Canadian Journal of Physics
Revue canadienne de physique

Virtual Laboratory Applications in Physics Teaching

Journal:	<i>Canadian Journal of Physics</i>
Manuscript ID	cjp-2017-0748.R1
Manuscript Type:	Article
Date Submitted by the Author:	27-Nov-2017
Complete List of Authors:	Mirçık, Özden; Türkiye Cumhuriyeti Milli Eğitim Bakanlığı, Education; Saka, Ahmet; Karadeniz Teknik Üniversitesi
Keyword:	Virtual labs, physics teaching, Virtual labs applications, developing virtual lab, present virtual labs
Is the invited manuscript for consideration in a Special Issue? :	33rd International Physics Conference of Turkish Physical Society

SCHOLARONE™
Manuscripts

Virtual Laboratory Applications in Physics Teaching

Özden KARAGÖZ MIRÇIK

PhD Student, ozdenkar@gmail.com

Prof. Dr. Ahmet Zeki SAKA

KTÜ Karadeniz Technical University, Trabzon-Turkey

azsaka@gmail.com

Abstract. Existence of a wide variety of virtual laboratories leads to dilemmas among practitioners in terms of selection of such programs and adaptation of them to the subject matter in the pre-service and in-service teacher training processes. The aim of this study is to inform physics educators, teachers and pre-service teachers of the virtual labs used in teaching physics nowadays, as well as the scope, design and features of such software. So they used in teaching physics particularly from primary education to university level are introduced and compared, their superior and weak aspects are highlighted, and target audiences, design characteristics, scopes and details, experiment analyses levels, levels of proximity to reality, and user friendliness are presented considering the data obtained from the literature review carried out based on the content analysis method. Thus, this study is intended to contribute to utilization of the virtual physics labs by users with expected efficiency.

1. Introduction

The virtual laboratory is defined as a computer environment which provides the real-time simulation opportunity in the tests and experiments which are required to be carried out and performed in order to acquire the application experience in education (1). In this respect, the virtual laboratory is modeling the reality in computer environment as a simulation-based multi environment (2). Its most important characteristic is that the user interface is with the higher interaction (2, 3). The virtual laboratories could be also used in lots of theoretical and experimental areas such as mathematics, physics, chemistry and engineering sciences, medicine, military and pilot trainings (1, 4, 5). These programs could present the characteristics which could not be carried out and performed in class environment in the physics tests and experiments and which are considerably useful for the education purposes (3, 6). The experiments which may last for a quite long period of time in real life could be virtualized within just several minutes in the virtual laboratory environments or could present the neglected points and details which are not regarded during an experiment in an ideal environment as well. This process is comprised of the educative computer centered/oriented tools with high interaction which contain sound, visuals and films as well as the multi environments which are being processed within a certain logic order and mathematical rules (2, 7). These programs not only could provide the student with the opportunity of working in accordance with the teacher control and knowledge but also could present to the mentioned student with the opportunity of learning with the trial-and-error approach (8).

In science education, the virtual laboratory applications make a contribution to increasing academic successes for the students and for them to develop positive attitudes towards the courses and for carrying out and performing the concept learning in an effective manner. In addition to this, the students could embody the concepts which belong to the real world which they have formed in their own minds by means of using the virtual laboratory programs and the teachers could use the virtual laboratory programs as assistant tools within the process of assessing their students as well. It is emphasized that it is supported to be used in the educational strategies which are based on the collaborative learning method and the constructivist approach (3). In addition, it is taken attraction that the virtual laboratory programs could make as positive influence as the real laboratories in actuality and it causes the formation of the constructivist learning environment (9). It is further stated and specified that this kind of interactive learning methods could lead the way to the students in learning the complicated events and concepts in the real world and could assist the students in order to develop accurate mental models (10).

The virtual laboratories do not replace the traditional laboratories totally, however, could be an influential and supporting alternative (1, 11). In particular, they make it possible to carry out and perform the difficulty and expensive tests and experiments in more economical and required manner (2, 5, 7, 9, 12). These programs could be also deemed useful with regard to examining the rarely seen events, simplifying the complicated systems, slowing down and fastening the time with respect to the handy, cheap and motivating aspects (13). The virtual laboratories which present the opportunity to carry out and perform the unlimited tests and experiments for the

educational institutions which have insufficient laboratory facilities enhance and increase the learning in addition to being more useful, cheap and secure in comparison with the traditional laboratories and thus their usages are getting more and more attractive with regard to their characteristics of controlling the education environment and keeping the accurate records exactly (1, 14).

Physics is an area which is considerably appropriate for usage of the virtual laboratory programs with regard to having much more and complicated information infrastructure in terms of the subjects included, assisting in perceiving the events which we encounter in the everyday life and containing numerous learning object as well as the mathematical and symbolic analyses. We see that the works and studies which are carried out and performed on the subject of usage of the virtual laboratories in physics education have become widespread in line with the developing technology recently (8, 11, 15, 16). Based on the developments which have been experienced in the computer and communication technologies, lots of virtual laboratory environments are being designed and implemented with the purpose of using in this area. Also, nowadays, various soft wares (Matlab, Java, Flash, etc.) are being used for the purpose of forming them properly (1, 17). By means of the software utilized, the user interactions and the functionalities of the virtual laboratories could be increased. In addition to this, these programs not only could be installed and operated in and via computers but also they could be operated through a computer network as well. However, it is quite complicated and troublesome work to prepare and use a virtual laboratory program. Because of this reason, in spite of the fact that such usage is needed on a lot of areas, its production remained in restricted number in actual meaning.

Nowadays because of the fact that the virtual laboratories which are used in physics education is quite versatile, it is necessary to know the specific characteristics and to choose the correct program in order to form an effective learning and education environment. This situation makes it compulsory to research the present virtual laboratories which are being used in the physics education and to present the opportunity to the educators to choose and compare them properly.

2. Aim

The purpose of the study is to present the virtual laboratory programs which are being used in the physic education nowadays and their coverage, scope, designs and usage characteristics to the valuable attention and knowledge of the program developers, physics educators, physics teachers and physics teacher candidates.

3. Method

In the study, the virtual laboratory programs which are being used in the physics education beginning from the primary school level to the university level are introduced and some comparisons were made and then the superior and weak points are emphasized and presented properly by means of taking into consideration the data which are obtained from the literature scanning which is carried out and performed based on the "content analysis method" for its specific characteristics such as the target audience, design characteristics and features, subjects contained and the detail presentation, test and experiment analysis levels and the degrees of proximity to the reality and the certain functionality and usability levels.

4. Virtual Laboratory Applications in Physics Teaching

Nowadays the virtual laboratories which have been developed implemented and suggested as directed at the usage of the virtual laboratories in physics education and also their specific characteristics are presented in the Table-1 below.

Table 1. Virtual Laboratory Applications and Features in Physics Teaching

Name of virtual lab	The target audience	Coverage	Used platform		Features
			PC	WEB	
Edison	Secondary School and University	Electricity, Electronic	X	X	<ul style="list-style-type: none"> The program provides the opportunity to work to multi users at the same time through a computer network. The user could choose the objects existing in the program and could transfer them into the experiment environment and could make the required settings and adjustments (rotating, changing the values, etc) accordingly. The simulations have realistic appearances and effects and they present the graphical data analyses. In line with the developing technology, the program has 3-dimension real physical environment image effect and the sample tutorials as well.

Tina Pro	Secondary School and University	Electricity, Electronic	X		<ul style="list-style-type: none"> It is considered that the program which gives the opportunity to use the objects only symbolically could make the work of the new-starter persons on the subject difficult. It present the detailed graphical data analyses.
Interactive Physics	Primary School and Secondary School	Mechanical, Kinetic, Electricity, Magnetism, Waves, and Energy	X		<ul style="list-style-type: none"> The program has not only symbolic but also 3-dimensional image effect; and it could show the result of the experiment mechanisms formed both mathematically and graphically. It provides the user with the opportunity to form, record and analyze unlimited number of experiment mechanisms.
Crocodile Physics	Primary School, Secondary School and University	Force, Motion, Electricity, waves ve optic	X		<ul style="list-style-type: none"> It provides the user with the opportunity to form and install circuits to not only symbolic but also 3-dimension images, to record them, to form the required graphics and to perform the mathematical analyses properly and correctly. In addition to this, it is easy to use not only for the teachers but also for the students with regard to presenting the tutorials and the experiment/test sets.
Circuit Shop	University	Electricity, Electronic	X		<ul style="list-style-type: none"> The program contains advanced level of electricity and electronics course applications as well. Although there is not any 3-dimension object in the program, it is still possible to install electronic circuits in the digital and analogue structures. In addition to this, it could be also used as digital oscilloscope. Thanks to the education video which is provided together with the program, the analogue and digital electronic concepts could be simply learned. There are some special symbol support and assistance as well. That is to say, the text, line, oval, rectangular and circuit elements could be added or some special signs could be formed. The library file could be updated. Thus, various symbols such as MP3, satellite, radio, video recorder, AV receiver, DVD, VCR, wide screen TV, HDTV, IR remote, RF splitter could be formed as well.
JHKSOFT Electricity Lab	Secondary School	Electricity, Electronic	X		<ul style="list-style-type: none"> The visuality has the top priority in the program. In general, the program which is being applied and implemented in the secondary school physics courses is easy to use and it provides the user with the opportunity to present the experiments as desired and required, to form them together with thousands of experiment components properly.
Elektronics Workbench (EWB)	Secondary School and University	Electricity, Electronic	X	X	<ul style="list-style-type: none"> The program which provides the opportunity to make application on the objects which are seen schematically in the program presents the experiment results both mathematically and graphically. The program also provides the opportunity to work together with the minor groups (which are composed of 10 persons) or major groups (which are composed of 25 persons) while it is for single user. It is obviously necessary to have a certain level of knowledge on the area in order to be us the program effectively.
Pspice	University	Electricity, Electronic	X		<ul style="list-style-type: none"> The text based files which are called "netlist" are used in the introductory part of the program. Netlist could also contain the various model definitions, similarity types, measurement points, starting conditions and the arithmetic transactions, together with the elements in the circuit. All of the real analogue and digital simulations could be realized and fulfilled, from the high-frequency systems to the low-power IC designs. It has an extensive library. It is obviously necessary to have a certain level of knowledge on the area in order to be us the program effectively. Programa girişte "netlist" olarak adlandırılan metin tabanlı dosyaları kullanır. Netlist, devredeki elemanlarla birlikte, çeşitli model tanımlamalarını, benzetim tiplerini, ölçüm noktalarını, başlangıç şartlarını ve aritmetik işlemleri de içerebilir. .
Physlets (PHYSics appLETS) (PHYSLETS)	Secondary School and University	All physics subjects		X	<ul style="list-style-type: none"> It provides the user with the opportunity to make application on the ready modules rather than forming his own design. It has 2-dimension and 3-dimension image effect. There are some videos, drawings, symbols and mathematical graphics in the program. It also provides the educators to assess and evaluate the student by means of the interactive tests

PhET	Secondary School and University	All physics subjects		X	<ul style="list-style-type: none"> It is possible to perform the drag and drop usage, shifting and radio buttons and similar other graphics and intuitional controls and visualization in the program. Thus, the result-cause correlations and the multi-connection demonstrations could be shown effectively too (such as the movement of the objects, graphics, number readings, etc). There are also some measurement tools and equipments which contain the schedules, chronometers, voltmeters and thermometers in the simulations in order to encourage for more qualitative researches and studies. It has a digital library and the users are able to use, change, modify and add the simulations there easily.
Java Applets	Primary School, Secondary School and University	All physics subjects	X	X	<ul style="list-style-type: none"> These environments which could be considered at a simpler level in comparison with the other softwares are the free softwares which are easy to use in order to explain and describe a certain event with its most fundamental condition. They have 2-dimension appearance in general. Even if the accuracy is ensured in terms of graphics and usability, it is still difficult to ensure and satisfy the integrity among the subjects. Each separate heading relating to the subject to be explained is being given with separate files. It has a digital library and the users are able to use, modify, change and add the restricted simulations which are prepared and arranged in compliance with the minor targets there.
Stella (System Thinking Educational Learning Laboratory with Animation)	Primary School	All physics subjects	X		<ul style="list-style-type: none"> Stella is a simulation development and implementation program which is composed of the stock, flow, converter and connector elements and which also ensures observing the qualitative interactions of the variables in the system and which ensures understanding the framework and graphical interface of the system. They show the variables and cause-effect relationships by means of figures and then they produce the model equations accordingly. Whenever the program is started and operated properly, it gives some graphics which show the result tables and the change of the system behavior based on the time.
PowerSim	Secondary School and University	Electricity, Electronic	X		<ul style="list-style-type: none"> The explanation is being made by means of the writings and symbols rather than the realistic graphics. Because of this reason, it could be more effective in the concept learning. It presents the opportunity to make the graphics, formula and calculations in full details. It provides the user with the opportunity to make application on the modules on the modules instead of the limited usage.
Proteus	University	Electricity, Electronic	X		<ul style="list-style-type: none"> It ensures forming the electricity and electronic test and experiment tests at an advanced level. It is composed of two modules as Isis (scheme drawing) and Ares (print circuit drawing) sub programs. While making and performing the analysis of a circuit which is drawn via Isis, it is possible to realize the same as printing circuit drawing automatically in Ares.
Modellus	Secondary School and University	Electricity, Electronic	X		<ul style="list-style-type: none"> These are some cognitive models which give the opportunity to the user in order to observe the multi conceptual tests and experiments concurrently with the user.
Çizgi-Tagem	University	Electricity, Electronic		X	<ul style="list-style-type: none"> It provides the user with the opportunity to form the tests and experiments on the 3-dimension BreadBoard.
Virtual Labs Electricity DL	Primary School	Electricity, Electronic	X		<ul style="list-style-type: none"> The users could form the tests and experiments by means of using the similar graphics as identical to the real ones for the electricity circuit elements and could make and perform the examinations and researches in details.
Open Source Code Applications	Primary School, Secondary School and University	All physics subjects		X	<ul style="list-style-type: none"> It presents the simulations which are prepared by means of the 2 and 3 dimensional graphics to the users. Thus, it provides the user with the opportunity to use the desired and required scenarios and course applications as desired as well. It is in the form of short simulations in general. It is required to use more than one simulation package in general in order to transfer a subject.
Electric Circuits Kitbook	Primary school	Electricity, Electronic	Book and maket		<ul style="list-style-type: none"> It is a set which is used to measure the concept information relating to electricity by means of presenting the models, books and multiple choice tests. The students could carry out and perform some simple experiments by means of the materials which are contained.

As it is seen in the Table 1; in the selection of the virtual physical laboratory programs which could be implemented in the physics education, whenever it is carefully examined by means of taking into consideration the target audience, subject and the platform used, it appears that the importance of the graphics and usability is considerably significant for the primary school and secondary school level in particular (2, 8). In this context, it is indicated 2 or 3-dimension real physical environment image effects increase motivation and understanding of students (2, 9, 11, 18, 20, 21). This situation could be expressed based on to these programs provide numerous experiments in a safe environment (1, 3, 6, 7, 9). However, the level of the target student increases, it is seen that there arises an obvious increases in the concurrent usage and presentation of the simulations which take part in the digital libraries mostly by the physics educators (10, 18). This is explained with their need for more complex applications and the desire to develop different experimental setups (19). In this context, teachers and students need a digital library for archiving the experimental setups for evaluating and reusing (19, 20). In addition to this, it is seen that the teachers and the students make contribution to these libraries (19, 20).

5. Conclusions

Whenever it is carefully examined by means of taking into consideration the target audience, subject and the platform use in the selection of the virtual physics laboratory programs to be used in the education of physics, the fundamental criteria have been specified and determined in the selection of the programs to be used in the education of physics (Table 1). Taking into consideration the results of the literature researches and studies, it is necessary to take into account the following criteria in choosing and using the virtual laboratories:

- It should be appropriate (age, culture, language, etc.) for the students for the target audience.
- It should cover the targets, contents and experiments of the subject to be applied.
- It should be also in compliance with the physical conditions of the environment in which the education shall be provided.
- The design and the usability characteristics (symbol, button, color, form, etc) should be appropriate for the education program and the students.
- It should contain the samples and courses (tutorials) which are appropriate for the education program and the students.
- It should include the mathematical formulas and analyses. Thus, the student could form his own model both visually and could conclude the same but also could analyze them by means of seen the mathematical results. This situation could be useful in correcting the concept mistakes for the students and assessing the students for the teachers (8, 21).

Taking into consideration and examining the present case, the results obtained are stated and specified as follows:

- The experts and the teachers could choose the appropriate program by means of using the above-mentioned Table 1 (11, 22).
- As it is seen in the Table 1, the virtual laboratories are developed for the “Electricity and Electronics” subject in the physics course in general (1, 4, 11, 16, 17, 18, 21, 22).
- In the secondary school and primary school levels, the exaggeration and immoderation in the graphics increase.
- While using the virtual laboratories which are composed of the simulations mostly in the primary education and secondary education, it is also seen that the remote controlled virtual laboratories are being used in the higher education.
- The open-source coded simulations are being presented usually in the form of digital libraries. It takes part as in the form of the small simulation packages which include a single target instead of the full virtual laboratory program which covers everything. Thus, it provides the users with the opportunity of combination and correction in accordance with their own scenarios and needs.
- The new versions of these programs appear based on the developing technology and some positive developments arise in terms of not only design but also usability.

6. Suggestions

The following suggestions are being presented in choosing the correct virtual laboratory program to the experts and teachers in order to ensure using the virtual laboratories in an effective manner in the education of physics:

- The suggestion of the experts and teachers, that is to say, using them in similar studies and contribution to the educational process should be well-proven.

- The virtual laboratory programs used should cover and satisfy these needs because the detailed subject and extensive subject content, mathematical analysis, graphical formation and interaction proportion shall increase as the age of the target audience increases.
- It is necessary to present to the user the opportunity to work freely with the open codes instead of making applications in accordance with some certain patterns (4).
- The students should acquire the skill to make and perform the numerical measurements and evaluation of the test mechanisms as formed by them (8).
- It should provide the students the opportunity to write the formulas and the basic rules of physics on their own (8).
- As the age of the target increases, the specializations and education requirements appear for the sake of usability.
- The virtual laboratories should be formed for an effective learning environment on the other areas than the electricity and electronics subjects of physics.

REFERENCES

1. E. Akın & M. Karaköse. “Elektrik ve Bilgisayar Mühendisliği Eğitiminde Sanal Laboratuvarların Kullanımı”, Elektrik-Elektronik-Bilgisayar Mühendislikleri Eğitimi 1. Ulusal Sempozyumu EEBM 2003, Ankara (30 Nisan-2 Mayıs 2003).
2. A. Scherp, “Software Development Process Model and Methodology for Virtual Laboratories”, Proceedings of the 20th IASTED International Multi-Conference ‘Applied Informatics’ (AI 2002), Innsbruck, Austria.
3. J.M. Moshell & C.E. Hughes. Virtual Environments as a Tool for Academic Learning, in Handbook of Virtual Environments: Design, Implementation, and Applications (K. M. Stanney, Ed.), Lawrence Erlbaum Associates, (2001) 893-910.
4. M. Baser. “Effects of Conceptual Change and Traditional Confirmatory Simulations on Pre-Service Teachers’ Understanding of Direct Current Circuits”, *Journal of Science Education and Technology*. (2006) 15, 367–381 [doi:10.1007/s10956-006-9025-3].
5. S. Jeschke, T. Richer, & E. Zorn, “Virtual Lab”, DFG Research Center Matheon, TU Berlin, 2001.
6. A.K. Noor, & T.M. Wasfy, (2001). “Simulation of Physical Experiments in Immersive Virtual Environments”, Engineering Computations, Vol.18 No.3/4, MCB University Press, 0264-4401, pp.515-538.
7. R. Guzzi, S. Scarpanti, G. Ballista, W. Di Nicolantonio, (2005). An Educational Development Tool Based on Principles of Formal Ontology. *Educational Technology & Society*, 8(1), 80-89.
8. L. Oidov, U. Tortogtokh & E. Purevdagva, “Virtual laboratory for physics teaching”, Proceedings of the International Conference on Management and Education Innovation, (MEI’ 12), IACSIT Press, Singapore, 2012. 319-323.
9. Z. Tatlı & A. Ayas, Virtual Laboratory Applications in Chemistry Education, World Conference on Learning, Teaching & Administration, 29-31 October 2010, Cairo, Egypt.
10. R.L. Miller, J.F. Ely, R.M. Baldwin & B.M. Olds, (1998). High-order thinking in the unit operations laboratory. *Chemical Engineering Education*, 32(2), 146-151.
11. E. Bozkurt (2008). Fizik Eğitiminde Hazırlanan Bir Sanal Laboratuvar Uygulamasının Öğrenci Başarısına Etkisi, Ph.D. thesis., Selçuk Üniversitesi, Konya.
12. N. Özden. “Deneyisel Öğretim Yöntemlerinde Benzetişim (Simülasyon) Kullanımı”, IV. Uluslararası Eğitim Teknolojileri Sempozyumu 2005, Sakarya, Türkiye
13. Tekdal, M. Etkileşimli Fizik Simülasyonlarının Geliştirilmesi ve Etkin Kullanılması, V. Ulusal Fen Bilimleri ve Matematik Eğitimi Kongresi, 2002, ODTÜ, Ankara
14. Bozkurt, E. & Sarıkoç, A. (2008). Fizik Eğitiminde Sanal Laboratuvar Geleneksel Laboratuvarın Yerini Tutabilir mi?. *Selçuk Üniversitesi Ahmet Keleşoğlu Eğitim Fakültesi Dergisi*, 25, 89 -100.
15. A. Jimoyiannis & V. Komis, (2001). Computer simulations in physics teaching and learning: a case study on students’ understanding of trajectory motion. *Computer and Education*, 36, 183-204.
16. J. Kukkonen, T. Martikainen & T. Keinonen, (1997). Simulation of Electrical Circuit in Instruction by Fifth Graders, VccSSe-Virtual Community Collaborating Space for Science Education, Socrates.
17. M. Gündüz, Ö.K. Baykan & F. Yıldız, (2007). Elektronik Deneyleri için Sanal Laboratuvar Uygulaması. *Selçuk Üniversitesi Teknik Bilimler MYOTeknik-Online Dergi*, 6(2), 61-74.
18. T. Jaakkola & S. Nurmi, (2008). Fostering elementary school students’ understanding of simple electricity by combining simulation and laboratory activities. *Journal of Computer Assisted Learning*, 24, 271–283.
19. T. Malloy & G.C. Jensen, “Utah Virtual Lab: JAVA interactivity for teaching science and statistics online. Behavior Research Methods Instruments & Computers”, 2001.

20. S. Bull, P. Gardner, T. Jackson, M. Lancaster & S. Quigley, (2007). Revealing Students' Misconceptions, Birmingham Education, Theory and Action 1(1), 11-15. <http://www.landtddevelopment.bham.ac.uk/journal>. Good practice case study.
21. S. Michelet, J.M. Adam & V. Luengo (2007). Adaptive learning scenarios for detection of misconceptions about electricity and remediation. *International Journal of Emerging Technologies in Learning*, 2(1), EBSCO.
22. D. Biel, J. Vento & R. Costa-Castelló, (2010). On the role of virtual laboratories in an undergraduate power electronics introductory course, ACES-Control Avançat de Sistemes d'Energia, IOC-DT-P-2010-02.

The companies produced virtual labs and published web sites:

- <http://www.designwareinc.com>
- <http://www.designsoft.com>
- <http://www.interactivephysics.com.sg>
- <http://www.crocodile-clips.com/>
- <http://www.cherrywoodsystems.com/cshop1.htm>
- <http://www.easy-edu.com/english>
- <http://www.electronicworkbench.com>
- http://vnatsci.ltu.edu/s_schneider/physlets/main/
- <http://phet.colorado.edu/>
- <http://www.iseesystems.com/>
- <http://www.powersim.com>
- <http://www.labcenter.com/index.cfm>
- <http://www.hmhinovation.com/Edmark.php>
- <http://www.allaboutcircuits.com>
- <http://www.cizgi-tagem.org/>