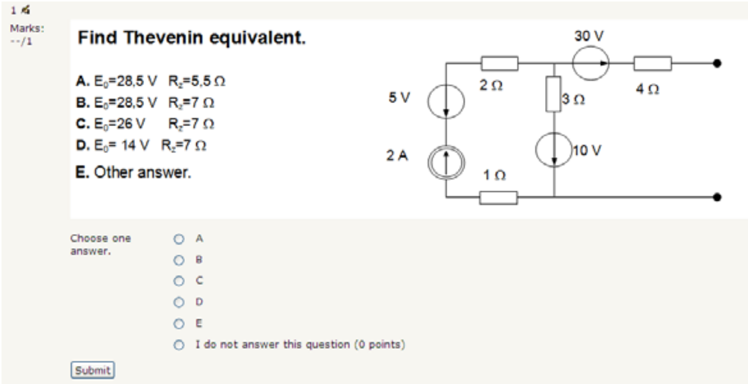

FIGURE 4
QUESTION Q6 OF AN INTRODUCTORY TEST

We are going to address the concept of Thevenin's theorem again, while discussing solution of nonlinear circuits; in particular – the simplification of its linear part (*application*). At this stage of the course it is impossible, as the necessary knowledge has not been delivered at the lecture. Figure 4 present the question Q6.

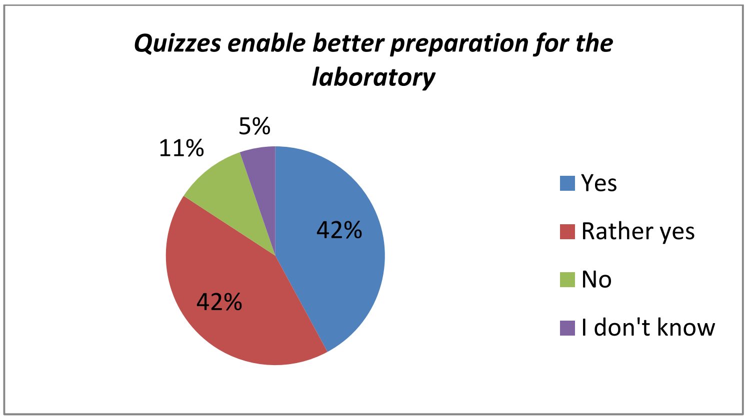

FIGURE 5
STUDENTS' ATTITUDE TO PRE-LAB QUIZZES

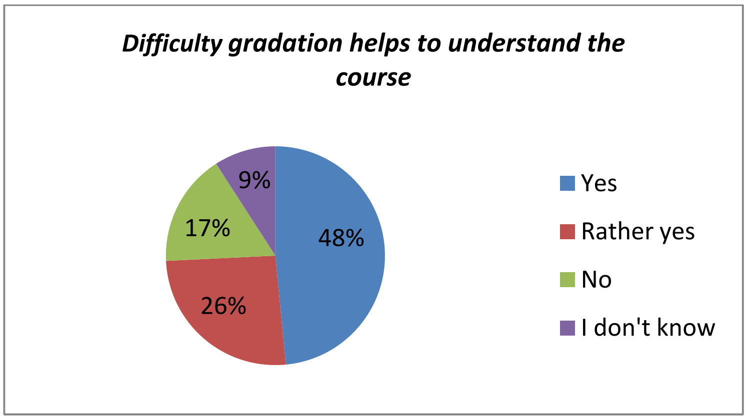

FIGURE 6
STUDENTS EVALUATION OF DIFFICULTY GRADATION

As the test were introduced last semester, there is not enough feedback to fully evaluate their influence on the students' performance in the laboratory. However, the answers of the students' survey confirm the usefulness of the quizzes. Figure 5 presents the students evaluation of the statement *quizzes enable better preparation for the laboratory*. It can be seen that 84 percent of students appreciate the tests (sum of 'yes' and 'rather yes' answers). We have also inquired whether the *gradation of the difficulty level helps in understanding the course*. In this case majority of students is satisfied with such approach, as can be seen inthe Figure 6.

Revision of the introductory tests

Adequate difficulty level of introductory tests (including lower level – knowledge, comprehension) and focusing on the practical issues is necessary in order to decrease students' failure rate and improve students' attitude to the Circuit Theory laboratory. We have thoroughly analysed current repository and performed the following actions:

- All purely theoretical question have been eliminated (example: *plot Laplace equivalent for a coil with nonlinear initial condition*).
- A number of practical questions has been added (example: *How to measure the resistance of Thevenin's equivalent? What is the maximum value of the current in the given circuit?*).
- Many questions have been replaced by more practical equivalents, e.g. a question *Plot the shape of overshooting in case of* ***idealized*** *coil* has been replaced with: *Given a* ***practical*** *coil, what shape of an overshooting do you expect? Which of the circuit elements will the overshoot take place on?*
- Whenever possible, questions were converted in order to include two parts. That is, students are given two questions, one of them belonging to the lower order category.

Most of computer quizzes questions have been copied into this repository, which should encourage students to solving the proposed quizzes. The modified introductory task repository will be applied starting the next semester.

CONCLUSIONS

The goal of our study was to identify the main causes of students' poor performance in the Circuit Theory laboratory. We have verified whether all of the course components enable sufficient preparation for the laboratory work. We have also analysed the contents of the laboratory exercises and the pre-lab short tests in order to find out which levels of knowledge they address. Our findings were as follows: students possess insufficient knowledge, even though the theoretical context is fully covered by lecture. Many students cannot identify theoretical ideas which are relevant to the laboratory exercises. In particular, lack of the lower level knowledge components inhibits application of the medium level elements and therefore prevents successful execution of the laboratory exercises.

The authors have suggested the following modifications of the laboratory program:

- more *calculate – assemble* exercises,
- more obligatory pre-laboratory tasks of graded task difficulty,
- *practice – oriented* introductory tests of adequate difficulty level.

Pre-laboratory quizzes of the graded difficulty have been accepted by both teachers and students. The adequate difficulty level of pre-lab tests (including the lower level cognitive categories – *knowledge, comprehension*) and focusing on practical issues have decreased students' failure rate and changed their attitude to the course.

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