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The Development of an Interactive Virtual Laboratory Simulation Software: A Case Study of Basic Physics Experiments

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Abstract
This paper presents the techniques for the development of a web-based interactive virtual laboratory simulation software with a case study of basic Physics experiments to determine the acceleration due to gravity. The virtual learning environment has been developed in the following manner, namely: *1)*. Determine the computer programs and applications to be used in the software using the hyper text mark-up language (html); *2)*. Design software content Based on java applets; *3)*. Model the laboratory interface, experimental materials, equipment and characters necessary for the virtual Physics laboratory; *4)*. Develop the virtual laboratory; *5)*. Collect expert opinions about the virtual laboratory; *6)*. Finalize and test the virtual laboratory for simulation; and *7)*. Deployment of the virtual laboratory software for use by clients. The paper also presents the attributes related to the interface of the software and attributes related to the use of the virtual laboratory software as a material in education. The effectiveness of the proposed interactive virtual laboratory software is justified by its deployment for use by secondary school students with positive responses through interactions and questionnaires. Comprehensive techniques on how to compute the acceleration due to gravity and generate the corresponding predictive mathematical models for the experiments have also been presented together with the associated programs written in MATLAB. The limitations of the virtual laboratory simulation software and directions for further improvements are briefly highlighted.
Keywords: Hyper text mark-up language (html), interactive virtual laboratory, Java® Applets®, Physics experiment.

1. Introduction

Computer-based teaching and learning is increasingly becoming widespread and it has been important especially at difficult subjects in science for over two decades. Computer-based learning is a method, which uses computers in a learning media and strengthens students' motivation and educational processes. It gives opportunities to both students and teachers to learn and teach more quickly and to combine active learning with computer technology. Andaloro et al., (1997) explained that using computers increases motivation and desire for the lectures and laboratory in the process of learning. It has been shown that computer based learning influences the successes of the students much more positively than traditional methods (Reed, 1986; McCoy,1991; İbiş,1999; Yiğit and Akdeniz,2000). It has also been identified that the successes of the students increase in Physics lessons taught using computers (Bennett,1986; Yiğit and Akdeniz, 2003; Meyveci, 1997).

The teaching simulations prepared to be used in educational activities as one of the software types are able to create a teaching atmosphere like laboratories where students are active. Various interference possibilities in simulation programs for example, the user giving different initial values in the experiment in computer medium give the possibility of "Learning through inventing" which is one of the different methods (Şen, 2001). Simulations are also simplified and abstracted parts of some real events and applications (Şengel et. al, 2002). Simulations are the transfers of the events with specific limitations in daily life to the computer medium. Computer-based learning is the closest one to the laboratory medium and offers a student interaction. Simulations help the students to form their own cognitive models about events and processes. Simulations also offer the opportunities for observing easily the events that occur too slowly or too fast in the lab and are very dangerous to be tested in it and cost dearly.

The laboratories equipped with computers and especially with simulations (due to the reason that they are very productive in terms of time) give opportunities to the students to ask questions of changeable nature like " if X is. …, then Y is…." As the students feel free asking questions in this manner and take feedbacks immediately, they enter a process that works well in terms of conceptual changes. Computer transforms difficult and boring activities into easy ones in Science subjects. For this reason, computers encourage the students to be the part of science classes and participate in similar learning experiences (Soylu and İbiş, 1999; Gülçiçek and Güneş, 2004). Jimoyiannis and Komis (2000) examined the effect of computer simulations on students to understand the orbital movements, by using basic concepts related with kinematics, in a study made in physics teaching. As a result of this study, it is seen that teaching basic concepts of kinematics through simulations has brought about successful results and has contributed highly to learning process.

In a study in which the influence of computer based physics activities on students' acquisitions is searched on the subject of Simple Harmonic Motion, it is concluded that the teaching realized by the simulation program with an applied dynamic system is more successful than the teaching implemented by traditional methods (Karamustafaoğlu et al., 2005). And also in this study it is stressed that a well-prepared simulation is not very adequate by itself and it is necessary to support the simulations considered to be used in order to be able to obtain good results from instruction with the instructive programs concerning related subjects and concepts.

Recently some studies have been performed about whether the computer simulation experiments or traditional laboratory experiments are effective on the students' successes about Science subjects. Some parts of this studies show that the computer simulation experiments are more effective. (Svec and Anderson, 1995; Redish et al., 1997). However, Miller (1986) as well as Choi and Gennaro (1987) couldn't find a meaningful difference between computer simulation experiments and traditional laboratory experiments (Şengel et al., 2002).

Virtual physics laboratory are highly interactive software, comprising simulations of real Physics laboratory customized for the needs of researchers and students. These software programmes provide students with the opportunity to study under the control and within the knowledge of the teacher, and to learn using trial and error. The most important attribute of virtual physics laboratory is that they should have a highly interactive user interface. Users are able to perform experiments using the laboratory materials in any order by moving the objects using input device.

According to Özdener (2005), virtual laboratory are tools that simulate phenomena that cannot be investigated or observed in natural environments or in cases where the laboratory facilities are limited. Thanks to these programmers, users have the opportunity to learn by experimenting and testing using different parameters. For example, they provide the opportunity to perform experiments in different environments with different gravitational forces (e.g., on another planet or at the poles), and to investigate the incidents in detail by controlling the time (e.g., slowing down the movements of electrons in a conductor for easy observation). Furthermore, virtual laboratory also provide the opportunity to conduct investigations and experiments without harming any living creatures. Virtual laboratory are capable of simplifying experiments based on the user's skill level. For example, they enable users to understand the subject and solve the problem by showing multiple forces affecting an object directionally.

In this study, the determination of acceleration due to gravity using simple pendulum has been designed and implemented using the proposed simulation-based virtual laboratory. Its effects on students become active in their learning by seeing, observing and doing. Many researchers in science education admitted that laboratory studies increase students' interest and abilities for the science subjects (Bryant and Edmunt, 1987; Bekar, 1996; Algan, 1999; Bagci and Simsek, 1999).

The main objective of this study is to develop a web based interactive laboratory with basic physics experiment as the case studies through: *1)*. the development of a java program that implements the interactive virtual laboratory, and *2)*. the development of a client based server interface for the simulation of the virtual laboratory using Firefox browser as the client and host Computer running the java based program as the server**.** The study is expected to form a platform for the development of advanced web- based virtual laboratory in Nigerian Universities especially in sciences and engineering.

2. Research Methodology

The research model is both descriptive, aiming to determine the attributes of the virtual laboratory software developed for use in secondary education. Physics practical on the determination of acceleration due to gravity using a simple pendulum, as a result of the literature review, and methodological, aiming to develop an interactive session in order to make physics practical more easy for students of senior secondary school curriculum.

The manual for the experiment on determination of acceleration due to gravity using simple pendulum was prepared based on the curriculum of the senior secondary school in Nigeria. An interactive web-site that comprises of the details like the title of experiment, aims and objectives, apparatus, procedures and conclusion for the experiment has been designed and developed. The content of the virtual Physics laboratory software has also been prepared. Before the preparation, previous virtual laboratory applications with positive and constructive comments directed to these applications were reviewed and discussed in Section 1.

Following this review, it was determined that previous virtual laboratory applications used in the Physics laboratory contained only one or two dimensions. That is, some of the previous applications focused on visual dimensions but no instructional model was applied during development, whereas other applications prioritized representations but neglected student interaction. Still some others presented a very large laboratory environment but users were found to lose time, get tired, and, if they eventually managed to use these environments, took longer time to arrive at solutions.

These findings were considered during the development of the virtual laboratory used in the current

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study. The virtual learning environment was developed in the following stages:

1). Design the computer programs and applications to be used in the software using the hyper text mark-up language (html);

2). Develop software content Based on java applets;

3). Model the laboratory interface, experimental materials, equipment and characters necessary for the virtual Physics laboratory;

4). Develop the virtual laboratory;

5). Collect expert opinions about the 6cfrreqvirtual laboratory;

6). Finalize and test the virtual laboratory for simulation;

7). Deploy of the virtual laboratory software for use by clients.

2.1 Step-by- Step Laboratory Procedure

The Virtual laboratory software introduces experimental rules, laboratory equipment and materials to the students as shown in Fig. 1 and Fig. 2. Also the procedures to perform experiments in the virtual laboratory care also introduced. Students can select an experiment from the pull down menu. Students are assisted with step-by-step descriptions and screen capture images of the simulation software as illustrated in Fig. 3, Fig. 4 and Fig. 5. The top page contains links to different sections of the virtual laboratory, brief description of each sections (aim and objective of the practical, apparatus, procedures, simulation, conclusion and questions) is provided to indicate the function of each section.

Fig. 1: The main page of the virtual laboratory system.

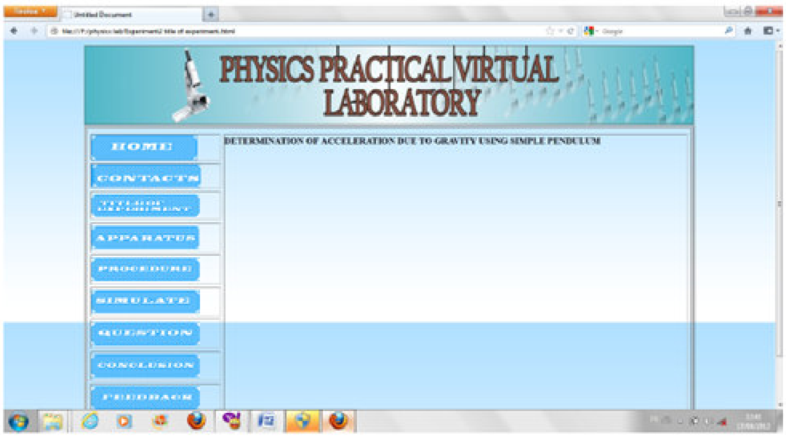

Fig. 2: The page showing the title of the experiment.

Fig. 3: The page showing the apparatus for conducting the experiment.

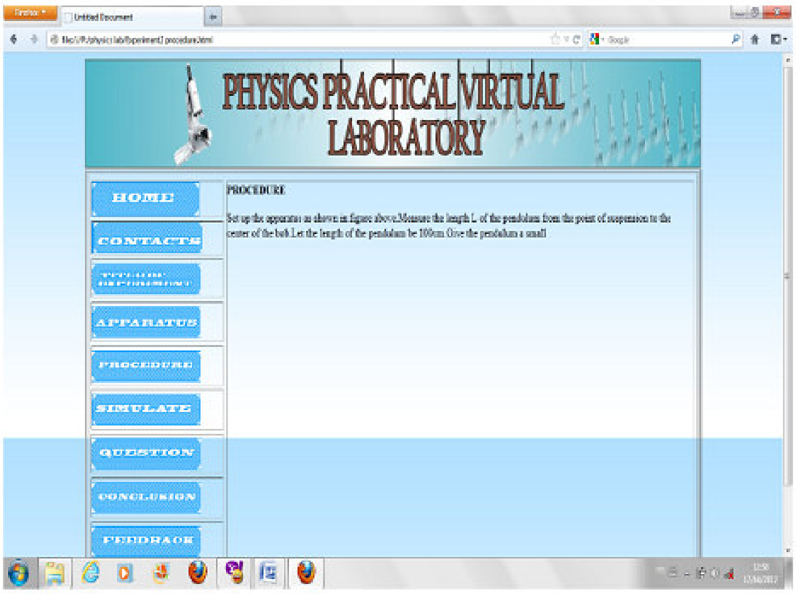

Fig. 4: The page showing procedures for carrying out the experiments in the virtual laboratory system.

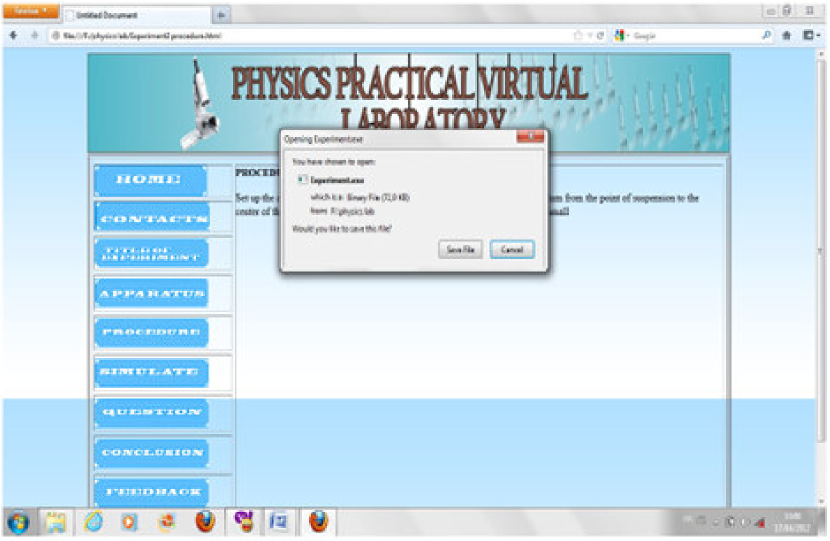

Fig. 5: The program compilation page showing of the simulation environment.

2.2 Usability Attributes

According to Okon et al. (2006), the usability attributes of the virtual laboratory programme have been identified and classified under three main headings, namely: *1)*. attributes related to the interface of the software; *2)*. attributes related to its use as a material in education; and *3)*. attributes related to product and service support.

2.2.1 Attributes Related to the Interface of the Virtual Laboratory Software

Attributes related to the interface of the software includes: *1)*. It is compatible with the operating systems (Win XP, Vista, Linux, etc.); *2)*. It does not raise difficulties during the installation process; *3)*. It provides secure log-in opportunity for different users; *4)*. It requires extra hardware to be used (touch screen, mouse etc.); *5)*. The experiment mechanisms created can be shared over the Internet and the Intranet; *6)*. Users have the capacity to select and use any objects they want; *7)*. It has an interactive structure; *8)*. It creates a motivating environment for the user before starting experiments (For example, asks questions about the subject of displays up-to-date experiment mechanisms); 9*)*. It provides users with the opportunity to change the experiment tools; *10)*. It starts with the status of being not empty. (e.g. "1 kg" for a mass selected by user); *11)*. Users can adjust the running speed of the experiment setting as they wish; *12)*. Screen arrangement is printable; *13)*. It provides users with the opportunity to run multiple experiments simultaneously; *14)*. It provides the opportunity to change the common attributes (speed, mass, etc.) of multiple experiment settings simultaneously; *15)*. It provides users with the opportunity to cancel the experiment while running; *16)*. It provides the opportunity to resume a previously created experiment; *17)*. Menus have easy-to-access location on the working environment; *18)*. Screen image can be copied to another environment; *19)*. Snap shots of the modules can be taken; *20)*. It provides interface to other software; *21)*. It supports paths such as minimum and maximum values for components (i.e. it has the bottom and top limits the objects can get in the real life); *22)*. It provides video-voice conference opportunity during multiple-user operation; *23)*. It has timelines showing the real-life duration of applications; *24)*. It provides the opportunity to correct an error in the experiment setting; *25)*. When required, inactive or broken down tools can be added to the experiment sets; *26)*. It provides users with the opportunity to change the working environment; *27)*. It provides the opportunity to assign a password to an experiment setting created; *28)*. Some tools of the experiment setting created by users can be classified as required; *29)*. It has a shortcut icon on the desktop; *30)*. It allows the use of shortcut keys (such as copy (Ctrl + C) and paste (Ctrl + V) for rapid operation of the programme; and *31)*. It allows users to work both over the Internet and from the compact disc (CD).

2.2.2 Attributes Related to the Use of the Virtual Laboratory Software as a Material in Education

Attribute related to the use of the software as a material in education includes: *1)*. It is capable of covering the curriculum of the target group; *2)*. The sample models match with the curriculum of the identified target group; *3)*. Makes curriculum recommendations to teachers for effective use; *4)*. Makes studying program recommendations to students for effective use; *5)*. Convenient for use in group works; *6)*. Users can be evaluated based on their performance; *7)*. Users are provided immediate feedbacks; *8)*. Encourages users to do research (asking questions, proposing projects, etc.); *9)*. Experiment tools and sample experiments match with the learning and teaching; *10)*. Contains tutorials; *11)*. Provides examples relating to the subject; *12)*. The experiment tools show parallelism with the improvements in technology; *13)*. Has a structure that would assist in development of creativity of students by providing the opportunity to perform experiments infinitely; *14)*.

Allows users to automatically create the graph relating to the experiment setting created; *15)*. Provides the opportunity to save and load any previously performed works; *16)*. Provides different working environments depending on the level of normal users; and *17)*.Technical information can be obtained and consultancy services are provided for the program when necessary.

3. Results and Discussions

3.1 Evaluation of the System

The page showing the procedures for carrying out the experiments in the virtual laboratory system is shown in Fig. 4 while the program compilation page of the simulation environment is shown in Fig. 5. The set-up for the implementation and demonstration of the proposed virtual laboratory software to perform simple pendulum experiment in physics is shown in Fig. 6. First, the length of the pendulum is specified the “Start Experiment” button is activated by pressing to initiate and perform the experiment as shown in Fig. 7. The results for each experiment with different length are recorded and tabulated as shown in Fig. 8 from where further analysis can be performed.

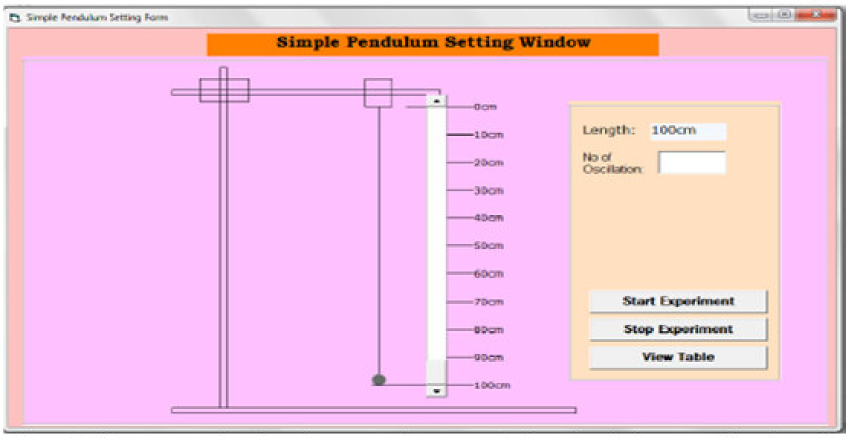

Fig. 6: The page showing the second stage of the simulation exercise for the determination of acceleration due to gravity using simple pendulum.

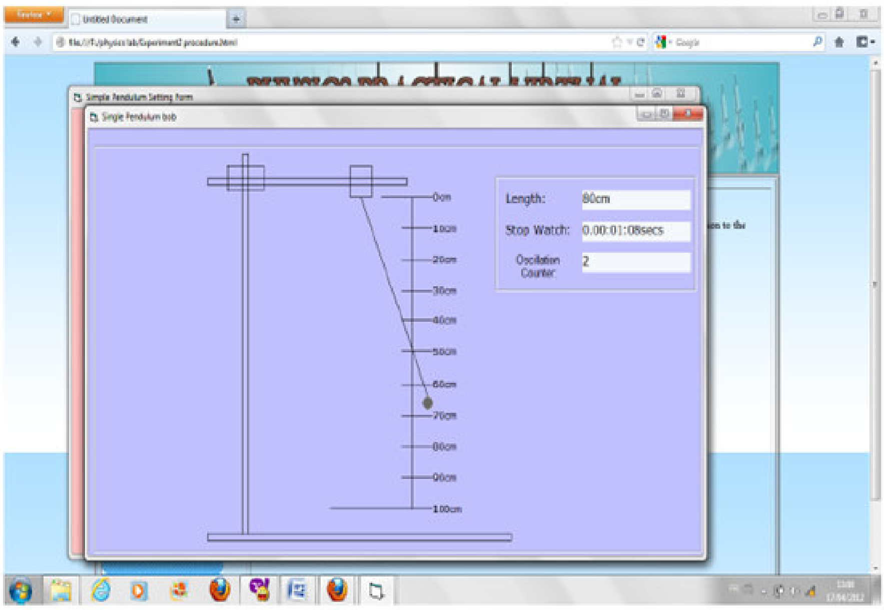

Fig. 7: Simulation pane for the simple pendulum experiment of length 80 cm for 20 oscillations with simulation results.

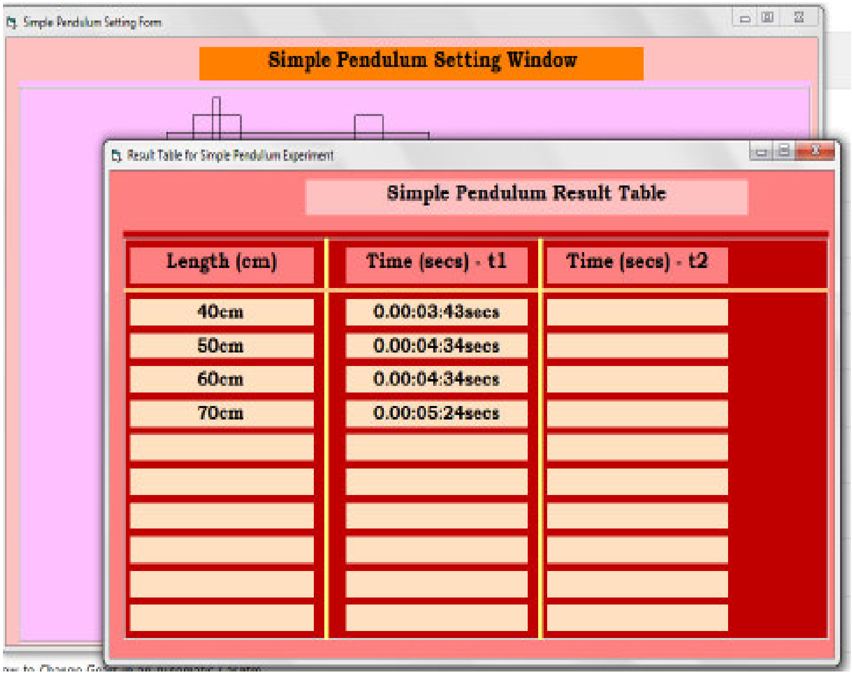

Fig. 8: Tabulated simulation results for 4 experiment using different lengths.

Furthermore, fifteen students of three different secondary schools in Ibadan Oyo state Nigeria were introduced to the virtual laboratory. They experienced the Virtual laboratory system in a computer laboratory for three hours. Before trying the virtual laboratory, the students had worked for four hours in a real hand–on laboratory on measurement acceleration due to gravity using the simple pendulum set-up.

In order to assess students' view of this laboratory approach a questionnaire was given to each student immediately after their first experience of the virtual laboratory system in the computer laboratory. In addition, students were able to write feedback, comments on the back of the questionnaire. The questionnaire aimed mainly to obtain students views about learning virtual laboratory, users interface and to investigate the needs of the students in this virtual laboratory. All the fifteen students responded to the questionnaire and their response was analyzed. Finally, eight students were randomly selected from the students and interviews were performed to probe, in an open way how this virtual laboratory approach affected their learning and also to investigate their views on this new laboratory approach.

3.2 Results

All the fifteen students trying the virtual laboratory system returned the questionnaire. From the responses to the questionnaire, most students indicated a positive attitude towards the virtual laboratory system and reported that the virtual system encouraged and motivated them to learn better. Most students found it interesting to perform experiments through the virtual laboratory. General feedback and student interview responses also revealed a positive response towards the virtual laboratory system.

Table 1: Questions and responses from students based on questionnaires.

S/N	Question	Yes	No
1.	Have you entered a Physics laboratory before?	13	2
2.	Have you done an experiment on determination of acceleration due to gravity using simple pendulum before?	10	5
3.	Have you heard about virtual laboratory before?	0	15
4.	Would you like to work in a virtual laboratory?	15	0
5.	Did the demonstrated virtual laboratory motivate you or encourage you to learn better?	9	6
6.	Was the virtual laboratory boring or interesting?	12	3
7.	Are you familiar with using the Internet?	8	7
8.	Do you have access to computer in your school?	2	13
9.	Have you experienced working with the virtual laboratory before?	0	15

3.3. Results of the Questionnaire

The responses from students based on the questionnaire conducted are summarized in Table 1.

Students Comments: *1). I like this virtual laboratory system, I can do it anytime. I can do it again easily at home and understand more about the experiment.*
2). It is very interesting to us and I don't feel bored in doing experiment.

However, prior ability and experience of students may affect how students devote their time to learn through internet. Some students related the interests of using virtual laboratory to their previous knowledge of web browsing.

Students Comments: *1). I do not feel interesting as I am not familiar with browsing the web.*
2). I am not so familiar with the computer. So I prefer to do experiment in normal laboratory class.

Nearly all students expressed a preference for more interactive content, email and discussion group that could be used to fulfill these requirements. Also students found it boring if they only read materials provided in the virtual laboratory system. That is why they requested more multimedia content.

Students Comments: *1). I like to have more discussion about the laboratory with my classmates and teachers.*
2). I like video or movie.

3.4 Discussions

In previous studies investigating the effects of virtual laboratories on student achievement, virtual laboratory applications induce an expectation of higher student achievements (Yavru, 1998). However, when the previous studies were reviewed, there was no stable relationship between student achievement and the use of virtual laboratories. Some previous studies reported that virtual laboratories positively influenced student achievement (Clark, 1998; Akpan and Andre, 2000; Jimoyiannis and Komis, 2000; Blaylock and Newman, 2005; Bozkurt, 2008), while others reported no significant differences in learning outcomes between traditional environment and virtual environment (Bernard et al., 2004). Some other studies reported that traditional laboratories were more effective, despite the fact that virtual laboratories provided a variety of benefits (Eylon et al., 1996; Gustavsson, 2002).

The results of the present study suggest that virtual laboratories are at least as effective as real laboratories in terms of acquainting students with experiment process providing students with a safe experimental environment , allowing students to conduct experiments individually (Bozkurt, 2008), providing users with more options in shorter time with interaction with simultaneously symbolic presentation levels to the user (Ozdener and Erdogan, 2001).

At the end of the study, the virtual laboratory software was shown to be at least as effective as Physics laboratories. It was determined that students in the control group could complete the experiments with reasonable results; felt self-confidence among the students was observed; the students could associate the experiment with daily life; and they had the opportunity to symbolically explain each levels of each experiment. It is anticipated that virtual Physics laboratories will be adopted as supplementary and supportive elements in future. This will provide not only an effective learning environment but will also minimize school expenditures and the time spent on such activities to a large extent.

4.0 Performance Comparison of the Proposed Virtual Laboratory Software and Standard Laboratory Experiment

4.1 Experimental Results

Twenty five (25) experiments were conducted using the proposed virtual laboratory simulation software for arbitrarily chosen different number of oscillations: 50, 25, 100, 75, and 10 for arbitrarily chosen different length of pendulum (in cm): 20, 40, 60, 80 and 100 cm respectively. The results obtained from the experiments are presented in Table 2.

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Vol.7, No.1, 2016

Table 2: Experimental results based on the proposed virtual laboratory simulation software.

Simple Pendulum Result Table

Length (cm)	Time (secs) - t1	Time (secs) - t2
20cm	0.00:19:07secs	
40cm	0.00:37:04secs	
60cm	0.00:23:33secs	
80cm	0.00:33:18secs	
100cm	0.00:38:18secs	
100cm	0.00:18:73secs	
80cm	0.00:16:31secs	
60cm	0.00:11:46secs	
40cm	0.00:09:04secs	
20cm	0.00:04:60secs	
20cm	0.00:19:07secs	
40cm	0.00:37:07secs	
60cm	0.00:47:06secs	
80cm	0.01:08:07secs	
100cm	0.01:18:07secs	
100cm	0.00:57:62secs	
80cm	0.00:50:15secs	
60cm	0.00:35:20secs	
40cm	0.00:27:71secs	
20cm	0.00:14:27secs	
20cm	0.00:01:78secs	
40cm	0.00:03:43secs	
60cm	0.00:04:34secs	
80cm	0.00:06:16secs	
100cm	0.00:07:07secs	

Furthermore, the graph for the variations of the number of oscillations, length of pendulum and the time of oscillations are shown in Fig. 9. It can be observed that the time (23.33 s) at the third point for 50 oscillations with pendulum length of 60 cm appears incorrect since it is supposed to increase rather than reducing. However, the general observation is that for a given number of oscillation, as the length of the pendulum increases so does the oscillation time increases and vice versa

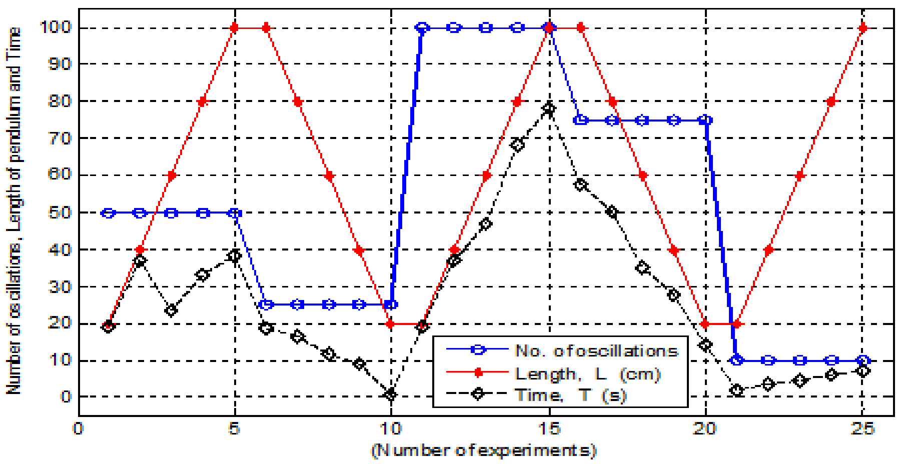


Fig. 9: Variations of the number of oscillations, length of pendulum and the time of oscillations

4.2 Acceleration due to Gravity Computation

Computation of the acceleration due to gravity (g in m/s^2) was computed according to the following general equation (Jones and Childers, 1999):

$$T = 2\pi\sqrt{\frac{l}{g}} \qquad (1)$$

From where $$g = 4\pi\frac{l}{T^2} \qquad (2)$$

where l is the length of the pendulum in meters (m) and T is the time in seconds (s).

Although, the computation g using Equation (2) based on the data obtained and shown in Table 2 gives 0.9654 m/s^2 which is not correct when compared to the standard value of g = 9.8 m/s^2; but the basic idea here is to introduce and show the students how the experiments can be carried before the actual conduct of similar experiments in a standard laboratory.

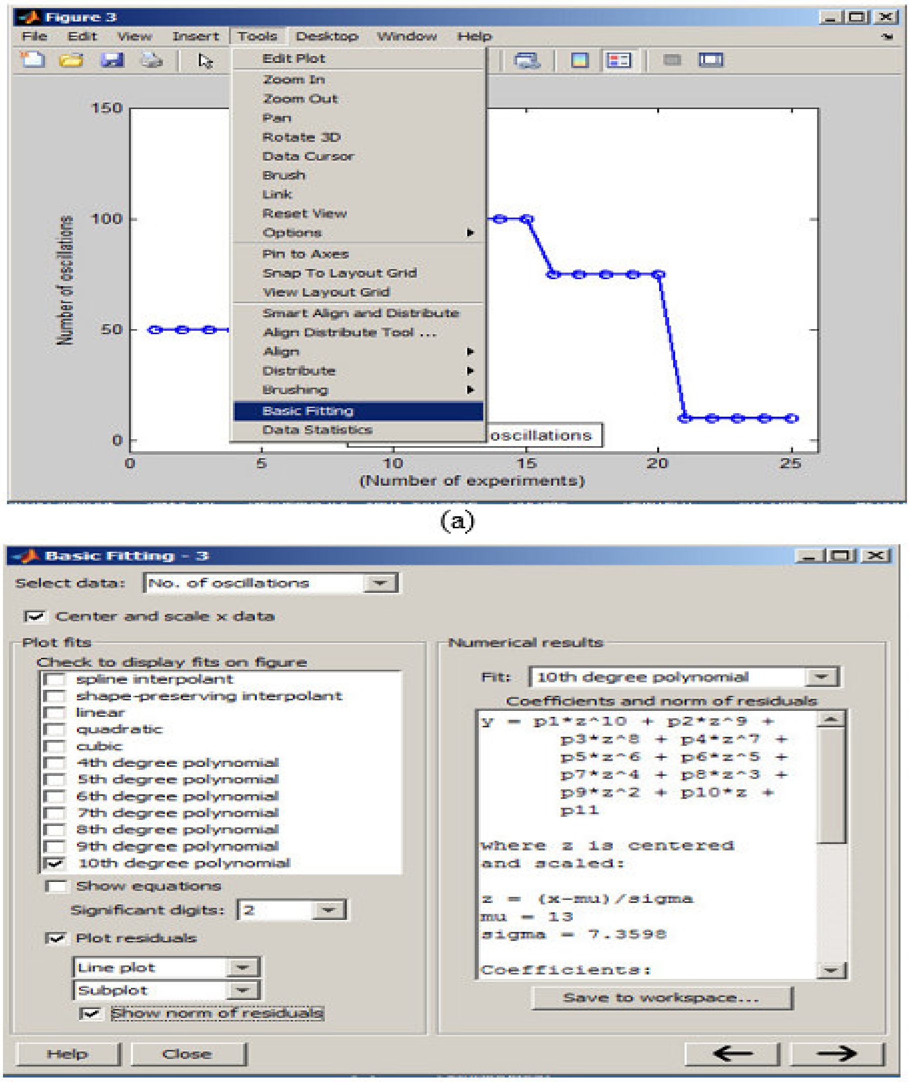
4.3 Predictive Mathematical Model for the Pendulum Experiment

Generally speaking, data are usually acquired from measurements or observations after carefully performing experiments. While some experiments can be simple, some can be challenging and time consuming. Thus, after successful experiments, predictive models can be developed that can be used for future predictions, estimations or forecasting given a single or multiple values for some or all the parameters of the system under consideration.

Thus, we extend this idea to the data obtained from the pendulum experiment as follows using the MATLAB/Simulink® (MathWorks, 2012) modeling and simulation software. For this illustration, we consider the graph for the number of oscillations only from Fig. 9.

i) After plotting the graph, select and left-click from the graph menu: Tool → Basic Fitting as shown in Fig. 10(a)

ii) On clicking the Basic Fitting option, the diagram of Fig. 10(b) pops-up. Although the “spline interpolant” and “shape-preserving interpolant” gives more accurate fitting results; but for the category of students considered for this demonstration, we chose between linear and 10th degree polynomial where the equations can be viewed as in Fig. 10(b). The remaining procedures are detailed and shown in Fig. 10(b) while the result of this fitting is shown in Fig. 11(a) for the number of oscillations.



(b)

Fig. 10: Procedures for fitting experimental data using MATLAB Basic Fitting tool: (a) selecting the fitting tool, and (b) fitting the data to generate suitable mathematical model.

Note that selecting the "*Center and scale X data*" check box improves the precision of the computed parameters when MATLAB displays the following warning: "*Polynomial is badly conditioned. Removing repeated data points or centering and scaling may improve results*". This is because a design matrix is constructed during the fitting procedure to compute estimates of the polynomial parameters. MATLAB displays a warning when the abscissa values (X) are large; because one column of the design matrix always contains 1s, and because powers of large X values can be orders of magnitude larger than 1, the precision of the parameter estimates suffers. Selecting this option, the columns of the design matrix are brought to the same order of magnitude by centering the X data at zero mean and scaling the data to a unit standard deviation. The scaling factors, *mu* = 13 and *sigma* = 7.3598, for all three parameters are the same.

Repeating the same procedures for the length of the pendulum and the time for given numbers of oscillations produce the graphs shown in Fig. 11(b) and Fig. 11(c) respectively. The respective predictive mathematical models for the three (3) parameters of the pendulum experiment are summarized in Table 3 written as a MATLAB program. Thus, given the length of pendulum (y_pend) and the time for a complete oscillation (y_time), the acceleration due to gravity can be readily computed using the program provided in Table 3.

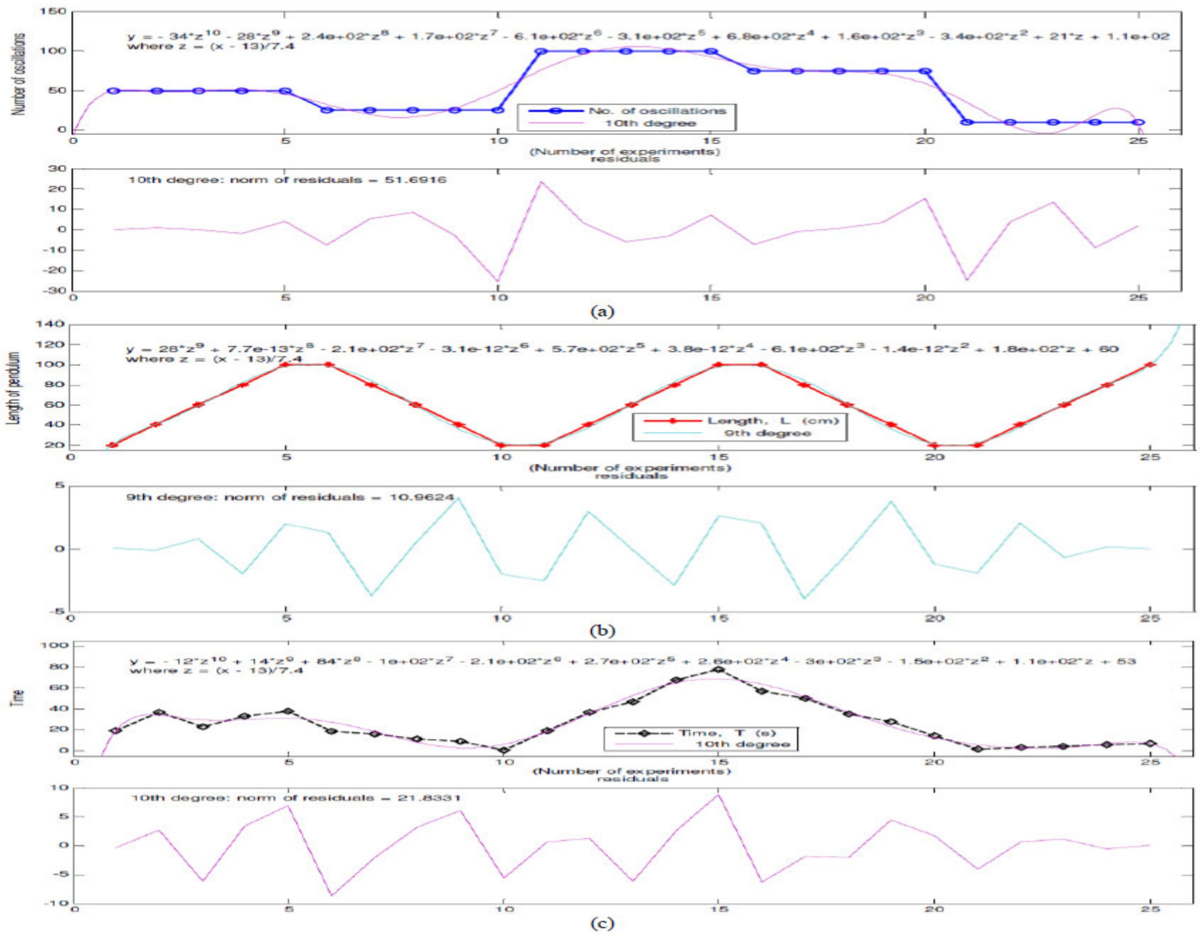


Fig. 11: Basic fitting of experimental results to generate a predictive mathematical model for each data set using MATLAB's Basic Fitting tool: (a) number of oscillations, (b) length of the pendulum, and (c) time for each number of oscillations.

Table 3: A predictive mathematical model for computing acceleration due to gravity

```
clear all; close all; clc;

x_osc   = ??;       % Number of oscillation
x_pend  = ??;       % Length of pendulum
x_time  = ??;       % Time for each number of oscillations
mu      = 13;       % mean
sigma   = 7.3598;  % standard deviation
%====================== Number of oscillation ===========================
         z = (x_osc - mu)/sigma;
         p1_osc = -34.188;    p2_osc = -27.999;   p3_osc = 240.21;    p4_osc = 166.8;
         p5_osc = -608.01;    p6_osc = -309.32;   p7_osc = 676.36;    p8_osc = 156.84;
         p9_osc = -335.42;    p10_osc = 20.816;   p11_osc = 105.99;
y_osc   = p1_osc*z^10 + p2_osc*z^9 + p3_osc*z^8 + p4_osc*z^7 + p5_osc*z^6 + p6_osc*z^5 +
         p7_osc*z^4  + p8_osc*z^3 + p9_osc*z^2 + p10_osc*z  + p11_osc;
%===================== Length of pendulum%==============================
         z = (x_pend - mu)/sigma;
         p1_pend = 27.724;          p2_pend = 7.7384e-13;     p3_pend = -211.67;
         p4_pend = -3.1476e-12;    p5_pend = 574.58;          p6_pend = 3.8215e-12;
         p7_pend = -610.86;         p8_pend = -1.4488e-12;    p9_pend = 179.75;
         p10_pend = 60;
y_pend = p1_pend*z^9 + p2_pend*z^8 + p3_pend*z^7 + p4_pend*z^6 + p5_pend*z^5 +
         p6_pend*z^4 + p7_pend*z^3 + p8_pend*z^2 + p9_pend*z   + p10_pend;
%================== Time for each number of oscillations ================
         z = (x_time - mu)/sigma;
         p1_time = -12.069;  p2_time = 14.095;        p3_time = 83.73;
         p4_time = -101.25;  p5_time = -214.82;       p6_time = 267.05;
         p7_time = 255.15;   p8_time = -303.39;       p9_time = -145.35;
         p10_time = 113.63;  p11_time = 52.832;
y_time = p1_time*z^10 + p2_time*z^9 + p3_time*z^8 + p4_time*z^7 + p5_time*z^6 +
         p6_time*z^5  + p7_time*z^4 + p8_time*z^3 + p9_time*z^2 + p10_time*z +
         p11_time;
%================= Compute acceleration due to gravity (g) ==============
g_num          = 4*pi^2*y_pend;
g_den          = y_time.^2;
accel_gravity = g_num/g_den
```

5. Conclusion

The web-based interactive virtual laboratory simulation software presented in this study will provide a stimulating learning environment to motivate students, promote a more active form of learning, and provide simulation processes that are demonstrated in standard laboratories. The feedback from students indicates that they appreciate this innovative working environment and feel encouraged to learn more effectively in this way. The virtual laboratory could therefore provide a complement to traditional laboratory resources. The Fact that the students do not have real hands-on experience is however considered a draw back. The virtual laboratory simulation software can only give a "real world"- like experience in performing practical laboratory work but this should benefit students in learning the subject.

This conclusion is also supported by the theory that, by maximizing interactivity, virtual laboratory applications render students active thinkers instead of passive observers and thereby construct effective and meaningful learning processes (Tamir, 1978). However, previous studies have stated that virtual laboratories facilitate the formation of conceptual models by providing activities that improve cognitive skills (Akaygun and Ardac, 2004).

Since physics is closely related to daily life, the use of an "*associate with real life*" tab within the software is expected to contribute to student achievement Some experiments can usually only be performed using a demonstration method, for reasons such as a lack of laboratories, insufficient material and crowded classrooms. For these experiments, it is clear that virtual laboratories can provide a valuable alternative to traditional laboratory applications (Ozdener, 2005). Students should be exposed to more laboratory applications and activities so that they can recognize laboratory materials and equipment. Knowing that students who do not have proper pre-knowledge and experience could not be successful while they were doing experiments (Uluçinar et al., 2004), one can see that a virtual laboratory environment provides students with the opportunity to develop interest in practical oriented courses such as physics, chemistry, biology, e.t.c.

At the end of the study, the virtual laboratory software was shown to be at least as effective as physics laboratories. It was determined that students in the control group could complete the experiments with reasonable results; they felt self-confident; they could associate the experiment with daily life; and they had the opportunity to examine each experiment. It is anticipated that virtual Physics laboratories will be adopted as supplementary and supportive elements in future. This will provide not only an effective learning environment but will also minimize school expenditures and the time spent on such activities to a large extent.

The techniques presented for the computation of the acceleration due to gravity and generating the predictive mathematical models can be adapted for other application real life scenarios where a single data is acquired at each time step.

The interactive virtual laboratory simulation software proposed in this study can be improved through many cycles of design, testing and modification. Supplementing the interactive virtual laboratory simulation software proposed here with synchronous communication methods such as video conference could enable instructors and students to interact directly on-line in real-time. Implementing discussion group or frequently asked questions could provide more channels for students' discussions.

References

Akaygun A. N and Ardac D. S. (2004): "Effectiveness of multimedia-based instruction that emphasizes molecular representations on students understanding of chemical change", *Journal of Research in Science Teaching*, vol. 41, no. 4, pp. 317–337.

Akpan, J. P., and Andre, T. (2000): "Using a Computer simulation before dissection to help students learn anatomy", *Journal of Computers in Mathematics and Science Teaching*, vol. 19, no. 3, pp. 297 – 313.

Algan, Ş. (1999): The influence of the Computer Based Physics Teaching on the success of the student and Modern Mathematics and Science Programs applied in Turkey in the years between 1962 and 1985", *Ankara: Gazi University, Institute of Science* (Unpublished Master Thesis).

Andaloro, G., Bellamonte, L. & Sperandeo M. (1997): "A Computer-Based Learning Environment in the Field of Newtonian Mechanics", *International Journal of Science Education*, vol. 19, pp. 661–680.

Bağcı, N. and Şimşek, S. (1999): "The influence of different teaching methods in teaching physics subjects on student's success", *The Journal of Gazi Education Faculty*, vol. 19, no. 3, pp. 79 – 88.

Bekar, S. (1996): "The influence of Lab Based Science Teaching on student's success", *Ankara. Gazi University, Institute of Science* (Unpublished Master Thesis).

Bennett, R. (1986): "The Effect of Computer Assisted Instruction and Reinforcement Schedules on Physics Achievement and Attitudes Toward Physics of High School Students", *Dissertation Abstracts International*, vol. 46, no. 2, 3670A.

Bernard, R. M., Abrami, P. C., Lou, Y., Borokhovski, E., Wade, A., and Wozney, L. (2004): "How does distance education compare with classroom instruction? A meta-analysis of the empirical literature", *Review of Educational Research*, vol. 74, no. 3, pp. 379 – 439.

Blaylock, T. H., and Newman, J. W. (2005): "The impact of Computer-based Secondary Education", *Education Chula Vista*, vol. 125, no. 3, pp. 373 – 384.

Bozkurt, E. (2008): "The effects on students' success of a virtual laboratory application prepared in the physics education", *Selcuk University, Konya* (Unpublished PhD thesis).
Bryant, R. J. and Edmunt, A. M. (1987): "They Like Lab-Centered Science", *The Science Teacher*, vol. 54, no. 8, pp. 42-45.
Choi, B. and Gennaro, E. (1987): "The effectiveness of using computer simulated experiments on junior high students: understanding of the volume displacement concept", *Journal of Research in Science Teaching*, vol. 24, pp. 539 – 552.
Clark, H. (1998): "Using Language", *Cambridge University Press*, Cambridge.
Eylon, B., Ronen, M. and Ganiel, U. (1996): "Computer Simulations as Tools for Teaching and Learning: Using a Simulation Environment in Optics", *Journal of Science Education and Technology*, vol. 5, pp. 93 – 110.
Gülçiçek Ç. and Güneş, B. (2004): "Materializing the concepts during Science Instruction: Modeling Strategy, Computer Simulations and Analogies", *Science and Education*, vol. 29, no. 134, pp. 36 – 48.
Gustavsson, I. (2002): "Remote laboratory experiments in electrical engineering education", *Proceedings of the 4th IEEE International Caracas Conference on Devices, Circuits and Systems, Aruba*, I025-1–5.
Ibiş, M. (1999): "The influence of Computer assisted Science Instruction on the success of the students". *Ankara Gazi University, Institute of Educational Sciences* (Unpublished Master Thesis).
Jimoyiannis, A. and Komis, V. (2000): "Computer simulations in Physics teaching and learning: A case study on students understanding of trajectory motion", *Computers and Education*, vol. 36, pp. 183 – 204.
Jones, E. and Childers, R. (1999): Contemporary College Physics, 3rd ed., McGraw-Hill Company, Inc., U.S.A.
Karamustafaoğlu, O., Aydın, M. and Özmen, H. (2005): "The influence of the Physics activities supported with Computer to the learning of students: An example of Simple Harmonic Activity", *The Turkish Online Journal of Educational Technology – TOJET*, October 2005, vol. 4, no. 4, Article 10.
MathWorks (2012): The MathWorks Inc., MATLAB & Simulink® R2012b, *Natick, USA*. www.mathworks.com.
McCoy, L. P. (1991): "The Effect of Geometry Tool Software on High School Geometry Achievement", *Journal of Computers in Mathematics and Science Teaching*, vol. 10, pp. 51 – 57.
Meyveci, N. (1997): "The influence of Science instruction supported with computer to the success of the students and to the attitude of the students against computer", *Ankara University Social Science Institute* (Unpublished Master Thesis)
Miller, D. G. (1986): "The Integration of Computer Simulation into the Community College General Biology Laboratory", *Dissertation Abstract International*, vol. 47, no. 6, 2106-A.
Okon, M., Kaliszan, D., Lawenda, M., Stoklosa, D., Rajtar, T., Meyer, N. and Stroinski, M. (2006): "Virtual laboratory as a remote and interactive access to the scientific instrumentation embedded in grid environment", *Proceedings of the Second IEEE International Conference on e-Science and Grid Computing*, Washington DC, USA, pp. 642 – 649.
Ozdener, N. (2005): "Using simulation for experimental teaching methods", *Turkish Online Journal of Educational Technology (TOJET)*, vol. 4, no. 4, pp. 93 – 98.
Ozdener, N. and Erdogan, B. (2001): "Improving the virtual laboratories which give the possibility of evaluating the experimental data and giving feedback", *Educational Science Journal of MU Faculty of Ataturk Education*, vol. 14, pp. 107–120.
Redish, F. E., Jeffery S. M., and Steinberg R. N. (1997): "On the Effectiveness of Active Engagement Microcomputer based laboratories", *Department of Physics, University of Maryland College Park*.
Reed, B. B. (1986): "The Effects of Computer Assisted Instruction on Achievement and Attitudes of Underachievers in High School Biology", *Dissertation Abstracts International*, vol. 47, no 4, 1270-A.
Şen A. İ. (2001): Approaches in Science Instruction supported with Computer" *Journal of Gazi Education Faculty*, vol. 21, no. 3.
Şengel, E., Özden, M. Y.& Geban, Ö. (2002): "The Influence of the simulated experiments supported with computer on high school students comprehending the replacement and velocity concepts", V *National Science and Mathematics Education Symposium*, Ankara:
Soylu, H., & Ibiş, M. (1999): Science Education supported with Computer, *Third Science Education Symposium*.
Svec, M., T., and Anderson, H., (1995): "Effect of Microcomputer-Based Laboratory on Students Graphing Interpretation Skills and Conceptual Understanding of Motion", *Dissertation Abstracts International*, vol. 55, no. 8, 2338-A.
Tamir, P. (1978): "An Analysis of Laboratory Activities in Two Modern Science Curricula; Profect Physics and PSSC." Paper Presented at the National Association for Research in Science Teaching Annual Meeting in Toronto, Ontario, pp. 79 – 91.
Uluçinar, Ş., Cansaran, A. & Karaca, A. (2004): Evaluating the applications of Science Laboratory" *Türk Eğitim Bilimleri Dergisi,* vol. 2, no. 4.
Yavru, Ö. (1998): The influence of the laboratory experiments on the success of the 4th and 5th graders of the

primary schools about the subject of Mechanics and on internalizing these concepts. Istanbul: *Marmara University, Institute of Educational Sciences* (Unpublished Master Thesis).

Yiğit, N. & Akdeniz, A. R. (2003): "Developing the Materials during Physics instructions supported with computer students working papers", *IV National Science Symposium*, Hacettepe Education Faculty, Ankara.

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