ASSESSING EFFECTIVENESS OF INTERACTIVE ELECTRONICS LAB SIMULATION: Learner's Perspective

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ABSTRACT

Simulation enables learning by doing and provides opportunity to explore the modeled domain. Interactive simulation allows to present information in more dynamic, compelling and interactive way with engaging environment. This paper discusses the application of interactive simulation supporting the actual laboratory session of basic Electronics lab activities. For this, interactive simulation for one of the basic electronics lab activity was designed, developed with state of art technology 'Flash MX 2004' and evaluated for its effectiveness. A particular focus of this investigation is on how the use of interactive simulation influences learners' approach to learning. Pre test and post test were administrated on the target group, using quasi-experimental research methodology.

'Total quality' of developed package was evaluated by administrating a separate questionnaire. The comments and ratings obtained in the learners' insights provided the basis for the learning impact study. This investigation indicated that the 'self paced interactive simulation' provides added value to the learners for the study of fundamental concepts of both theory and lab, able to perform lab experiment prior to an actual laboratory session and reach to the level of proficiency.

Keywords: **Computer Simulation; Electronics Engineering; Computer assisted learning; Multimedia; Interactive eLearning; IT use in engineering Education; Practical Learning Support; Distance Learning**

INTRODUCTION

In engineering education, concepts taught through lectures are often complemented by laboratory experiments. Laboratories are critical to enable learners, such as engineering learners, to develop knowledge and skill. To perform such lab activities in the laboratory, a learner gets maximum 3 hrs per experiment in conventional as well as distance education system. During this stipulated period, learner has to perform various lab activities.

He/she does not get sufficient time to observe response of the given circuit for various component values and think critically on obtained response. Further, in the distance education, heterogeneity of the learners as well as non-uniform quality of course content delivery at each study centre creates a serious problem in imparting technical education.

Hence, distance learners lack in the practical skill and have to face lot of difficulties may be due to poor quality of instructional material, unavailability of well qualified and experienced instructor, limited duration of practical contact session at the study centre, lack of up to date laboratory infrastructure and so on. All these factors further influence the loss of motivation, understanding of complex concepts, and the development of engineering approach to solve realistic problems. One solution to avoid these difficulties is to develop a supplementary lab material which creates exciting, engaging and simulating practical environment. In which, practical activity content should be presented in a way that it will provide in depth exploration of the electronics concepts, allows learner to understand how electronics circuits operate and can be utilized in real life situations. Further, learner should get an overall idea of how to perform the experiment, analyze the effect of various component values on the circuit response and be confident to handle various equipment/instruments in the laboratory. Interactive multimedia simulation is an appropriate way to complement engineering education for the following reasons, it:

- **Helps to comprehend basic concepts clearly thus increases the pace of learning**
- **Offers uniformity in dissemination of quality content at various study centres and does not depend on the instructor's skills anymore.**
- **Integrates fundamentals of any subject, which are often responsible for the success/failure of a learner**
- **Improves assimilation and memory since it stimulates all senses of the human body simultaneously. Multimedia enriches pedagogy through integrating different media such as graphics, sounds, music, voice, videos and animation.**
- **Provides complete control to learner so that they may review the learning material at their own pace and in keeping with his/her own individual learning styles, interests, needs, and cognitive processes.**

On this backdrop, it was decided to develop a standalone interactive multimedia simulation lab environment for 'Basic Electronics' course of 'Electronics Engineering Programme', to explore circuit operation and lab procedures effectively. But in general it cannot replace experiments in real lab, since simulation is only as good as a comprehension model. However, the combination of real lab and simulation can greatly enhance the understanding of real world situations.

RESEARCH OBJECTIVES

This research project involved designing, developing and piloting interactive computer simulation. It was to implement instructional design principles to enhance learning via interactive multimedia, within a context of Electronics lab activities. This also involved a development of randomized self test with immediate feedback based on theory and lab knowledge. The objectives of study are to;

- **Test effectiveness of developed simulation lab activity on learners' comprehension using a randomized self test with immediate feedback based on theory and lab knowledge.**
- **Evaluate the total quality of simulated electronics experiment in perception of the learners**
- **Investigate the usefulness of developed simulation environment in enhancing the overall proficiency of the learners**.

REVIEW OF RELATED LITERATURE

Van Schaick Zillesen (1990) gives a description of educational computer simulation with characteristics:

> **'*The major purpose of an educational computer simulation program is to provide students with a representation of a part of reality. The students are able to manipulate this representation, e.g. by changing the properties of the representation or by changing the conditions under which the representation operates. The behaviour of the representation as a result of these changes is similar to that of the represented part of the reality.'* (p. 1)**

Thomas and Hooper (1989) discuss the instructional use and sequencing of computer simulation and its effect on students' cognitive processes. The sequence in which learning occurs influences the stability of cognitive structures (Ausubel, 1968). New knowledge is made meaningful by relating it to prior knowledge and optimization of prior knowledge is done through sequencing. According to Gokhale (1991), simulations used prior to formal instruction build intuition and alert the student to the overall nature of the process. When used after formal instruction, the program offers the student an opportunity to apply the learned material.

Based on Hung (2001) review of available research and literature, he suggests that there is a role for behaviorist, cognitivist, constructivist and social constructivist models of learning in the design of educational simulations. Learning through simulations also supports the process of learning via situated cognition. According to the theorists, knowledge is built through interactions between the learner and his/her environment. Simulations permit learners to build knowledge through interactions with their virtual environment. Experiencing and exploring the context and relationships between objects, concepts and the world are key elements in facilitating such knowledge construction (Duncan, 1995; Hung, 2001).

Simulations can offer unlimited opportunities to practice, which supports learning via the behaviorist approach of drill and repetition. Simulations also offer learner the opportunity to test new knowledge, strategies, skills and techniques in a virtual, risk-free environment. Many educators believe that experiencing failure such as this is a critical component in the learning process (Schank, as cited in Galarneau, 2005). In particular, computer simulation exercises based on the guided discovery learning theory can be designed to provide motivation, expose misconceptions and areas of knowledge deficiency, integrate information, and enhance transfer of learning (Mayes, 1992). Magnusson and Palincsar (1995), simulations are seen as a powerful tool to teach not only the content but also thinking or reasoning skills that are necessary to solve problems in the real world. The purpose of the simulation is to enable users to explore interactions between the elements, observe system operation over the time and ask *what if* questions about the effects of changes to any of the system elements or attributes (Sauve, Renaud, & Kaufman, 2005).

Even with the advantages of simulations, hands-on labs are tremendously important in the industrial technology curriculum. The professional success of a technologist is directly related to her/his ability to transfer knowledge gained in the academic environment to real-world situations.

The basic premise of experimental learning theory is that students learn as a result of doing or experiencing things in the world, and learning occurs when mental activity is suffused with physical activity (Smith, 1995). Acquisition of manipulative skills is only possible through the use of real instruments and real experimental data. Therefore, to enhance learner learning, the technology curriculum must integrate the effective characteristics of both computer simulations and lab activities.

In addition to literature on media studies and the use of various media in general, there are studies that specifically investigated the use of computer technology and simulation software in the teaching and learning of electronics. Gokhale compared a "canned" simulation program that requires a learner to apply "rules of logic" with hands-on laboratories in teaching logic circuits. He also examined the effects of sequencing of the instruction and the laboratory on teaching and learning. He found that there were no significant differences in posttest scores between the groups who used computer simulation and those who used the hardware laboratory.

Gokhale reported that using Electronics Workbench to design an amplifier circuit before designing, building, and testing the circuit in the hardware lab helped an experimental group perform significantly better on problem-solving tests. Other articles that discussed the use of interactive laboratory simulation using digitized stop-action video, to supplement teaching laboratories in chemistry for distance delivery, author Dietmar Kennepohl (2001) concluded in his study that, using simulation learners completed in-laboratory work in a shorter time frame and showed a slightly higher performance in the practical laboratory component. Shuhui Li (2005) demonstrated the mechanisms and approaches developed for strong correlation between theories and hands-on experimentations using modern computer tools for the purpose of quality education of a laboratory course in electric and electronic circuits.

Other than literature review, researchers has done survey of many circuit simulations, available in market and used primarily to build and test circuits. For example, the circuit simulation programs *SPICE*, *APLAC, PSPICE* from Cadence, and *Intusoft ICAP/4*, which are mainly used for designing circuits. Other circuit simulations that facilitate learning in electronics labs. Examples are *Multisim*, part of the *Electronics Workbench* product and *Circuit Maker* are popular circuit capture and simulation systems that are also used for education. Both Circuit Maker and Electronic Workbench may reduce the cost and time of laboratory learning experiences. These are commercial product; it is beyond the reach of many educational institutions and students because of accessibility.

This researcher is not directly comparing real laboratory work with simulations alone, or with simulations that are readymade and commercially available. This researcher will test the effectiveness of self-developed interactive simulations based on instructional pedagogy, which suits the targeted learning goals.

METHODOLOGY

The research described in this paper comprises a quasi-experimental research methodology. A quasi-experimental is particularly suited where, a researcher possibly does not have a control over participants' characteristics like the level of knowledge, grasping capacity, background etc and it is necessary to select participants for the different conditions from previously existing group.

According to Wiersma William (1991), 'Quasi experiment research involves the use of intact groups of participants in an experiment, rather than assigning participants at random to experiment'.

In this research intact group was fourth semester learners of B.Tech Electronics programme. Here, independent variable was the product 'Practical Simulation On Wien Bridge Oscillator' and performance level of learner was the dependent variable. This is study of pre test and post test of one group.

A pre-test was administered to all participants prior to the treatment to assess learners' prior knowledge of theory and lab activity for Wien bridge oscillator, referred as pre experimental evaluation. Then a group of individuals was exposed to a product (media stimulus) for a period of time i.e. the influence of independent variable and finally a posttest was administered to measure treatment effects. This test was randomized and designed to assess the content that was previously learnt and to have the learners apply the learned material.

A 't' test was administered to find out the significance of the difference between mean scores of the pre test and post test. Then participants were asked to evaluate quality of the developed simulation using an established rating instrument and to provide feedback for improvement of resource.

Prototype Design and Development

The core part of any design and development of computer simulation is the adoption of proper instructional design strategies. The effective instructional design strategy in the engineering domain should be based on important pedagogical and technological considerations.

It is also important to formulate how available technology can be used to facilitate desired learning objectives within the psychological and pedagogical constraints (Arun S. Patil & Zenon J. Pudlowski, 2003). In the case of an instructional strategy applied to the engineering domain, it is suggested to apply an effective, experiment-oriented and heuristically approached strategy. Hannafin (1997) points out that those individual learners who have limited prior knowledge may lack the initial understanding of the concept, which is required in order to quickly assimilate new information.

As a result, learners tend to be more dependent on the instructional structures provided by the designer in order to acquire a new concept or knowledge. It is essential to consider the available methodologies, as well as individual learning styles and learning abilities, while developing any instructional strategy.

Cabrera, Krishnamurthi, & Rhode (2007) in their research rightly presented that the Flash-based role simulation as an effective learning strategy, compared to passive Web tutorials, for promoting research integrity.

Further, stated the advantages of implementing the Flash-based simulations which involved interviewing content experts, designing storyboards, developing and testing the simulations, and delivering them online as a part of learning modules.

Table: 1
Outline of content organization in the frame format of Flash Mx 2004

SN	Frame	Description
1	**Welcome Screen**	**Invokes the practical simulation topic 'Wien Bridge Oscillator'**
2	**Main Menu [**Refer: Fig 1**]**	**Shows Content outline like Pre test, Learning Objectives, Material Required, Theory, Procedure, Experiment, Study Tips, Home Assignment, Self Test & Post Test. Learner can escape already known topic and jump to the desired one.**
3	**Pre test**	**To test prior knowledge of the learner a randomized pre test is embedded**
4	**Learning Objectives**	**Learning objectives are stated with action verb based on Blooms taxonomy**
5	**Material Required**	**Shows required components and equipments to perform the experiment in physical lab as well as in simulation**
6	**Theory**	**From pre-requisites to summary complete theory of Wien bridge oscillator is presented w use of text, animated graphics.**
7	**Procedure [**Refer: Fig 2**]**	**A step by step procedure about how to mount the test circuit on the breadboard was animated and steps involved performing the experiment was explained to get feel of real lab environment. It could help learners while writing lab report.**
8	**Experiment** **[**Refer: Fig 3a and 3b **]**	• **To perform experiment, learner has to enter various component values, required supply voltage within specified range [Refer: Fig 3a]** • **Circuit diagram gets automatically updated as per entered values [Refer: Fig 3a]** • **Learners can immediately observe the output waveform on the math driven simulated oscilloscope where learner can measure amplitude and frequency parameter same as in real lab. For accurate measurements, learner can adjust both the parameters using Volt/div and time/div knob on the simulated Oscilloscope [Refer: Fig 3b]** • **By varying components values, supply voltage etc learner can conduct "What if …" investigations.**
9	**Observation Table, Result & Conclusion**	**Offers opportunity to average learners to go through the simulation again, at least to see effect of gain, frequency and supply voltage variation on the circuit operation. Further provides help while writing lab report**
10	**Study Tips**	**For further study, a list of reference books, web links, and data sheet of IC 741 in PDF format is given to study its electrical characteristics and specification.**
11	**Home Assignment**	**To motivate further reading and enhance understanding level, descriptive type of items is presented based on the content covered.**
12	**Self test**	**To get immediate, most realistic and effective feedback about the lab content learned, 'randomized with feedback mechanism self test' is embedded. Additionally, at the end of self test, learner's performance is reported in the form of total correct answers, total wrong answers and total percentage.**
13	**Post test**	**Based on the theory and lab activity content covered, randomized post test is embedded. At the end, learners' achievement in the form of total correct answers, total wrong answers and total percentage is presented.**

For instructional strategy, distance education pedagogy for laboratory experiments was used, referred as self instructional material (SIM) and for multimedia simulation, design of the activity followed recommendations provided in *Educational Characteristics of Multimedia:* A Literature Review (Luann, K. Stemler (1997).

Considering above viewpoints, Wien bridge oscillator lab activity was designed and created with the computer program 'Macromedia Flash Mx 2004'. Following Table: 1 shows the outline of content organization in the frame format of Flash Mx 2004. All materials were tested through a pilot before full implementation.

Figure 1

Shows Content outline presented in simulatic

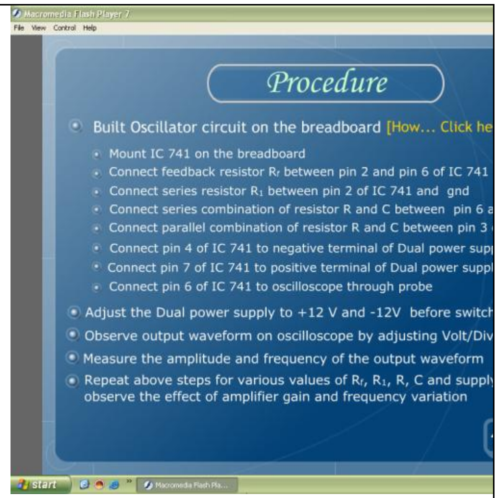

Figure 2

A step by step procedure about hov to build circuit and simulate it

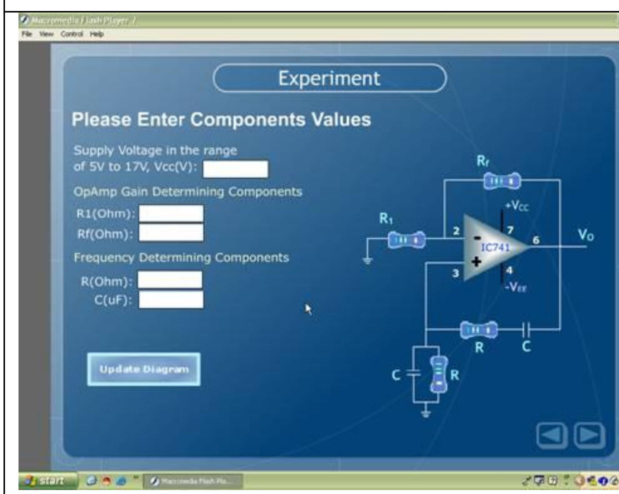

Figure 3a

Experiment screen where learner can entere component values to observe circuit output

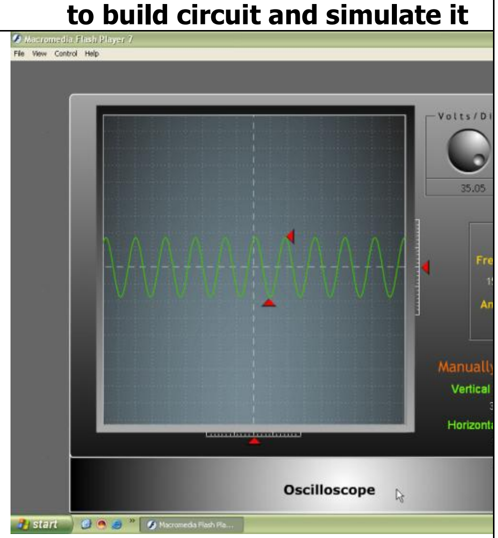

Figure 3b

Animated Oscilloscope shows outpu waveforms for entered component values

Unique Feature

- **Discovery Oriented - Interactivity**

Interactive electronics lab simulation is a tool for discovery learning and helps students visualize and learn abstract concepts.

It develops inquiry skills and electronic circuit knowledge by allowing the students/users to vary nearly any physical parameter (e.g., component values, power supply) and to measure its effect on nearly any measurable quantity (e.g., output waveform, gain, output frequency).

Other Features

- **Enables anywhere anytime self-learning**
- **Offers opportunities to learners to try out the lab activity before it is implemented, to practice 'n' number of time in a low-risk environment and to develop confidence to perform lab tasks competently**
- **A control panel provides easy point and click access to input and output devices, making it efficient to run simulations and conduct "What if ..." investigations**
- **Helps learners discover that real problems are open to interpretation and may support many different solutions**
- **Includes realistic graphical representation of the breadboard and equipments**
- **Provides access to simulated equipment such as an oscilloscope**
- **Self test with immediate feedback about answer given, motivates learner to study content in depth**
- **Can be used as supporting or supplementary learning material for hands-on experimentation Basic Electronics Course, for both conventional and distance education learner**
- **Accommodates individual differences in learning styles**
- **Well organized content with sufficient depth and logical flow of presentation**
- **Well illustrated diagrams with text and graphics animation**
- **Simple and intuitive navigation, pleasant color scheme**
- **Web compatible and reduced file size (1.24MB), can be delivered on web and/or CD-ROM**

Participants

Yashwantrao Chavan Maharashtra Open University, Nashik offers B.Tech Electronics Engineering programme through School of Science and Technology. 'Basic Electronics' course is offered at fourth semester and a core subject of this programme. In Maharashtra state, about 30 counselors offer academic support to annually enrolled 300 learners at 30 different study centers. The sample for this study included 34 learners (11.33%) of total population offered at 4th semester. For convenience, researcher had selected four study centres for evaluating the effectiveness and quality of the final product.

Instruments

A questionnaire was specially designed and used to collect learner's individual assessments of the quality of the developed simulation lab activity and its effectiveness. The instruments used in this study were developed by the author. Both pre test and post test were in randomized in nature. There were 20 items designed to measure learner's understanding of theory and related lab activity of Wien bridge oscillator and hence belonged to the cognitive and psychomotor domain. Bloom's taxonomy (1956) was used as a guide to develop a blueprint for the pre test and post test. Learner's questionnaire included total 36 items to evaluate the product. The data regarding general background information of learners were collected from 8 items and the media exposure and its use was ensured from 2 items.

The quality of product i.e. the feedback about the practical simulation of Wien bridge oscillator was collected from 26 statements, each of which was followed by four answer choices indicating degree or intensity.

All these 26 statements were rated by learner after use of the product. To evaluate the effectiveness of product, rating scale was used so as to enable the respondents to express themselves more precisely.

Treatment

Evaluators were given a copy of developed lab simulation on CD (cross-platform for Windows operating systems) with both written and oral instructions, and an evaluation form to determine its effectiveness and impact on learning.

DATA ANALYSIS

General Information of Respondents

The general background information of learners was collected through eight questions of pre test questionnaire. This was essential for determining the entering behavior of the learners. The learners' responses were tabulated as given below.

Table: 2
Agewise, Genderwise and Areawise Respondents in Sample

	Age Group				Gender		Area	
	15-20	21-25	26-30	above 30	Male	Female	Urban	Rural
No. of Respondents	21	8	0	5	33	1	18	16
Percentage Response	61.76	23.53	0	14.71	97.06	2.94	52.9	47.1
Total	34				34		34	

The above percentage showed (see table 2) that maximum enrolled learners for B.Tech in Electronics programme are from the age group of 15-20. It is evident that 29 respondents (comprising over 85%) were from the first two groups. They were young and interested enough to work through the content being presented in multimedia format.

Further, from the percentage it was revealed that maximum learners of this programme were male. On this background, the researcher felt the need to examine the reasons of low enrolment of female learners.

Table: 3
Qualificationwise and Employment wise Respondents in Sample

	Educational Qualification					Employment Status		
	SSC	HSC	ITI	Diploma	Degree /P Grad	Un-employed	Employed	Self Employed
No. of Respondents	20	10	1	3	0	27	6	1
Percentage Response	58.8	29.4	2.94	8.82	0	79.41	17.65	2.94
Total	34					34		

This indicator may provide some further reasons to study. The percentage of urban and rural learner showed nearly equal distribution of sample respondents.

This indicated the learners from the rural area also enrolled to this Programme, to satisfactory extent The quantity in the above table 3 indicated that maximum enrolled learners for B.Tech in Electronics Programme had SSC qualification, followed by HSC, diploma and ITI. The percentage of employment status quantity indicated that maximum enrolled learners for this programme were unemployed.

They had enrolled to this course full time or learnt along with other education. There were some learners who were self-employed and did this programme either for self-satisfaction or to acquire latest knowledge.

Media Exposure and Use

The information regarding the number of learners who had exposure to CD and able to continue to work through the content matter', was collected by two questions in the pre test questionnaire.

Table: 4
Based on familiarity with use of computers for education/learning and Access to Computer

	Computer Access at				Familiarity with use of computers				
	Home	Work pl	Cyber c	Study Centre	Use Internet often	Use computer t help with homework/ oll school projects	Use Internet to help with homework/ sch /college project	Use CD ROMs to learn	Subscriber to a learning site
No. of Respondents	7	4	4	19	25	11	10	5	3
Percentage	20.5	11.8	11.8	55.8	73.5	32.35	29.41	14.7	8.82
Total	34				34				

The above percentage showed (see table 4) that for this Programme, all the enrolled learners had access to computer. One of the prominent Features of this programme is that the study centres offer computer facility to learners hence most of the learners prefer to have a computer access at study centre rather than cyber cafe or work place.The learners of this programme were well acquainted with the use of computer and internet for learning purpose. Some of the learners already used CD ROMs to enhance the understanding of course content and few of them were subscribes some educational CDs too. This showed more positive attitude of learner towards eLearning.

Table: 5
Analysis of Questions Based on Cognitive Level

Cognitive Level	No. of Questions	Percentage
Knowledge	5	25
Comprehension	10	50
Application	5	25
Total	20	100.00

Content Based Questions

The general awareness level of learners about the content was collected through 20 (twenty) questions of pre test questionnaire (see table 5) with three different cognitive levels. It contained 17 (Seventeen) multiple choice questions, 2 (two) fill in the blank questions and 1 (one) true or false type of question.

Each question of pre test was given 1 mark, thus 20 questions carries total 20 marks. After collecting pre test data from respondents, product was given to them to explore for a week. At the end of week, the same questions of pre test were asked to solve as a posttest to test enhancement in comprehension of content and performance level. Both pre test and post test were randomized in nature and embedded in the product but to keep record these tests were carried out in written form as well.

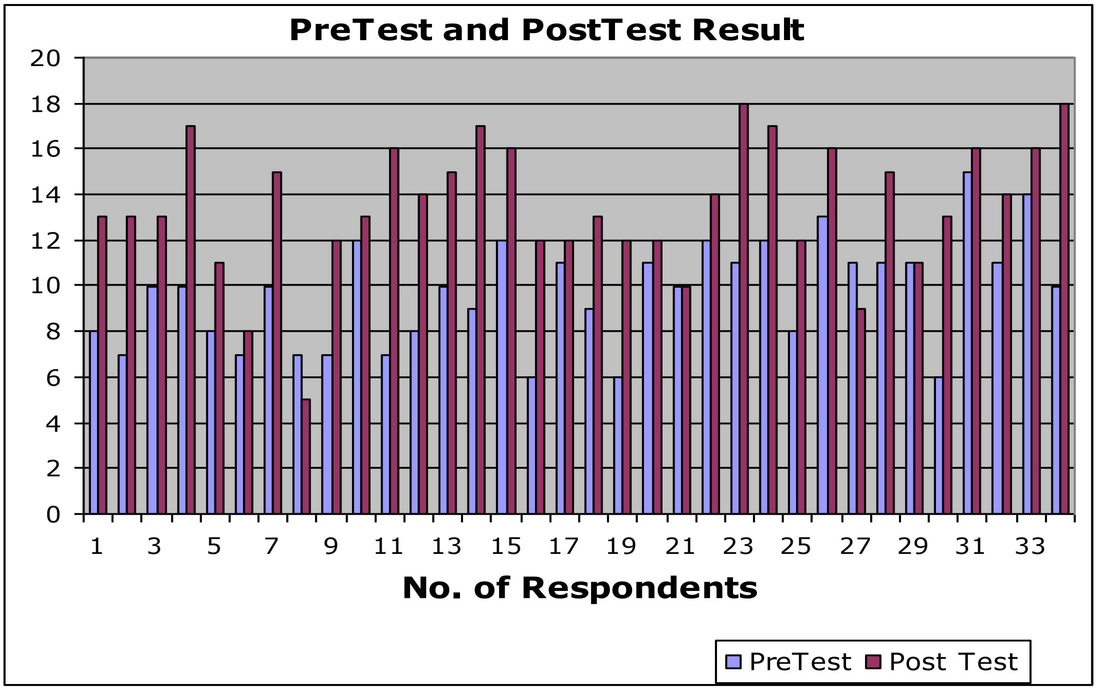

Fig: 4
Bar Chart summarizes the analysis of pre test and Post test scores

Table: 6
Difference between Post Test and Pre test Score

SN	Range	No. of Respondents Score	%
A	**Different levels of Increase**		
1	**≤10%**	**7**	**20.59**
2	**11-15%**	**4**	**11.76**
3	**16-20%**	**4**	**11.76**
4	**21-25%**	**5**	**14.71**
5	**≥25%**	**10**	**29.41**
B	**No Change**		
		2	**5.88**
C	**Negative Change**		
		2	**5.88**
	Total	**34**	**100.00**

Here, bar diagram (see fig 4) is used to represent the obtained score of individual in pre test and posttest more clearly. The visible increase in the height of bars representing post test scores indicated visible increase in the post test scores of the learners. From the difference column (see table 6), more than 50% of respondents were shown significant enhancement in their performance level.

Only two respondents (5.88%) had score less than pre test score after exploring product, which indicates unfavorable response. This response depends on how often they have taken advantage of computer while learning or whether they were familiar with language used to explain the content.

Statistical Analysis of Pre test and Post Test Score

Following Table 7 summarizes the important statistical information regarding the pre test and posttest data of 34 respondents.

Table: 7
Statistical Analysis of Pre test and Post Test Score

Parameters	PRE TEST	POSTTEST
No. of Respondents 'N'	34	34
Max	15	18
Min	6	5
Sum	330	458
Mean	9.7	13.47
Median	10	13
Mode	11	13
Standard Deviation 'σ'	2.3423	2.9049

The post test mean is greater than pre test mean which is an indicative of significant increase in the respondent's performance level and usefulness of product in communicating content. This indicated that the learners understood the content presented with the help of state of the art of multimedia technology, hence, product provides an enhanced or augmented learning experience at a low cost.

Table: 8
Results of paired t –test

Respondents 'n'	Mean of Differences '$\overline{D}$'	Std deviation differences 'σ_{diff}'	t- value observed	Critical t-value from table for one tailed test
34	3.7647	2.8290	7.75941	1.645 for 5% level of significance 1.282 for 1% level of significance

The observed value of 't' is 7.75941 (see table 8) exceeds the critical value for rejection of 'H_o' null hypothesis (i.e. the mean of difference of before and after treatment is zero). Thus, we reject H_0 at 1% as well as 5% level of significance and would be reasonably confident to conclude that the product had been effective for imparting content and learners' performance is better after the use of lab simulation.

Evaluation of product by target group

To evaluate the product by the target group, total 26 statements were asked to respond.

Table 9
Scorewise Frequency Distribution of Reponses

Range	No. of statements	%
95-100	4	16
101-106	6	24
107-112	6	24
113-118	4	16
119-124	3	12
Above 125	2	8
Total	25	100.00

Each statement rated the various aspects of this product on a scale of 1 to 4, where 1 equal "strongly disagree" and 4 equal "strongly agree". 1 represented the lowest and most negative impression on the scale and 4 represented the highest and most positive impression. The 26th statement was related to comments or suggestions hence it was not included in the following score value Table: 9.The following figures 5 shows the bar chart of scorewise frequency distribution of participants' responses mentioned in the Table: 9.

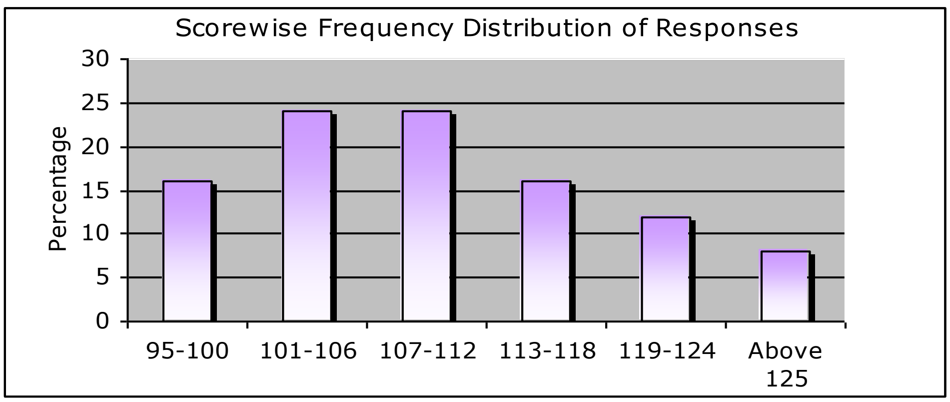

Figure 5
Scorewise Frequency Distribution of Reponses

Observations and Interpretations

The overall response of respondents for all the statement were towards rating scale 3 (Agree) and 4 (Strongly Agree). The highest response was 129 for question no.9 and lowest was 97 for question no. 24 and 25. This indicated that the response of respondents has in favour of all the statements. Results of the questionnaire revealed that the score for statements 1, 20, 24 and 25 is less than 100; researcher has tried to find answers of it.

Statement no. 1 The learning objectives are clear to me,

Out of 34 only 30 respondents replied. 40% respondents strongly agreed while 50% respondents were shown only agreed response whereas 6.67% respondents were disagreed and only 3.33% respondents were strongly disagreed.

This indicates that 10% respondents didn't understand learning objectives of this product. They require extra inputs; they may require instructor's help while performing this experiment or prefer group activity.

Statement no. 20 I can learn on my own now

Here like statement no.1, out of 34 only 32 respondents were replied. 34.38% respondents were strongly agreed while 46.88% respondents were shown only agreed response whereas 15.63% respondents were disagreed and only 3.13% respondents were strongly disagreed. This indicated 81% respondents were confident to perform Wien bridge oscillator practical activity on their own after exploring this product. Remaining 19% respondents were not sure about it, they would require more practice.

Statement no. 24 The product information helped me to solve and apply to problems mentioned in the home assignment

The total 64.70% respondents were in favour of this statement. Whereas 23.53% respondents were disagreed and 11.76% respondents were strongly disagreed about this statement. This indicated 35.26% respondents found Wien bridge oscillator product information insufficient, they would require extra efforts and help to solve the home assignment questions. This happen only in situations such as either they would not have tried to solve questions or they might have skipped theory part covered in the product.

Statement no. 25 Some technical knowledge is essential to operate this practical simulation product

The 39.39% respondents were agreed and 30.30% respondents were strongly agreed that to use this product some technical knowledge is essential. Whereas 24.24% respondents were disagreed and 6.06% respondents were strongly disagreed about this statement. They felt that there is no need of technical knowledge to operate this product, since the product offers user friendly interface.

Discussion based on the obtained Data

Overall, learners surveyed found the actual operation of computer simulation to be fairly straightforward. That is, the simulations were easily accessed on the computer (80%), accuracy of content, theories, principle, instructions and procedures explained in the product were clear and easy to follow (84%).

From the favorable responses of the respondents it is cleared that the activities covered in this product with enough practice and feedback, graphics animation, simulation environment, fonts and other visual elements, user-friendly interactivity (76%) helped them to learn better at self pace. From respondent remarks, it was found that they were excited and satisfied by this new learning environment (68%) perhaps because it took relatively less time to test circuit operation by varying parameters and they received immediate accurate feedback. Respondents greeted the technology with enthusiasm and overwhelmingly considered that this product is helpful in understanding difficult concepts, performing practical activities in the lab confidently (81%) and without help of instructor. Learners felt that the randomized self test with immediate feedback and quiz in the product reflected the information presented in simulation was quite well (90%) and this also strongly reinforced the theory material (82%) as well as lab activities (86%). This was found from improved mean post test score. A slightly lower score (60%) was assigned to operate this practical simulation product, some technical knowledge is essential. They felt enjoyable and lively while learning through this product.

The content presented in multimedia format increases the retention but respondents (19%) were not sure of themselves whether they would be able to perform the experiment in lab on their own; one would requires more practice or efforts to achieve mastery over content.

FINDINGS

Research Objective 1

Test effectiveness of developed simulation lab activity on learners' comprehension using a randomized self test with immediate feedback based on theory and lab knowledge. **From statistical analysis table, the mean of the posttest score (13.47) was significantly higher than the mean of the pre test score (9.7). This difference was significant at observed value of t=7.7594 for 5% and 1% level of significance.**

Research Objective 2

Evaluate the total quality of simulated electronics experiment in perception of the learners
From the product evaluation in perception of learners, all the evaluators agreed that the lab simulation were successful in enhancing the users' ability to learn the theory concepts as well as pre-lab work activity covered. The overall quality of the developed 'lab activity simulation' was satisfactory. That is, the instructional strategy used in the simulation was self directed learning and that was according to content and requirements.

These are instructional strategies that are likely to involve learners as active participants; however, the study suggests that in order these strategies to function properly, a good planning and organization step is necessary before development and implementation.

Research Objective 3

Investigate the usefulness of developed simulation environment in enhancing the overall proficiency of the learners **After conducting a statistical analysis on the test scores, it was found that learners who used the computer simulation, performed significantly better on knowledge, and overall competency about how to precede for real lab work. It gave learners an opportunity to test circuit operation by varying parameters and received immediate accurate feedback. Thus, self-directed learning allows the learners more time for critical thinking and drawing conclusions.**

CONCLUSION

The paper described how the laboratory component of the course is being integrated more and more effectively by means of technological innovations. It further described the evaluation, which was focused on usability of the learning materials, instructional effectiveness and learners' attitudes. Learners liked the possibility to create their own learning path. They enjoyed multimedia used: clear graphics with animation, interactive exercises, and simulations with professional software system. Feedback was considered understandable and useful.

The simulation was implemented as pre-laboratory exposures. The combination of simulation and in-lab components offers advantage in time efficiency so that the in-lab portion can be reduced in length and cut the requests for assistance in the real lab. Interactivity and learner control of the simulated lab activity were highly valued by learners. In the light of evaluation, learners using the simulation have a slightly better knowledge of the practical aspects directly related to lab work.

In addition, learners liked the instructional methods used in general; most of the regular learners stated they preferred this self-paced mode of learning to the face-to-face education. All part-time learners were positive to the hybrid model of education.

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