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Electric circuit interactive laboratory

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Abstract

Ensuring the best teaching quality and promoting the critical thinking and hands-on experience of students are main concerns in the continuous development plan of the laboratories in the Electrical and Computer Engineering Department at the American University of Beirut. To this end, laboratory course materials are not only subject to constant updates, but also innovative teaching methods and evaluation techniques are developed. This paper outlines a new teaching methodology and novel academic Moodle-based evaluation techniques applied in a lab environment specific to Electric Circuits Laboratory which is a basic required course for all students majoring either in Computer and Communications Engineering or in Electrical and Computer Engineering in the Electrical and Computer Engineering department. The objectives of this course are to familiarize students with various circuit and electronic devices and their applications, to teach them how to use basic laboratory instruments, and to introduce them to laboratory techniques to implement and analyze electronic circuits. The motivation to implement the new changes was due to many observations and problems encountered while teaching the course for several years. The inventive teaching and evaluation approach have been applied so far for three semesters. Significant improvement in students' comprehension of the material, depicted in a considerable increase in class average of the final exam, proved the success of the adopted method. Besides, an increase in class participation and involvement was noticed and course assessment done by students scored very high.

Keywords

Electric circuits, electronics, evaluation methods, interactive teaching, laboratory, Moodle

Introduction

Modern technology has redefined how humans think in a fast-paced world and this has had its effect also on college students. Consequently, educators are

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trying to find new pedagogical techniques and approaches to increase students' concentration, interest, collaboration, interactivity and information retention in class.

In this paper, an innovative teaching and evaluation approach is proposed and applied in a lab environment specifically to an Electric Circuits Laboratory. It was recently noticed that students have a poor motivation towards circuits and electronics labs compared to years ago where students were very excited in such courses. They used to consider the lab as a new world where they get the opportunity to discover how real things work and practice using new equipment and components. Nowadays, students think that software is everything, that computer screen is the most powerful device, and their only role as students is to press on some keys and results will be shown.[1]

The approach developed in this paper makes use of technology in the learning process and assessment to satisfy students' demanded instant gratification and increase their concentration levels and involvement in the lab through an active interaction and discussion of results. However, the approach also takes into consideration the preservation of a real lab environment where students do not miss hands-on experience and where conventional topics and course outcomes in such a basic introductory lab course are satisfied. The major challenge in this teaching method lies in the balancing between the achievement of students' excitement and retention and the satisfaction of the fundamental objectives of engineering instructional laboratories.

The rest of this paper is organized as follows. The next section discusses related pedagogical concerns and motivation for the proposed approach. After that, a course overview describing the course and the laboratory setup is discussed in addition to the teaching approaches followed prior to lab redesign. Then, a detailed section explains the course logistics, content, instructional procedure, and assessment methods adopted after the lab redesign by introducing the implementation of the "Interactive Lab" new teaching and evaluation methodology. In the last two sections, the results of this implementation are studied and conclusions on the overall methodology are drawn.

Literature review

As students' mentality changes, teaching methods are also changing with the help of technology. New possibilities are opened in the laboratory such as simulation, data acquisition, remote control, and rapid data analysis.[2] New terms describing labs appeared in the literature such as virtual lab, remote lab, online lab, traditional lab, and interactive lab. In Hodge et al.,[3] virtual lab was implemented to mimic some problems that students face in real lab: bad connections, faulty components, and incorrect setting of equipment. Gustavsson,[4] presents a remote lab scheme to save time, space, and cost. The use of computer data acquisition and measurement keeps students more focused on results.[5] Asumadu et al.,[6] present a real-time remote wiring of electrical and electronic circuits over the Internet that allows flexibility, spontaneous delivery of material, and global access. The advantages of remote and virtual labs are in saving time, space, and cost.[7] On the other hand, Lowe et al.[8] presented a case study and literature survey about the effective cost of remote labs. The presented survey shows that 24% of authors did not mention the cost, 68% uses the cost as rationale for remote labs, and only 8% do a direct discussion of cost.

Software packages can be used to assist and enhance the lab teaching of electric circuits.[9] Odeh and Al-Khatib,[10] propose a prototype of a remote lab that provided an optimal solution to achieve a lab services in academics institutes that are not equipped with the appropriate infrastructure. Rico et al.'s [11] goal of building virtual labs is to reduce the cost of real lab and time limitation and decrease the cost of commercial software solution and replace them by open source software. Tawfik et al.,[12] describe the hardware and software infrastructure of remote labs that removes the administration and adoption costs of hands-on sessions. Orduna et al.,[13] state that the developers of remote laboratories must be aware of the limitations it is imposing to students in terms of security and administration problems. Richter et al.,[14] present a number of challenges that a remote lab faces such as network security and installing proprietary software at client.

Diwakar et al.,[15] present three different infrastructural types of virtual labs. The common between these types are: collaboration part such as chat forums, records, and news, and evaluation part such as result sheet, lab report, quiz, and test. Technology is used in the lab in order to help students in management, interaction, and assessment.[16] Some software tools are used to submit homework or quizzes in order to evaluate and check plagiarism in less time that the traditional way.[16,17] Short periodic quizzes lead to better understanding by studying small portions of material and not a large block.[18] Written communication skills are an essential outcome of the engineering technology program.[19] The author adds that the individual reporting of laboratory results are the typical measured outcome and it reflects the achievement of the student.

As observed from the literature, most references agree that virtualization has many advantages in terms of cost, time, space, and increasing students' interest and enjoyment. While motivating students is important, hands-on experience is much important as justified in the literature. Gustavsson[4] admits that nothing will replace synchronous learning through face to face interaction. The colloquy convened in San Diego, California in 2002 was formed to get a clear understanding of the objectives of instructional laboratories.[2,20,21] The colloquy converged on a list of 13 objectives; one of the objectives was to learn from failure. This shows that real experiments are necessary for students to develop skills to deal with physical processes and troubleshooting. Moreover, keeping the face to face communication and the interaction between students and between instructors and students enhances students' communication skills and motivates them to be involved in discussions as well as sharing results and ideas. Dongyan[22] states that increasing classroom interactions between instructor and students and among students has been found to be an effective way of helping student learning.

Course overview

Some courses in engineering are traditional by nature since the topics covered in such courses are basic engineering knowledge where there are limited opportunities to do major changes and updates in the material itself. An example is the introductory Electric Circuits Laboratory (EECE 310L) where students get introduced to basic electronic components, laboratory instruments, and different circuit configurations. Students majoring in Electrical and Computer Engineering (ECE) or Computer and Communications Engineering (CCE) at the American University of Beirut (AUB) are exposed in their first year to lab environment and hands-on experience in a course named "Introduction to Electrical and Computer Engineering" where they are introduced to different software packages used for engineering simulation and design such as MATLAB, PSPICE, and LABVIEW.[23,24] However, EECE 310L is the first laboratory course where students are required to apply the knowledge acquired from Electric Circuits and Electronics introductory courses by building functional circuit networks, learning how to use lab tools and equipment, take measurements, compute errors, analyze results, and troubleshoot hardware errors as well as applying lab safety rules. Hence, this laboratory course is believed to be a basic block for students in their engineering studies and laboratory experience, and the main challenge is to increase retention and excitement of the students while covering the conventional topics and outcomes. Accordingly, "The Interactive Lab" was introduced as a teaching and evaluation methodology that insures active student involvement in data collection, analysis, and criticism.

Course description

The EECE310L course is offered as a required laboratory course for second year students majoring either in CCE or in ECE at AUB. The laboratory is a 1-credit course with 3-h weekly sessions. The laboratory is usually offered for about 120–160 students divided into 6–7 sections with a maximum of 24 students per section. The course includes 11 experiments and one introductory session as shown in Table 1.

Lab setup

The laboratory room is equipped with 12 benches each equipped with a computer, a power supply, a digital multimeter, a function generator, a digital oscilloscope, a breadboard, and power and instrument cables (Figure 1). Each set of equipment and cables are organized in a labeled cabinet for each bench used by a group of two students throughout the semester. For every experiment, a different set of components are prepared on weekly basis in special kits holding the corresponding group numbers. Every team of students assigned to a bench is responsible for the proper utilization and organization of the equipment and the components kit. Regular testing of instruments, components, cables, and probes is performed before every experiment.

Table 1. Experiment names and objectives.

Experiment sessions	Experiment topics/objectives
Introductory session	Introduction to the course objectives, organization, material, calendar, etiquette, and grading system
Introduction to circuits and electronics lab	Introduction to basic safety rules and policies, lab tools and toolbox, electronic components
Equipment and instruments in the lab	Introduction to and use of lab instruments like breadboard, power supply, multimeter, function generator and oscilloscope
Voltage dividers and Thévenin's theorem	Design of voltage divider circuit, calculation and measurement of Thévenin voltage and resistance
RC and RLC circuits	Analysis of phase measurement, high pass/low pass and pass band filters
Diode rectifier circuits	Measurement and calculation of the characteristics of different rectifier circuits
LED and Zener diode	Characteristics, load and line regulation
Diode clipping and clamping circuits	Analysis of diode limiting and clamping circuits, characteristics, and applications
Op-amp circuits	Building different circuit configurations using op-amps, gain and bandwidth measurement
Transformer	Measurement of the transformer operating characteristics and modeling the transformer equivalent circuit
MOS transistor	Measuring characteristics of MOSFETs and experimenting MOSFET applications
Bipolar junction transistor	Measuring characteristics of BJTs and experimenting the applications of BJTs

BJT: bipolar junction transistor; MOS: metal–oxide–semiconductor; MOSFET: metal–oxide–semiconductor field-effect transistor; LED: light-emitting diode; OP-amp: operational amplifier; RC: resistor–capacitor.

Prior to lab redesign

While teaching this lab, it went through different development stages in terms of content, instructional procedure, and assessment methods. Initially, the lab was very traditional; each experiment was described by a lab manual where the lab instructor explains at the beginning of the 3-h lab session the experiment objectives, theoretical background, and the procedure to be followed. Students then follow the detailed experimental procedure in the manual while recording their measurements on their lab notebooks. Students are required to submit a complete detailed lab report for every experiment and before the beginning of the next lab session. The report includes objectives, lab tools and equipment used, measured values of components used, procedure, encountered problems, measurements, comparison to theoretical

Figure 1. A typical lab bench.

analysis of circuits, data analysis, and answers to some discussion questions in order to assess the students' comprehension of the experiment. The final course grade for a student is a combination of lab reports' grades, lab performance, in addition to a comprehensive written final exam conducted at the end of the semester.

As part of the continuous improvement process of the ECE laboratories, quantitative and qualitative course assessment is regularly performed. Students' remarks showed that writing full report for every experiment was an overload and time consuming for a 1-credit lab course. Besides, remarkable percentage of plagiarism was noticed in the reports since students lost interest in writing lab report for every experiment. In addition, instructors noticed that since students do the theoretical analysis in the report after the lab session, they cannot relate the measured values to the theoretical values and any errors in measurements are not noticed until after the lab session when it is impossible to repeat the experimental procedure.

To address these needs, some changes were introduced during the fall semester of the academic year 2007–2008. Lab reports were replaced by three fillable pdf forms as pre-lab, in-lab, and post-lab documents for every experiment to be submitted by the students. Pre-lab documents help them come prepared to the lab by doing some theoretical analysis of some problems in the labs. In-lab documents are used to record the lab measurements during the lab session. Post-lab documents include questions related to analysis of results, verification of results to theoretical analysis, and discussion questions.

After experimenting with the new approach adopted in the labs and compiling students' and instructors' evaluation of the course for three consecutive years, several problems were identified which motivated redesigning the lab in terms of teaching and evaluation methods to solve some drawbacks of the previous adopted methodology and enhance teaching techniques.

The "interactive lab" teaching and evaluation methodology

Motivation

In the light of the experience gained while teaching the lab, several problems motivated implementing the new teaching and evaluation methodology.

1. The lab includes large number of sections, and hence different instructors teach different sections of the same course. As per the policy of the Accreditation Board for Engineering and Technology (ABET), common exam and average for all sections are required, and thus the course coordinator strives to ensure covering same material, hints, and examples in multiple sessions.
2. It was noticed that students were not taking the pre-lab, in-lab, and post-lab documents seriously; sometimes they tend to copy values from each other or from reports of previous years without understanding and analysis, hence, failing to achieve the main purpose of the documents.
3. Due to the large number of enrolled students in this lab and the number of experiments offered, the load of grading of the pre-lab, in-lab, and post-lab for every student for every experiment is very big and time consuming.
4. Students follow the lab manual procedure step by step, recording their measurements but without correct analysis of the results measured (they even do not think if the measurements make sense or not while recording the measurements). They encounter problems when they do the analysis in the post-lab at which they cannot go back to the lab and repeat the measurements.
5. Theoretical background as well as lab procedure, objectives, and notes are usually explained in the first hour of the lab session. In the remaining two hours, students build the circuit, apply the lab procedure, and take measurements using the in-lab form. It was noticed that since all the explanation is done at the beginning of the lab session describing all the parts of the manual, students tend not to remember all the details. This is obvious sometimes when students ask for interpretations while applying specific sections in the experiment although the corresponding explanation has been done in the beginning of the lab session.

Implemented changes

Starting the fall term of the AY 2010–2011, "The Interactive Lab" teaching and Moodle-based evaluation methodology was implemented to address the above mentioned problems and the following modifications were implemented to better serve the learning experience:

1. Detailed power point presentations were developed for every experiment including theoretical background, analysis, and lab notes. The presentations were used to coordinate having the same material delivered across all sections (different instructors). The presentations are not provided to students on Moodle so that they are forced to get the information needed from lab manuals which is the main part in a lab environment. Presentations only help instructors explain the material and make students understand in an efficient way.
2. Pre- and post-labs were cancelled, only the in-labs were kept. All pre-lab calculations are added to the in-lab document where students are required to perform during the lab session, directly before they take the measurements for each section of the experiment. This will solve the problem of cheating; do the theoretical analysis directly before they take the measurements which help them make good sense of the results they record. All post-lab questions such as data analysis and discussions are done during class time. Consequently, more time is needed to complete the lab which is not feasible. One solution is to eliminate some of the experiment exercises, and the other solution is to automate the measurements. Both solutions are not recommended since the former method lowers the experiment value, whereas the latter eliminates hands-on experience and exposure to real experimental setups which is one of the main course objectives. To solve this problem, "the Interactive Lab" teaching methodology was invented as a compromise (refer to the next section).
3. Since the pre- and post-labs are cancelled, another tool for evaluation was established. To assess the students' comprehension, at the beginning of every lab session, each student must do a short Moodle-based quiz including post-lab and pre-lab questions (refer to the below section on "Drop Quizzes").

Teaching methodology depicted in a sample experiment

Each experiment is divided into multiple parts (2 to 5 parts) depending on the different circuit configurations or exercises in the lab manual. To demonstrate the application of the "interactive lab" teaching methodology, a real example of an experiment, namely "RC and RLC circuits" is selected to show a typical lab session flow. The session starts with a 10 min Moodle-based drop quiz including questions assessing comprehension of outcomes of the previous experiment in addition to questions needed for the current experiment such as theoretical computation of the transfer functions of resistor–capacitor (RC) networks and difference between lag and lead networks. This assures that students come ready to the lab with the basic needed theoretical background. After the quiz, the explanation of the experiment objectives and exercises is not done anymore as one chunk at the beginning of the session as it was traditionally; instead each part including some theoretical and experimental procedures is explained using power point presentation with illustrations. Then, the students are guided by the instructor to start the corresponding lab exercises, which are part of an in-lab report (detailed in the below section on "In-lab reports") prepared as online Moodle activity including theoretical analysis and calculations in addition to recording experimental measurements. In-lab exercises are timed activities where sample of theoretical calculations and experimental results for every setup are selected randomly by Moodle for each group of students. Accordingly, each group of students builds RC lead and lag networks with different values of passive components and parameters of input waveforms. Then, they use the in-lab Moodle exercise to input the recorded measurements, upload relevant snapshots of input/output graphs while instantaneously verifying with the theoretical values they computed and the theoretical background explained. When the time allocated for the exercise is over, the complete set of measurements is combined and presented by the instructor to the class on the spot. The instructor opens a discussion on the part done in different forms such as quantitative and qualitative analysis of results, source of errors, generated plots and graphs, relating data or procedures to real application, and comparison of different scenarios. For example, students are encouraged to analyze RC networks from different perspectives such as low/high pass filters, integrator/differentiator, lead/lag, effects of the filter on square waves from frequency domain perspective (harmonics) and time domain perspective (charging/discharging and time constants), All students actively engage in these discussions as they start comparing, inferring, and analyzing the measurements they took to that discussed analysis. At this level, and directly after the individual practice, the whole class will be acting as one group sharing their results and experiences, analyzing the results, and linking it to theory from different perspectives. The instructor as well tries to present recap questions as showing them input/output waveforms of a black box that students need to identify RC network. In addition, based on the discussed concepts, students are encouraged to think of real life practical examples that use such networks and when applicable the instructor can demonstrate and simulate a real application for the class. The integration of this lively discussion directly after the exercise not only enriches the environment with collaboration but also helps students get direct feedback after their experimentation in the time where they are most attentive to retain knowledge and learn from their mistakes. After these discussions, the instructor proceeds with the second part of the lab after which students start doing the next corresponding timed exercise followed by similar active discussions. The same procedure is repeated for every part of the lab.

Moodle-based evaluation/assessment methodology

The lab has multiple assessment tools including Moodle-based drop quizzes and in-lab reports, lab reports, and final exam, each with specific purpose and corresponding percentage of the final course grade as shown in Figure 2.

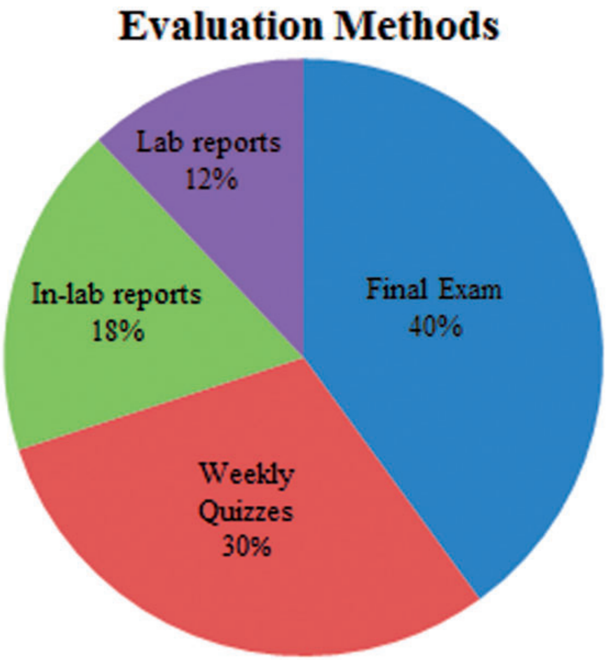

Figure 2. Evaluation methods.

Drop quizzes. Since the pre- and post-labs are cancelled, another tool for evaluation is established. To assess the students' comprehension, 10 min Moodle-based drop quizzes are added to every experiment covering post-lab and pre-lab questions. For every experiment, a bank of questions (around 40–70 questions) covering all concepts in the experiment are prepared. The quiz is timed, password-protected, and conducted individually at the beginning of every lab session including around 10 randomly selected questions. However, to insure that students get variety of questions covering all learning outcomes in the experiment, subcategories per topics are created and at least one random question per category is selected by Moodle (Figure 3).

A bank of 550 questions was prepared for the 11 experiments of the course. Different types of questions are used depending on the nature of the question most of which are corrected automatically by Moodle. The types include calculation-based questions, matching, drag and drop (Figure 4), essay, image target types where the user selects a part of the picture that corresponds to the correct answer as shown in Figure 5, multiple choice, True/False, and numerical questions. Besides, user-customized questions including combinations of the above types within the same question are also designed and used.

The drop quizzes conducted act as formative evaluation tools which enable instructors to identify students' weaknesses from easy access to quizzes results

Figure 3. Moodle snapshot showing a sample bank question of a quiz with corresponding categories as seen by the instructor.

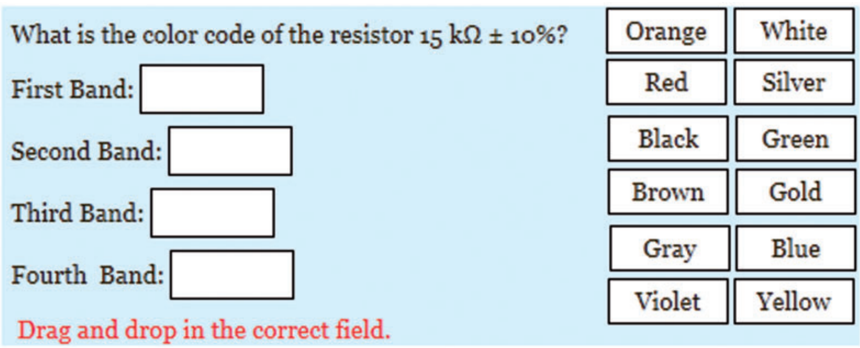

Figure 4. A sample drag and drop question.

and statistics, rate difficulty of concepts from students' perspectives, and take remedial actions accordingly to fill any learning gap. Besides, the drop quizzes keep students up-to-date with the course material.

Lab reports. The introduced quizzes solved the complaint of students about the overload in writing full lab report for every experiment since the quizzes were enough to test the students' knowledge on all covered experiment topics. However, writing a complete lab report is very important in a lab environment where students document lab procedures, compute theoretical values, record measurements, compute errors, analyze results, and answer discussion questions. Hence,

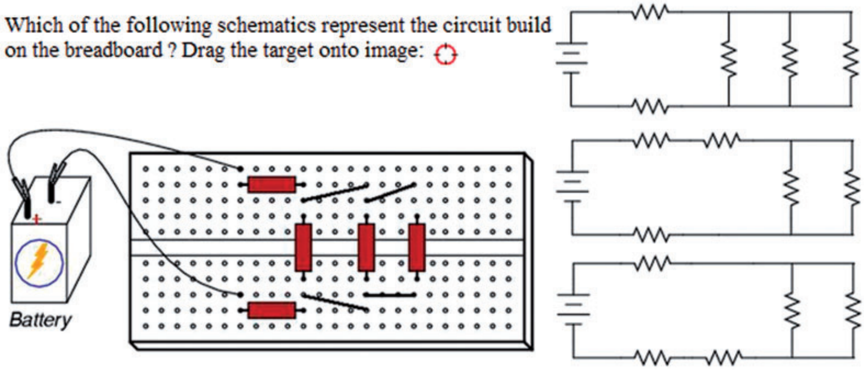

Figure 5. A sample of image target question.

two important experiments (one at mid semester and another towards the end of semester) were selected where students are required to do a full comprehensive lab report. Adding this component is important to teach students how to write and document a full lab report. Students submit their reports as a soft copy on Moodle. Embedded "Turn-it-in" software tool in the Moodle system generates cheating and plagiarism reports which help instructors grading the reports and evaluate their originality.

In-lab reports. All in-lab reports are prepared as online Moodle timed exercises where the users can log in and document their measurements, calculations, snapshots, discussion, and analysis. Allocated time depends on the complexity of the problem and allows for better synchronization among students, more structured lab time, and collective discussions and analysis after each timed exercise. To save lab time for discussions and analysis, different students are entitled to do different measurements of the same circuit selected randomly by the Moodle activity. The prepared numeric in-labs questions are populated with correct answers with a specific margin of error depending on the measurement type, circuit nature, as well as equipment and component tolerance. This allows system automatic grading of the in-lab for all students. In-lab reports can be accessed any time after the experiment is done. This will help students to review their measurements, get some feedback, and check their errors and mistakes.

Final exam. A comprehensive final exam covering all topics introduced throughout the laboratory sessions is prepared to evaluate students' comprehension. The exam is a 90 min Moodle-based exam including around 80 questions, uniformly distributed among the 11 experiments and covering lab procedures, circuit connection figures, design and calculations, extraction of specifications from datasheets, graph analysis, and circuit identification in addition to other topics. The flexibility in

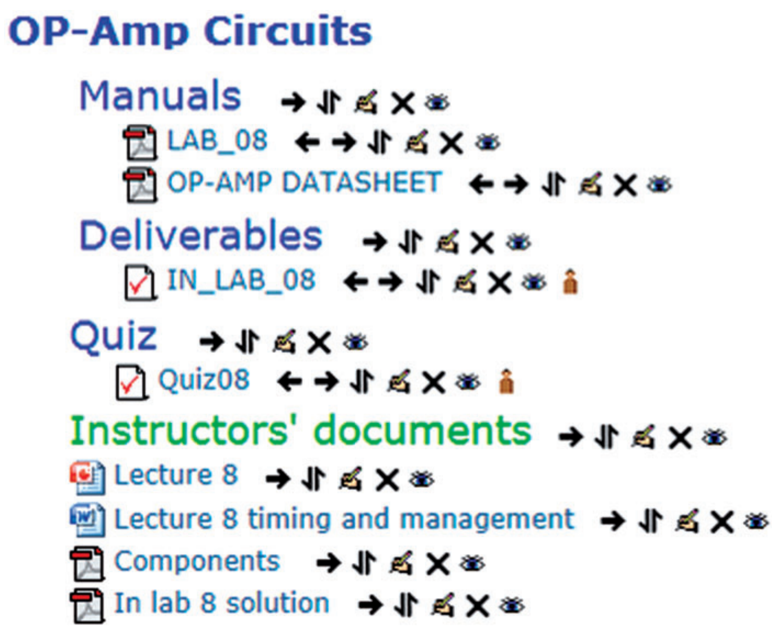

Figure 6. Moodle snapshot showing typical experiment module.

Moodle types of questions as well as figures and files integration within questions enrich the final exam and allow the instructor(s) to target any theoretical or practical type of questions.

Course logistics. In order to organize the course, a structured Moodle page is developed including modules for the 11 experiments. Each module contains two sections (Figure 6).

Student material: It includes lab resources (experiment manual and datasheeets), deliverables (in-lab and/or lab reports), and drop quiz activities. The same Moodle page is used for multiple sections of the same course throughout the week; hence, Moodle groups and groupings are used to allow access of students of a specific section to the corresponding activity at a specific time.

Instructor material: This section is only visible for instructors teaching the course to facilitate unifying and sharing lab material among different instructors teaching different sections. It includes power point presentation, timing plan that helps the instructor check the detailed timing of every activity in the lab, list of components to be prepared by lab personnel prior to each lab section, and solution manual for all the in-lab activities.

To provide a better quality in the lab, two graduate assistants (GAs) are assigned to help the instructor teaching a typical laboratory section with 24 students. This results in a very good instructor-to-student ratio in a lab environment. GAs monitor students while building circuits, recording measurements, help them in troubleshooting problems, identify any attempt of fake recordings of measurements, and keep track of students who are late to the schedule and try to identify their weak points. To prepare the GAs learn troubleshooting techniques and be ready to effectively help students, a weekly preparatory session is scheduled for them to implement the experiment one week before the students.

Results

The new teaching and evaluation methods have been applied for three consecutive fall semesters from the AY 2010-11 to AY 2012-13. No problems were encountered in any of the experiments and the new methodology achieved different objectives:

1. Enormous improvement was noticed in class in terms of comprehension of material and relating calculated values to measured values and to experimental procedures.
2. The lab is more exciting and students are always alert, doing theoretical analysis, relating it to the measurements on the spot, and then observing and analyzing the results directly during the lab session.
3. Increase in students' class participation and involvement was noticed during the lab session. At the end of the course, students are requested to fill in an anonymous survey that rates the achievement of the course learning outcomes and evaluates their comprehension of course topics. Figure 7 shows the course outcomes rating on a scale from 0 (minimum) to 5 (maximum) assessed by students for three consecutive years. This evaluation clearly shows that no outcome scored below 3.5 out of 5 and most outcomes scored on average above 4. This proves that the implemented methodology was effective and satisfied course set outcomes and objectives.
4. For the same final exam, 87 random Moodle-based questions are given. The class average changed from 49.56 during the fall term of the AY 2009-10 before introducing the new teaching methodology to 56.7 during the fall term of the AY 2010-11, 64.7 during the fall term of the AY 2011-12, and 61.25 during the fall term of the AY 2012-13. This indicates that the new teaching and evaluation method adopted in the lab starting the fall term of the AY 2010-11 and improved in the following terms enhanced the students' comprehension of the material.
5. Grading of quizzes and in-labs is mostly automated with feedback.
6. A bank of 550 questions was prepared for the 11 experiments of the course in addition to around 80 questions for the final exam. This tool allowed for interactive quizzes with a variety of questions.
7. Students learn how to write full lab reports and document results in a professional way.

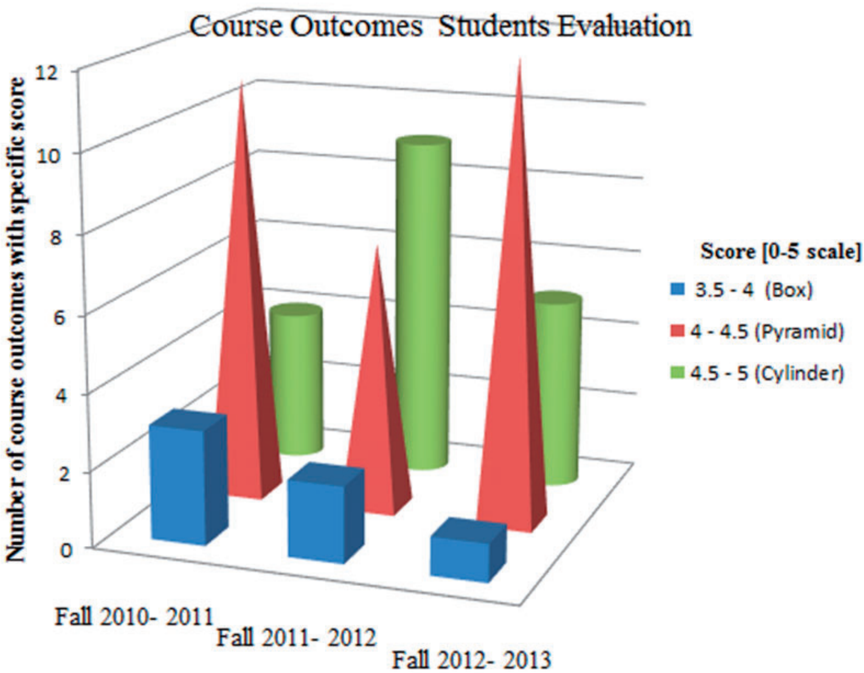

Figure 7. Course outcomes rating by students.

8. Quizzes conducted at the beginning of every lab session including pre-lab questions and post-lab questions of the previous experiment urge students to always be up-to-date with the material to be explained in the lab and the analysis of previous experiments.

Conclusion

A simple but effective and interactive approach for teaching and assessment in electrical engineering lab environment has been presented in this paper. The aim of the redesign is to create a dynamic interactive "learning environment" and achieve learners' enjoyable experience while satisfying the fundamental objectives of engineering instructional labs with real hands-on experience. The term "learning environment" covers not only place and space but the relationships, technology, e-learning tools, discussions, and creativity in delivery techniques which create a supportive environment accommodating the unique needs for every student to learn best and inspiring students to attain knowledge and skills.

The described scheme has offered a variety of educational advantages both from the learner and instructor sides. Advantages from the learner side are many, such as enhancing students' critical thinking, analysis, and concentration, involvement in hands-on technical educational applications with direct relation of theory to practice, motivating students by integrating technology to hardware labs, and fostering a two-way communication between students and instructors which improves students' participation. From the instructor side, the methodology allows instructors to know more about their students from easy access to feedback and statistics from quizzes and in-lab exercises, identify students' weaknesses, rate difficulty of concepts from students' perspectives, share and access resources easily, save time and resources in grading, achieve genuine evaluation, detect any attempt of plagiarism. The drawback of applying the proposed methodology is that it requires additional time to finish the experiment. This requires more organization, supervision, as well as proper time management skills to synchronize the class activities and discussions within the allocated time from the instructor.

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