Interactive Web-Based Virtual Electrical Lab

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Abstract: The use of World Web Wide for distance education has received increasing attention over the past decades. The real challenge of adapting this technology for engineering education and training is to facilitate the laboratory experiments via Internet. This paper introduces electrical engineering educators to the use and adoption of Java-applets in order to create online electrical engineering laboratory for students. These techniques have been used to successfully form a laboratory course which augments the more conventional lectures in concepts of electric circuits for engineers at Faculty of Engineering. The course objective is to provide a structured review of fundamentals of science and technology for the prospective students, wishing to study the Bachelor program in Electrical engineering. Improvements of the package will be undergoing to incorporate Web-based technologies (Internet home page, HTML, Java programming etc…). This Web-based education and training are intended to be evaluated via a class-tested within an undergraduate engineering course to report their experience with its use. The use of these labs should be self-explanatory and their reliable operation should have been thoroughly tested.
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Key words: Web-based education, Electrical engineering, Virtual laboratory, Software engineering, Java, HTML

1 Introduction

In measurement teaching, the great increase of students on the one hand, and the reduced number of technicians on the other, greatly requires the possibility of accessing simulated measurement instrumentation for virtual labs. In electrical measurement courses, particularly, these problems become more severe as a consequence of the more sophisticated and expensive apparatus now available which makes it difficult to keep the technical staff up-to-date, and the necessity for repeating the same experience many times in order to make all students able to operate the measuring instrumentation. These unique features make computers and education a field of study on its own [1]. The history of software engineering education was traced by Mead [2] which focused on some of the key players. Web-based education, Java and Shockwave applets, Web-based experiments, educational software, Web-based e-learning and evaluation will be reviewed in the following paragraphs.

Sethi introduced physics educators to the use and adoption of Java- and Shockwave-based applets in order to create virtual, online physics laboratories for their students [3]. These techniques have been used to successfully form a Laboratory course which augments the more conventional lectures in concepts of physics course. The laboratories have been instructor-led but are sufficiently self-contained to become part of a virtual classroom offering. An educational software tool–editor that will as primary goal to create Java applications and applets was created by Fetaji [4] and at the same time to provide mechanism for the user to compile his source code without leaving the editor. His goal is also set to provide a complete e-learning environment for the course object oriented programming in Java language. Barrettoa*et al.* [5] proposed a methodology based on Web technology and an association between the Java programming language and the authoring tool Flash. They described the methodology that enables the association between Java and Flash components.

Pniower*et al.* [6] reported on two Web-based experiments operating since spring 1998: a Michelson interferometer and a laser diode characterization experiments. Descriptions include benchtop optical and electronic experimental hardware, Lab VIEW software tools for hardware interfacing, HTML Web interfacing tools, and the video link setup. The impact of Intercollege’s Web-Based Teaching and Learning Environment which allows lecturers to develop Web-based educational material using Web-based educational software - WebCT (off the-shelf software) and Inter Learning (in-house developed software) was presented by Pouyioutas*et al.* [7]. Aichouni and Al Nais [8], suggested that computer based education approach can be used as a learning and a training tools to demonstrate statistical quality control concepts and their industrial applications for engineering students.

The potential of social learning in the domain of e-learning, through Communities of Practice of e-learning was proposed by Chikh and Berkani [9]. Communities of Practice represent an environment in which individuals, experts and novices, learn together to develop and improve their professional practices and skills. Martínez-Torres *et al.* [10] proposed to identify a set of external variables that should be taken into account prior to the design of an eLearning system for practical and laboratory training, using a scientific method called concept mapping. Dehnavi and Fard [11] presented a new e-learning model based on web applications with attendance control ability. The presented multimodal biometric based model is used to identification, authentication and tracking the users. Al-Zahrani [12] introduced Metrology educators to the use and adoption of Java-applets in order to create virtual, online Metrology laboratories for students. This Web-based education and training has been successfully class-tested within an undergraduate preliminary year engineering course and students reported a positive experience with its use.

In addition, Granlund*et al.* [13] discussed some basic properties of learning using web-based simulation with the focus on different types of learning goals (instructional goals) and on proper instructional strategies (pedagogical strategies) for web-based simulation. The replacement of traditional laboratories with virtual or remote laboratories is introduced by Bencomo [14] showing their advantages and disadvantages. The objective, strategy, and implementation details of an undergraduate course, Internet-based Instrumentation and Control, are presented by Zhuang and Morgera [15]. The combination is offered to senior-level undergraduate engineering students interested in sensing, instrumentation, control, and web programming that want to learn more about the integration of these technologies for solving real-world engineering problems. Giurgiutiu*et al.* [16] examined the hardware and software used for mechatronics/microcontroller education and discussed the interfacing between the microcontroller and the various electro-mechanical sensing and actuation components used in a mechatronics project. The use of functional modules for teaching interfacing skills to mechanical engineering students is described.

Abdul wahed and Nagy [17] introduced a new model of laboratory education, namely the TriLab. The model is based on recent advances in ICT and implements a three access modes to the laboratory experience (virtual, hands-on and remote) in one software package. A learning model was developed by Macdonald and Gabriel [18] to design a web-based master of business administration for advanced technology professionals as a framework. The main objective in developing this model was to incorporate pedagogical and technological considerations to maintain the benefits of the synchronous classroom experience while gaining the benefits of asynchronous learning and interactivity. Sun *et al.* [19] purposed to explore the learning effect related to different learning styles in a Web-based virtual science laboratory for elementary school students. The online virtual lab allows teachers to integrate information and communication technology (ICT) into science lessons. Their results of the experimental teaching and the survey show the feasibility and effectiveness of the Web-based learning environment being studied. It encourages further development of the Web-based virtual lab. Tiernan [20] aimed to enhance the learning experience of undergraduate engineering students and stimulate their research interests by incorporating hands-on, hardware linked programming. It was established that student experiences in designing and developing LabVIEW programs with associated hardware has hugely stimulated their interest and enthusiasm in the subject of industrial automation.

A multipurpose computer interface unit is designed by Dursun*et al.* [21], for existing regular experiment sets of electrical and electronics laboratories which includes embedded two channels digital storage oscilloscope, multimeters, digital inputs and outputs, miscellaneous function generators, a variable and some fixed power supplies in order to experiment in a more comprehensive manner without any need of external measurement devices or signal supplies. Eugéne [22] presented the whys, what's and how's of revolution of completely new engineering curriculum. An example of a multidisciplinary project at graduate level will be outlined. He concluded with the presentation of a laboratory exercise in basic electrical measurements illustrating the new educational method by its problem-based learning approach.This paper aims to adopt Java-applets in order to create virtual, online electrical laboratories for students and to build a Web-based education and training for electrical measurement.

2 Web-based education and training

Web-based educational experiments allow users to conduct laboratory explorations using electric apparatuses over the World Wide Web (WWW). Web-based experimentation is evolving rapidly and offers students convenient and repeated access to limited laboratory resources. The immediacy and accessibility of Web-based experiments can also assist new student outreach and faculty teaching effectiveness [6]. WWW is a popular and useful instructional tool for a many reasons. It is easily accessible, supports flexible storage and display options and provides a simple yet powerful publishing format to incorporate multiple media elements. The WWW provides an excellent platform for developing, organizing, spreading variety of resources, including class notes and outlines, long textual resources that resemble traditional textbooks, interactive tutorials, student questions and comments, and even simulations of individual class sessions. It also allows instructors to prioritize resources and students to reorganize the resources in the way that fits them best. Many universities and colleges have utilized the WWW for developing distance-learning education courses [7, 23, 24]. Figure 1 shows the Web-based education and its different areas of interest.

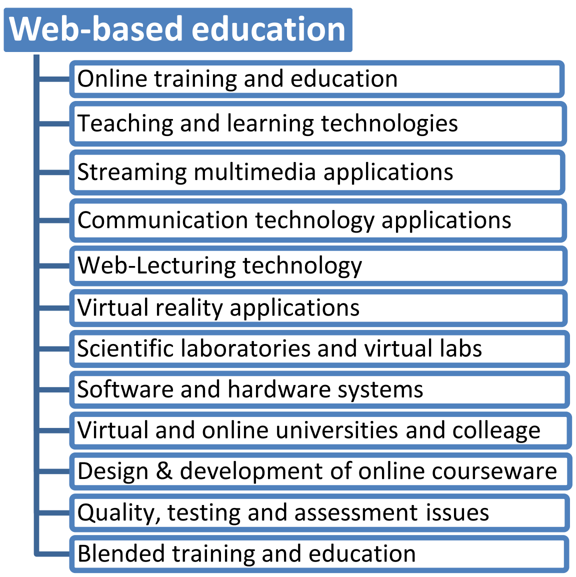


Fig. 1. Classification of Web-based education.

Velázquez-Iturbide and García-Peñalvo classified nine articles into three groups, namely e-learning and Web-based educational software, user-centered educational software, and visualization tools [1], Fig 2. The first group deals with e-learning and Web-based educational software. e-Learning and its different blended-learning variants are nowadays ubiquitous, at least at the university level. The second group is concerned with user issues. There are many different issues in and forms of user-centered educational software which are: user motivation, automatic assessment and correctors, interactive tutors, accessibility, and support to learning styles. The third group focuses on a particular class of software technology, namely visualization. The aim of visualization can be stated as making visible what is hidden, by using graphical representations. These articles represent two kinds of visualization, namely information visualization and software visualization. Although the latter can be considered a particular case of the former, their research interests and communities are currently different. On the other hand, collaborative networked learning is a form of collaborative learning for the self-directed adult learner. The collaborative nature of generative learning means that students need to work together toward common goals, just as employees must do in the workplace [25]. Many collaborative tools are available ranging from simple email through powerful (and expensive) internet-based synchronous meeting tools that include video and audio, plus features such as whiteboards, chat, and application sharing, Fig. 3.

The history of software engineering education was traced and what has been accomplished in degree programs and curricula, conferences and working groups, professionalism, certification, and industry–university collaboration was highlighted in Table 1 [2, 26]. Multimedia represent an integrated system, enabling contact with users, taking their attention and offering the possibility for informing them [9]. They utilize technical means for simultaneous acting through visual tools, enabling easy and intuitive control through user friendly graphical interface. Key elements of the multimedia include static and animated graphics, sound and text, video sequences.

Software engineering faculty face the challenge of educating future researchers and industry practitioners regarding the generation of empirical software engineering studies and their use in evidence-based software engineering [27]. Professional software engineers are constantly faced with having to cope with ever-changing technologies, along with the need to keep their knowledge up to date. These changes, the short innovation cycles, and the fact that software engineering is a knowledge-intensive activity lead to many learning situations where new knowledge is required to solve the challenges and problems at hand. Furthermore, in practice learning, is less a reaction to 'being learned' but more the reaction to a variety of working situations and related problem-solving activities, which requires experience-based learning.

Today, most software engineers are from the Baby Boomers generation (born 1946–1964) and from Generation X (born 1965–1980). A Net Generation (born 1981–1994) differs from the previous generations in terms of commitment, interaction, and learning style and hence puts new challenges upon education and the usage of technology [28, 29].It is almost universally accepted that the best way to convey these ideas is through a laboratory or a demonstration, where students can see Electrical Measurement in action and truly appreciate the natural world around them [3, 30].Figure 4 shows the use of computer and Web-based engineering education and training.

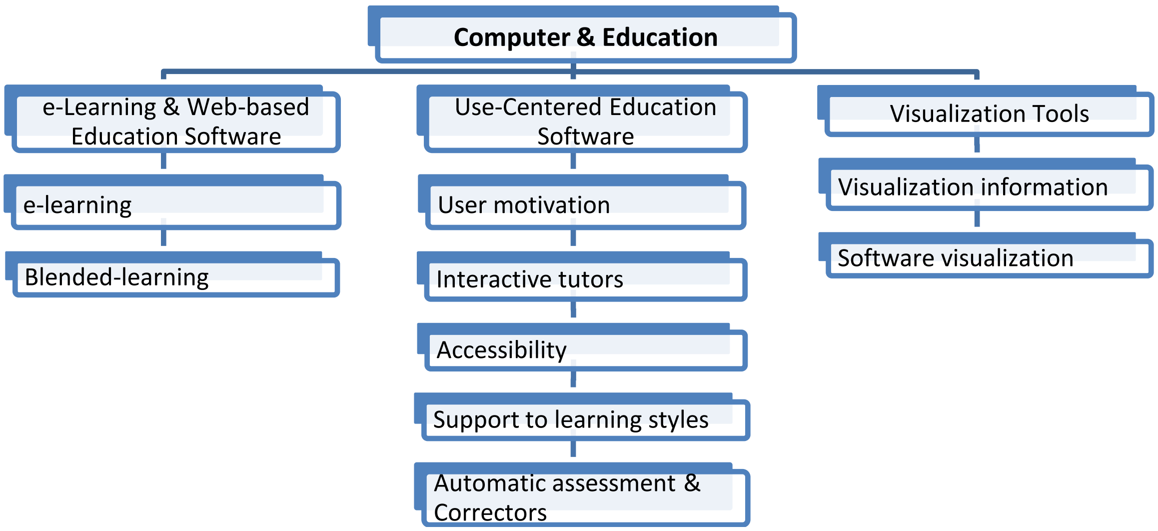


Fig. 2. Computer and Education.

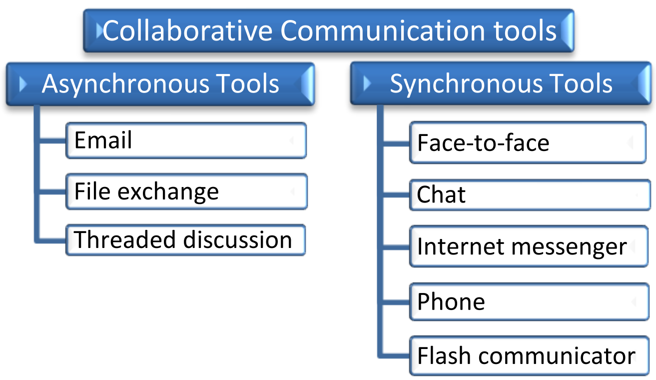


Fig. 3. Collaborative Communication tools.

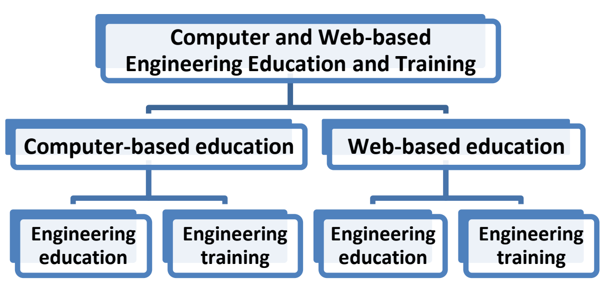


Fig. 4. Computer and Web-based engineering education

3 Hardware and Software Requirements

The two essential requirements of Web-based education are hardware and main programming medium. The virtual labs can hosted on any computer connected to the internet; as most universities already have some internet-ready computers, such labs require no additional investment in hardware. The only requirements are a Java enabled browser. The applets that form the core of the computer-based laboratory experience use standard Java. These applets are accessible from any computer that has a browser and an internet connection. For those labs that lack an internet connection, it is possible to package the applets themselves, along with the associated lab, onto a CD and distribute these to the students. These mini applications provide total interactivity, combined with full multimedia and graphics that allow students to easily visualize difficult concepts. Incorporation of Java and Shockwave applets allow each student to have an interactive, hands-on experience in a lab, a personalized learning experience, to eliminate equipment issues, to minimize experimental errors, and to help making online learning resources not only much easier but also more fun for students. The main costs associated with the development of labs are programmer-time in setting up the hardware and software and instructor time in customizing the labs for each specific course.

Table 1: History of software engineering education: Past, present and future.

Time	Period	History of software engineering education
Past	**1968**	• "Software engineering" term first appeared at the NATO Software Engineering Conference.
	1970s	• Software engineering education appeared at IBM.
	In the late **1970s**	• Master's degree programs in software engineering started to emerge. • A series of courses entitled Structured Programming Workshop (SPW), Structured Design Workshop (SDW), and eventually Advanced Design Workshop (ADW) were offered.
	1984	• Fairley wrote one of the first books on software engineering concepts and went on to become a leader in software engineering education.
	1986/1987	• The first Conference on Software Engineering Education (CSEE) took place.
	1991	• The first class of Multimedia Study Environment (MSE) graduate.
	In the early **1990s**	• The CSEE became the catalyst for a newsletter, the Forum for the Advancement of Software Engineering Education (FASE).
	1993	• A joint committee was formed by Association for Computing Machinery (ACM) and Institute of Electrical and Electronics Engineers (IEEE) Computer Society to promote software engineering as a profession.
	1995	• A Working Group for Software Engineering Education and Training (WGSEET) was formed.
	1995	• Undergraduate degree programs in software engineering education started to emerge, and in the US a merger of the accrediting bodies, Computer Sciences Accreditation Board (CSAB) and Accreditation Board for Engineering Technologies (ABET), made it possible for them to be accredited.
	1995	• Many universities established industry advisory boards so that their degree programs could remain relevant to their industry partners. These collaborations took many forms—joint research, regular work sessions or meetings, and the like.
	1997	• The CSEE conference series broadened its focus to include training and known as the Conference on Software Engineering Education and Training (CSEET).
	1997	• Distance learning became a popular concept as well as the establishment of branch locations among universities.
	1999	• Establishment of the Software Engineering Code of Ethics and Professional Practice (IEEE-CS) and an associated curriculum.
Present	**2008-2011**	• The CSEET has evolved to include the Academy for Software Engineering Educators and Trainers (ASEET).
		• New degree (PhD programs) in software engineering exist at a number of universities.
		• New degree programs, such as the MS in Information Technology – Software Engineering Management (MSIT-SEM) continue to be defined.
		• The number of conferences and conference tracks also has grown. Among of them are: Special Interest Group on Computer Science Education (SIGCSE, 2008), Innovation and Technology in Computer Science Education (ITiCSE), International Conference on Software Engineering (ICSE).
		• Today collaboration and information exchange and sharing are critical in driving both individual and organizational success. Communities of Practice (CoPs) represent an environment in which individuals, experts and novices, learn together to develop and improve their professional practices and skills.
Future		• Maybe a Master's curriculum will initiate which includes Integrated Software and Systems Engineering Curriculum.
		• Maybe three types of degree programs will initiate: computer science for researchers, software engineering for engineers developing mission–critical systems, and software professional degrees for practitioners developing non-critical systems.
		• From the view point of globalization, a creative evolution of delivery mechanisms and a multicultural teams and where you are located will be expected.
		• Conferences, working groups, and committees will help to develop a new generation of software engineering educators.
		• e-publishing, video conferences, Webcasts and Web-based collaboration mechanisms are becoming more common.
		• Professionalism continues to be a hot topic, and it's still unpredictable whether licensing or certification will become a major trend in the future. Litigation over software quality, safety, and security will become more common.
		• New specializations will emerge.
		• Need to exchange new ideas and application experiences face to face, to establish business or research relations and to find global partners for future collaboration.
		• Moreover emerge of education & management technologies should to bring the use of computing devices to a new level.

4 Creating Web-Based Experiments

Web-based simulation can be a powerful tool in education and training. The nature of simulation-based learning combined with the availability of the web make learning supported by web-based simulation a powerful strategy. In simulation-based learning, learners can experience environments that would be too costly, time-consuming, complex or dangerous to provide through other means [8]. Many engineering universities are currently under pressure to develop Web-based online education and training via virtual laboratories and classrooms [31]. In developing Web-based laboratories, four experiments were selected which have a clear learning value, that could easily be simulated, and whose results could be attractively displayed over the WWW. These electrical experiments are: Voltage source (Power supply), voltage metering, current metering, resistance metering, Ohm's law I, Ohm's law II, series connection of resistors, parallel connection of resistors, group connection of resistors, electrical power and voltage divider. The main objective is to develop a home page for the electrical measurement course to be hosted on internet for engineering students. The user interface of this application is simply an HTML page that can be used to invoke a Java applets and multimedia. Several HTML pages which include explanation of electrical engineering concepts have been designed. The selected dimensional measurements have been included as PDF files and multimedia**.** More developments are still under construction mainly in the form of Java applets to be added to virtual electrical lab. Figure 5 shows the main page of the lab built using HTML programming.

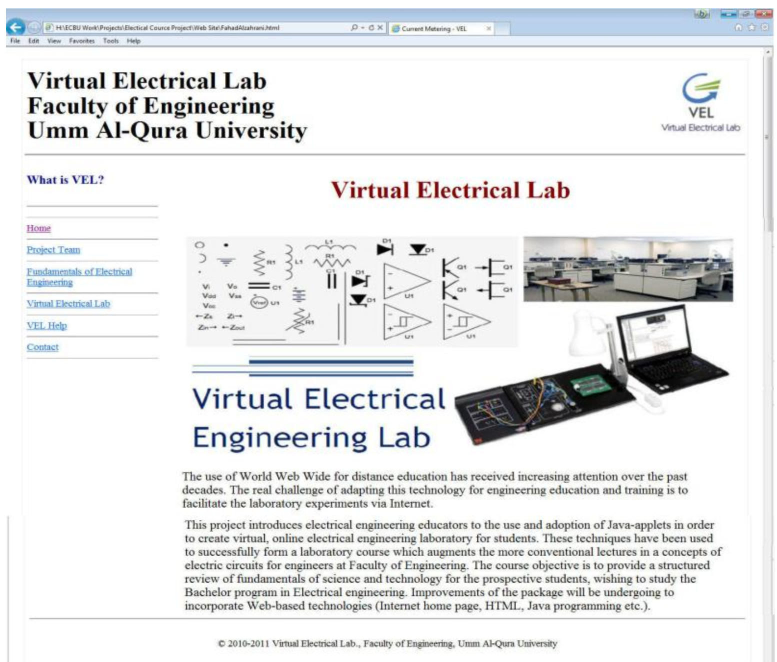


Fig. 5. Main Webpage of Virtual Electrical Lab

5 Sample lab

The Web's impact on traditional educational theories and practices are increasingly apparent. New innovations such as virtual colleges, laboratories, and universities are developed. These include innovative hardware and software technology, online testing and assessment, training and teaching applications, and courseware design and development.

Electrical lab has been designed to lead the student and thereby develop his sense of enquiry into how things work. Electrical measurements are not just a process of measurement that is applied to an end product. It should also be one of the considerations taken into account at the design stage. The user can built any electric circuit. Figure 6 shows an example of building electric resistance.

The main goal is to show how it can be easy to understand electrical measurement and to stimulate tools to do more exploration at home on their own computers. A set of computer-based metrology labs make use of Java applets that are available online or offline browsing. The provided labs were developed for the educational use at Umm Al-Qura University. Students are introduced to basic measurement techniques such electrical measurements. The following shows lab user guide to use and to measure current and voltage of objects using, for example, a voltage metering, Fig. 7.

The java applet shows you how to calculate and read the voltage passing through a resistance. The reading appears into the voltmeter *Text Field* in Volt. To observe how the values are red, click in the *"checkbox"* by *"show reading"* and drag the lower scale left or right to observe how the measurement is determined. Use the *"Reset"* button to restore the applet to the initial state. In order to test your ability to read a measurement, do not press "show reading" and then change any resistance (R_1 and/or R_2) values of the resistance into the resistance *Text Field*. The applet will wait for you to enter a value into the Voltmeter *Text Field*. If your answer is right, it will appear massage *"Well done"*.If your answer is not right, it will appear massage *"Sorry, wrong answer!".* After you type in an answer, press *Enter*. Figure 8shows a typical selected examples for voltage metering, current metering, Ohm's law I & II, series, parallel and group connection of resistors.

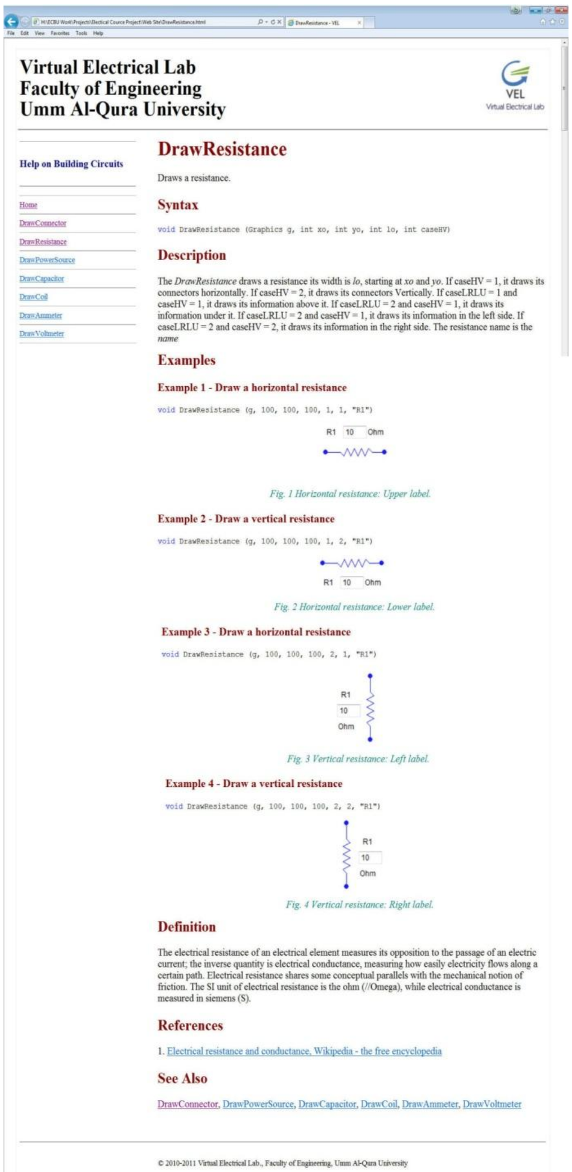
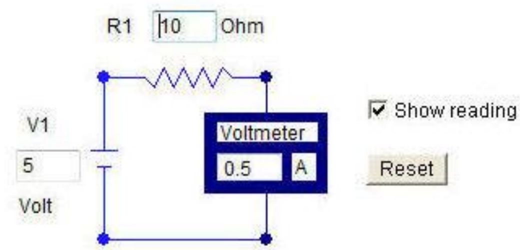
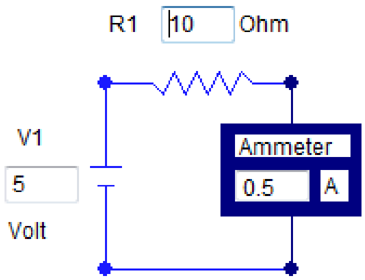


Fig. 6. Building electric circuit help web page of Virtual Electrical Lab.

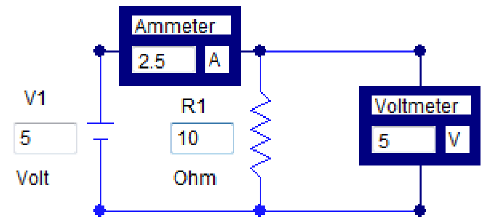
Fig. 7. Voltage metering web page of Virtual Electrical Lab.



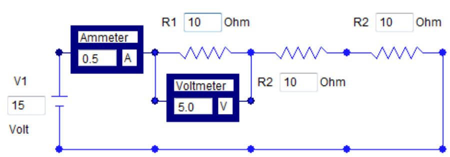
(a) Voltage metering.



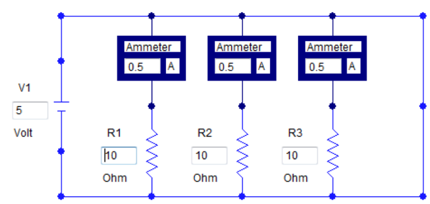
(b) Current metering.



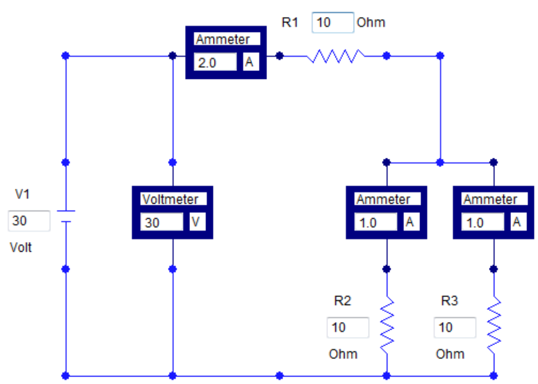
(c) Ohm's law.



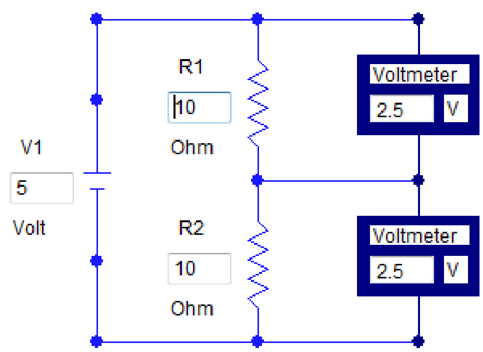
(d) Series connection of resistors.



(e) Parallel connection of resistors.



(f) Group connection of resistors.



(g) Voltage divider.

Fig. 8. Java Applets: A typical selected examples for voltage metering, current metering, Ohm's law I & II, series, parallel, group connection of resistors and Voltage divider.

6 Evaluation

Educational software firm was based on the vision that every student should be able to achieve personal success in reading and writing. The goal of instructional designers is to make learning easier, quicker, and more enjoyable. One of the main purposes of instructional designer's job is to help everyone to learn and be successful. So, it should be expected after reading educational materials, users will be able to make better measurements of the size or shape of an object concerning the introduced subject "Electrical Measurement". The content is written at a simple way based on standard textbooks so that it can easily and quickly introduce key ideas to a wide audience. A preliminary survey analysis based on student's feedback was reported. This survey analysis helps in designing and modifying the strategy of off-line material to be published on-line.

7 Summary and Conclusions

It is important to note that the aim of Virtual electrical labs is to provide enhanced educational and training support to the students in addition to traditional teaching and learning. It should be noted that this tool is very effective to increase the efficiency of learning and training. In a traditional university environment, virtual labs can also improve the engineering curricula in a cost effective way by establishing a timely connection between theory and practice. Web-based education and training offer many advantages to engineering and science education. Eleven Java applets: Voltage source (Power supply), voltage metering, current metering, resistance metering, Ohm's law I, Ohm's law II, series connection of resistors, parallel connection of resistors, group connection of resistors, electrical power, voltage divider, have been off-line run successfully with minimal problems. These experiences encourage us to develop other web-based education and training, improving the site with more Java applets. This Web-based education and training has been successfully class-tested within an undergraduate preliminary year engineering course and students reported a positive experience with its use. The use of these labs should be self-explanatory and their reliable operation has been thoroughly tested. In a future work, the usability, efficiency and effectiveness of the system both from the point of view of the lecturers and the students will be reported.

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