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Multimedia Simulation for Electronics Laboratory Activity in India

Chetana KAMLASKAR
Yashwantrao Chavan Maharashtra Open University, India
chetana.kamlaskar@gmail.com

ABSTRACT :

Laboratory courses help students to gain insight and understanding of the real world. Use of combination of interactive simulations and hands on experience in the lab provides more promising effect as simulation provides illustrations of phenomena that are not easily visualized. Further interactive simulations allow students to do otherwise more complex and hazardous experiments, offer full control to manipulate experimental variables and observed circuit behaviors, which helps to foster a deeper understanding of the experiments. The objective of this research project was to design and to create an interactive simulation for electronics lab and evaluate its effectiveness from counselor's outlook. For this, interactive simulation was developed on 'Wien bridge oscillator' which is one of the lab activities of basic electronics course offered at 4th semester of B.Tech Electronics Engineering. This paper presents a study that investigates the effect of using computer simulation. The results from the evaluation revealed that the simulation package was rated high in the areas of quality content, quality language, user friendliness, presentation flow, motivation etc. Whereas feedback, adaptation and auditory support along with visual material representation for visually disable learner, were areas identified that required enrichment. The findings from the study demonstrate that developed simulation package is a useful educational tool to improve overall effectiveness and efficiency of teaching-learning process.

I. INTRODUCTION

Engineering is a hands-on profession where 'doing' is the key. The overall goal of engineering education is to prepare students to practice 'engineering'. Thus, from the earliest days of engineering education, instructional laboratories have been an essential part of undergraduate and graduate programs. It could be said that most of the engineering instruction takes place in the laboratory. Students, on the other hand, go to an instructional laboratory to learn something that practicing engineers are assumed to know.

Like a conventional education setup, in distance education also, distance learner has to go at the study centre where he/she has to perform all experiments of the lab course, that are based on traditional equipments, devices, methods and techniques for measurements, data recording, and result analysis. However, distance learner lacks in the practical skill and has to face lot of difficulties, may be due to different learning styles and profiles, poor quality of instructional material, unavailability of 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, and therefore, greatly limit the effectiveness in the students' understanding of fundamental concepts and theories from the hands-on experimentation.

The viable solution for the above stated lacunas is use of relevant technology only. Hence, interactive multimedia simulation standalone software have been developed as an innovative and engaging tool for enhancing learning process, in the context of 'Basic Electronics practical course' of Electronics Engineering Programme, offered by Yashwantrao Chavan Maharashtra Open University (YCMOU). The well designed interactive multimedia simulation of lab environment is an effective way to train learner for performing lab activity as it facilitates a high degree of learner interaction and offers learner opportunities to,

- try out lab activity before it is carried out in real environment
- practice in a low-risk environment without affecting real data/equipment and can be used at anytime, anywhere
- Build self confidence and enable learner to self-assess whether he is ready to perform lab activity effectively in real environment.
- Observe responses of the circuit for various component values

Further, interactive multimedia simulation offers several advantages such as,

- Increases learner's access to a laboratory experience, since tone is not constrained to specific time and place
- Increases the learning speed and understanding of concepts, with which learner is known to have difficulty, through the use of interactive multimedia animations and simulations
- Offers uniform quality for every learner and does not depend on the instructor's skills anymore.
- Integrates basics of any subject, which are very often responsible for non-success of a learner.
- Improves learner's assimilation and memory, as it simultaneously stimulates all senses of the human body. Multimedia enriches pedagogy by mixing different media such as graphics, sounds, music, voice, videos and animation.
- Provides complete control to the learner so that one may review the learning material at one's own pace and in keeping with individual learning styles, interests, needs, and cognitive processes.
- Linking the simulation to reference information, self test with feedback and providing a built-in coaching function could also minimize the requirement of a full-time lab assistant.

To present advantages of the interactive simulation to the learners, researcher has developed multimedia simulation on 'Wien bridge oscillator' lab activity with the help of Flash MX 2004 as a prototype. It is one of the lab activities in basic electronics course offered at 4th semester of B.Tech Electronics Engineering of YCMOU.

II. PURPOSE OF THE STUDY

This research project involved designing, developing and piloting interactive computer simulation. It implemented instructional design principles to enhance learning via interactive multimedia, within a context of Electronics lab activities. The following research questions were examined in perceptive of the counselor's:

- What are the key factors in designing interactive simulation environment that are reusable for learning concepts in the context of electronics lab activities?
- To what extent can the simulated experiment supports learner interactivity and interest, and thus provides pedagogically rich learning environment that engages and motivates the learner?

III. REVIEW OF RELATED LITERATURE

It has been noted that choices in instructional methods are needed to maintain students' motivation and attention and to address different learning styles (Born & Miller, 1999). A simulation is one of the means that can reinforce cognitive knowledge and provides opportunity to the students to put theory into practice. Simulations often enhance motivation, encourage transfer of learning, and are efficient in regard to the length of time required by the student (Alessi & Trollip 1991).

Computer-based multimedia provides instructional designers the tools of animation, video, and sound to provide learners with working models that convey complex concepts. Specifically, multimedia simulations provide stimuli to auditory, visual, and kinesthetic learners. It is known that animations can increase learner interest and motivations, provide metacognitive scaffolding and mental models, and promotes visual stimuli to establish connections between the abstract and the concrete (Dooley et al., 2000). Multimedia simulations that utilize varying colors and fonts, audio and video streaming, and animation have the ability to appeal to all types of learners.

Simulations provide educators direct opportunities to include Gagne's nine levels of learning into instruction (Gagne, 1985) and allow the learner to explore a topic and receive feedback without public humiliation (Bill, 2001). Computer simulation affords teachers and instructional designers a powerful tool for sustaining knowledge retention and transfer" (Bill, 2001). One of the most powerful uses of multimedia is to immerse the user in a learning environment (Boyle, 1997).

Research supports the use of multimedia simulations and animations as effective delivery methods. A study of engineering students using a computer simulation in conjunction with classroom instruction indicated that a substantial gain in the retention of the subject matter was obtained compared to students using only conventional teaching methods [Firth, 1972). Menn (1993) evaluated the impact of different instructional media on student retention of subject matter. It was found that students remember only 10% of what they read; 20% of what they hear; 30%, if they see visuals related to what they are hearing; 50%, if they watch someone do something while explaining it; but almost 90%, if they do the job themselves even if only as a simulation.

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).

That means, interactive multimedia is well promising medium for reinforcing, extending, and supplementing what goes on in the real lab activity. In other words, guided discovery through labs and computer simulations that are properly designed and implemented could revolutionize education.

IV. METHODOLOGY

Faculty and students were asked to participate in the evaluation of the developed simulation lab activity using a rating instrument and interviews. The evaluation criteria are divided into questions covering the three main measures: reusability, interactivity and pedagogy. Faculties were given a copy of simulated lab activity on CD-ROM (platform for Windows operating systems). A questionnaire was distributed to counselors in order to study learning impact based on their use of the developed lab simulation. Faculties were also asked to evaluate the quality of the product using an established rating instrument and to suggest modifications for improvement.

V. DESIGN AND DEVELOPMENT OF PROTOTYPE

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 (Patil et al., 2003). In case of an instructional strategy applied to engineering domain, it is suggested to apply an effective, experimental-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.

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,. 1997). Wien bridge oscillator lab activity was designed and created with the computer program Macromedia Flash Mx 2004. Following table shows the outline of content organization in the frame format of Flash Mx 2004. All content materials were tested through a pilot testing before the full implementation of the product.

SN	Frame	Description
1	**Welcome Screen**	Invoke the practical simulation topic 'Wien Bridge Oscillator'
2	**Main Menu**	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	**Pretest**	To test prior Knowledge of the learner a randomized pretest was embedded
4	**Learning Objectives**	Learning objectives were stated with action verbs 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 was presented with use of text, animated graphics.
7	**Procedure**	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: Figure 1, Figure 2]	• To perform experiment, learner has to enter various components values, required power supply voltage within specified range. • Circuit diagram gets automatically updated as per entered values • Immediately learners can observed the output waveform on the math driven simulated oscilloscope where learner can measure amplitude and frequency parameters same as in real lab. For accurate measurements, learner can adjusts both the parameters using Volt/div and time/div knob on the simulated Oscilloscope • By varying components values, supply voltage etc. learner can conduct "What if …" investigations.
9	**Observation Table, Result & Conclusion**	For low level learners, offers opportunity 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 were given. Additionally, data sheet of IC 741 in PDF format was given to study its electrical characteristics and specifications.
11	**Home Assignment**	To motivate further reading and enhance comprehension level, descriptive type of items were presented based on the content covered.
12	**Self test**	To get immediate, most realistic and effective feedback about the lab content learned, 'randomized self test with feedback mechanism' was embedded. Additionally, at the end of self test, learner's performance was reported in the form of total correct answers, total wrong answers and total percentage.
13	**Post test**	Based on the content covered in theory and lab activity, randomized post test was embedded. At the end, learner's achievement in the form of total correct answers, total wrong answers and total percentage was reported.

VI. FEATURES

some of the features of developed interactive multimedia simulation are given here

- Enables self-learning at anywhere, anytime
- Offers opportunities to try out the lab activity before it was carried out, to practice 'n' number of time in a low-risk environment and to build self confidence to perform lab tasks competently

- Provides easy and click access to input and output devices, making it efficient to run simulations and conduct "What if …" investigations
- 'Mapping' out a model provides an effective learning environment for learners to gain understanding of physical systems
- Self test with immediate feedback motivates learner to study content in depth
- Can be used as supporting or supplementary learning material for hands-on experimentation in 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

VII. SAMPLE SELECTION

Yashwantrao Chavan Maharashtra Open University, Nashik offers B.Tech Electronics Engineering programme through the School of Science and Technology. 'Basic Electronics' course is at fourth semester which is a compulsory. All over Maharashtra state, about 30 counselors offer academic support to annually enrolled 300 learners at 30 different study centers. For convenience, the sample selection was limited only to Nashik and Mumbai region. The sample for this study included 34 learners (11.33%) of total population; and total 15 faculties/experts/Counselors from the above study centres related to this course were selected for the investigation of quality of the product and its learning impact.

VIII. 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 an impact on learning.

IX. DATA COLLECTION

A questionnaire was specially designed and used to collect counselors' individual assessments of quality of the developed lab simulation. The questionnaire consisted of total 26 questions / statements. Out of which, 14 items were aimed to evaluate the following quality parameters of the developed product.

- Content
- Instructional Technology
- Language
- Multimedia and Technical quality

Each of the items was followed by four answer choices indicating degree or intensity while remaining 12 items were open ended, asking for general opinion about the product. These tools were used to provide faculty with an opportunity to suggest modifications for improvement and to provide evidence that the use of 'lab activity simulation' positively impacted students' overall learning process.

X. DATA ANALYSIS

A questionnaire was used to take counselors opinion and hence to evaluate total quality of the product and impact on learning/teaching process of the course. Quality of the prepared product was evaluated by evaluating following parameters:

- Content
- Instructional Technology
- Language
- Multimedia and Technical Quality

A. Counselor/Expert Response to statements for Total Quality of the Product

1. Table 1: Responses of sample related to Quality of the Content

*R=No. of Respondents

Content Quality Parameter statements	Best		Better		Average		Poor		Total 'R'
	R	%	R	%	R	%	R	%	
1	12	80.00	3	20.00	0	0.00	0	0.00	15
2	7	46.67	7	46.67	1	6.67	0	0.00	15
3	11	73.33	4	26.67	0	0.00	0	0.00	15
4	8	53.33	6	40.00	1	6.66	0	0.00	15
Total	**38**		**20**		**2**		**0**		
%	**63.33**		**33.33**		**3.33**		**0**		

The questionnaire contained four statements related to quality of content in the product. 63.33% counselors/experts found quality as the best and they rated the most favorable response. 33.33% counselors/experts found it better whereas only 3.33% found it average. None of the experts rated it poor.

Conclusion:

Maximum counselors/experts found learning objectives correlated with content. They also found that content presented in the product is accurate, well illustrated with figures, sufficient depth on each important topic so quality of the product rated by them was 'best' for the target group.

2. Table 2: Responses of sample to statements related to Instructional Technology

*R=No. of Respondents

Quality Parameter	Best		Better		Average		Poor		Total 'R'
	R	%	R	%	R	%	R	%	
1	7	46.67	7	46.67	1	6.67	0	0.00	15
2	10	66.67	5	33.33	0	0.00	0	0.00	15
3	8	53.33	7	46.67	0	0.00	0	0.00	15
4	13	86.67	2	13.33	0	0.00	0	0.00	15
5	9	60.00	6	40.00	0	0.00	0	0.00	15
6	10	66.67	5	33.33	0	0.00	0	0.00	15
Total	**57**		**32**		**1**		**0**		
%	**63.33**		**35.56**		**1.11**		**0.00**		

The questionnaire contained six statements related to the quality of instructional pedagogy in the product. 63.33% counselors/experts found instructional quality as the best and they rated the most favorable response. 35.56% counselors/experts found it better and only 1.11% found it as average. None of the experts rated it as poor.

Conclusion:

Maximum counselors/experts found the product as per instructional pedagogy, and with enough number of self test questions with immediate feedback. They also found that the content presented in the product has logical flow and continuity, proper references and study tips, enough number of figures along with animation for better understanding so quality of the product rated by them is 'best'. Hence, product is found effective for the target group.

3. Table 3: Responses of sample to statements related to Language

*R=No. of Respondents

Quality Parameter	Best		Better		Average		Poor		Total 'R'
	R	%	R	%	R	%	R	%	

1	8	53.33	7	46.67	0	0.00	0	0.00	15
Total	**8**		**7**		**0**		**0**		
%	**53.33**		**46.67**		**0.00**		**0**		

The questionnaire contained one statements related to the quality of the language in the product. 53.33% counselors/experts found quality of language used in the product as best and they rated the most favorable response, while 46.67% counselors/experts found it as better. None of the experts rated it as average or poor.

Conclusion:

Maximum counselors/experts found quality of language used in the product appropriate for better understanding of content for the target group.

4. Table 4: Responses of sample to statements related to Multimedia and Technical Quality

*R=No. of Respondents

Quality Parameter	**Best**		**Better**		**Average**		**Poor**		**Total 'R'**
	R	%	R	%	R	%	R	%	
1	10	66.67	5	33.33	0	0.00	0	0.00	15
2	9	60.00	6	40.00	0	0.00	0	0.00	15
3	12	80.00	3	20.00	0	0.00	0	0.00	15
Total	**31**		**14**		**0**		**0**		
%	**68.89**		**31.11**		**0.00**		**0**		

The questionnaire contained three statements related to the multimedia and technical quality of the product. 68.89% counselors/experts found the multimedia and technical quality of the product as best and they rated the most favorable response. Whereas 31.11% counselors/experts found it better. None of the experts rated it average or poor.

Conclusion:

Maximum counselors/experts found the figures neat and properly drawn with captions, well illustrated with animation, so quality of product rated by them is 'best' for the target group. All counselors and experts overwhelmingly accepted that product provides user friendly interface.

B. **General Opinion of Counselors/Experts about the Product**

An open ended questionnaire was administered to gather general opinion of counselors / Experts about the product. It contained 13 open ended questions. For all questions experts have given positive opinion and hence overall quality of product was found effective. The questionnaire has covered the questions related with various attributes of the product such as academic expectations, learning style, easy to follow on screen instructions, enough number of self test and home assignment questions, clarity of graphics that creates enjoyable and exciting environment while learning etc. For all these questions counselors felt that the product meets all essential feature except audio.

Some of the counselors/experts suggested to use synchronized audio with graphics animation to enhance further understanding of the content which would offer opportunity to explore this simulated environment even visually disabled learners. Very few counselors offered any comments; here some of the questions are analyzed.

Q. No.2: Does the product encourage performance-based learning?

1. Table 5: Responses of sample related to performance-based learning

Response Status	**Total**	**%**
Yes	14	93
Yes with Comments	1	7
No	-	0
Total	15	100

From the collected data, it was observed that only 7% respondents gave their positive opinion with reason while 93% counselors/experts found that the product would be useful to encourage performance based learning significantly. In their opinion, the product does not only cover

practical aspects but theory aspects also, with randomized pretest, randomized self test with immediate feedback and randomized post test.

Conclusion:

Maximum counselors/experts found that the product encourages performance based learning as it helps students better understand the theoretical concepts and increases as well their comprehension by means of which, enhances their performance in the practical activity.

Q.No.4: Does the application successfully integrate technology and instruction?

2. Table 6: Responses of sample related to technology and instruction integration

Response Status	Total	%
Yes	15	100
Yes with Comments	0	0
No	0	0
Total	15	100

From the collected data, it was observed that 100% respondents gave their positive opinion without any reason.

Conclusion:

Maximum counselors/experts found that the product successfully integrates instruction and technology as it incorporates various media to enhance understanding of the content for students of dissimilar learning style. Thus, it provides a taste of the real world to the students.

Q. No.5: Does the software increase student understanding of the topic?

3. **Table 7: Responses of sample related to increase in student understanding of the topic**

Response Status	Total	%
Yes	12	80
Yes with Comments	3	20
No	0	0
Total	15	100

It was observed that only 20% counselors/experts gave their positive opinion with comments while 80% stated that the product significantly increases students understanding of the topic. In their opinion, product covers both theory as well as practical activities with the help of well illustrated and animated diagrams/figures/graphics, logical flow and presentation of content, from schematic of Wien bridge oscillator to final implementation and measurement of output of the circuit.

Conclusion:

Maximum counselors/experts stated that the product significantly increases students understanding of the topic as it integrates appropriate media to explain the difficult concept and diagram. However, they commented that the some training is essential to students to make optimum use of such new product.

Q.No.6: Does simulated practical environment help learner to get overall idea and build confidence to perform experiment in lab?

4. **Table 8: Responses of sample related to getting overall idea and building confidence to perform experiment in lab**

Response Status	Total	%
Yes	12	80
Yes with Comments	3	20
No	0	0
Total	15	100

Only 20% counselors/experts gave their positive opinion with comments while 80% found that the product significantly increases students' confidence and provides overall idea about how to perform Wien bridge oscillator experiment in the lab. In their opinion, product covers all practical activities like how to mount circuit on the breadboard. The simulated oscilloscope provides opportunity to student to learn about how to measure frequency and amplitude of the output waveform and test the circuit performance for various component values.

Conclusion:
Maximum counselors/experts found that the product significantly helps to get general idea and build self confidence to perform experiment in lab as it provides opportunity to perform all practical activities in safe environment before carrying it out in real situation.

Q. No.7: Does the product present easy to follow on screen instructions?

5. Table 9: Responses of sample related to easy to follow on screen instructions

Response Status	Total	%
Yes	15	100
Yes with Comments	0	0
No	0	0
Total	15	100

From the data, it was observed that 100% respondents gave their positive opinion without specifically giving any reason.

Conclusion:
Maximum counselors/experts found that the product presents

- Easy to follow on screen instructions
- Icon based navigation feature
- Menu driven user friendly interface

Q. No.11: Does the product provide opportunity to analyze the circuit behavior for various component values?

6. **Table 10: Responses of sample related to analyze the circuit behavior**

Response Status	Total	%
Yes	13	87
Yes with Comments	2	13
No	0	0
Total	15	100

Only 13% counselors'/experts gave their positive opinion with comments while 87% found that the product definitely provides opportunity to analyze the circuit behavior for various component values. In their opinion, simulated lab environment offers user interface to enter/select component values for which the students wish to find Wien bridge oscillator circuit response.

Conclusion:
The Product provides opportunity to analyze the performance of the Wien bridge oscillator in safe environment for various component values and enables learning to become fun and friendly.

Q. No.12: Does the product provide opportunity to build up confidence and accuracy to mount the circuit on breadboard?

7. **Table 11: Responses of sample related to mounting of the circuit on breadboard accurately**

Response Status	Total	%
Yes	10	67
Yes with Comments	5	33
No	0	0
Total	15	100

From the data, it was observed that 100% respondents gave their positive opinion without any reason. In their opinion, a well illustrated and animated step by step mounting of components on the breadboard, covered in the product, significantly helps to build up students' confidence. Back and forth navigation feature helps to understand each and every step of component mounting clearly.

Conclusion:

The product provides opportunity to learn about how to mount the circuit on breadboard accurately without fear of inadequacies or failure.

XI. FINDINGS

Research Question 1

What are the key factors in designing interactive simulation environment that are reusable for learning concepts in content of electronics lab activities?

The research project has demonstrated the development and evaluation of simulated lab activity on Wien Bridge oscillator using Flash Mx 2004. This simulation received very positive evaluations from 15 counselors from different study centres. Students of Electronics Engineering and educational experts also gave good evaluations to the simulation. The key factors in the design of this simulation was found to be: clearly defining the learning objectives, choosing an appropriate multimedia architecture, simulating real lab activities/equipments, providing high level of interactivity and learning control to user, embedding formative assessment in the form of randomized self test and study references within the simulation, and utilizing a participant-oriented evaluation design cycle.

Research Question 2

To what extent can the simulated experiment support learner interactivity and interest, and thus provide pedagogically rich learning environments that engage and motivate the learner?

Using the state of art of technology, Flash Mx 2004, a high level of interactivity within simulation was possible.

ActionScript of Flash Mx 2004 complied to effectively simulate circuit behavior by varying various parameters and enhance the learners' interest. The counselor evaluations emphasized the high value that is given to interactivity and user control within the simulation. Emulating an oscilloscope to observer and measure the circuit response, and how to build circuit on breadboard were highly valued. The ability to experiment and learn within a safe simulated environment was also equally valued. All evaluators agreed that the lab simulation was successful in enhancing the users' ability to learn theory concepts as it covered the pre-lab work activity. The inclusion of randomized self test with immediate feedback, randomized pre and post test provided opportunities for users to test their understanding of the concepts. The level of assessment could be increased for future or added to the current simulation. The lab simulation successfully augmented learning as how to perform the real lab experiment.

XII. CONCLUSION AND RECOMMENDATIONS

Research work presented in this paper has focused on the evaluation of electronics lab simulation from counselors' point of views. The detailed analysis in terms of Content, Instructional Technology, Language and, Multimedia and Technical quality parameters of the developed simulation from 15 counselors/experts has been described. Here simulation is not proposed to substitute present practical activities but to support the learning of electronics circuit operation and to provide practical skills which facilitate the learners to find fault and implement innovative ideas.

All the evaluators revealed that the developed lab simulation has potential to use as an effective teaching tool. Furthermore, an improved level of interactions between instructors and students, especially during practical session could be achieved. The counselors' evaluations emphasized high value to the randomized self test with immediate feedback, interactivity, and user control embedded in the simulation. The ability to experiment and learn a concept or to accomplish a desired practical task within a safe simulated environment was also highly valued.

One of counselors highlighted the importance of simulation related to the students' ability and learning process. The power of the simulation to increase the scope of experience through visual representation was paramount in case of less able students and enhances problem solving skill of the higher able students. Similarly, it allowed students to repeat experiments as often as necessary, which would not be feasible practically. This practice would enhance confidence level of students to prepare for practical end examination. Hence, developed interactive simulation is ideal for distance learning, demonstrations, lab run-throughs and pre-lab work. All counselors felt that the product meets all essential features of pedagogically rich learning

materials except audio. They suggested to do streamline audio with graphics animation to enhance further understanding of the content which would offer opportunity to explore this simulated environment even to visually disabled learner. Indeed, there are many directions we could take into further investigations.

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SAMPLE SCREENS

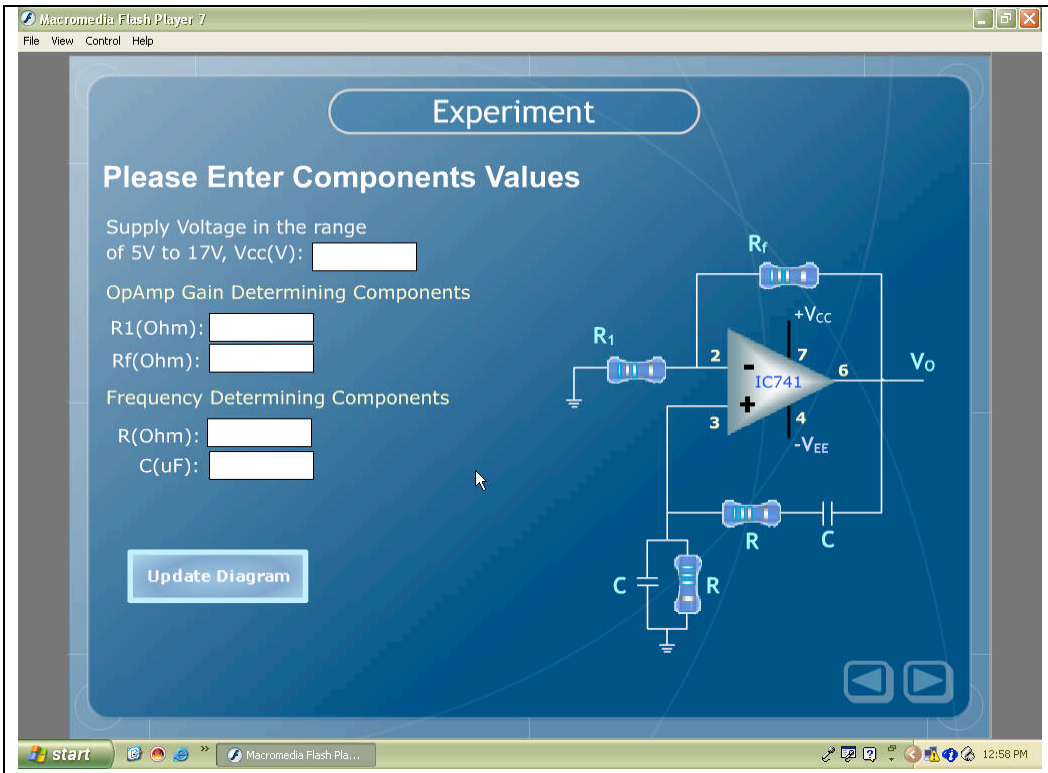

Figure 1: Allows user to test the circuit performance for various parameters by changing the component values

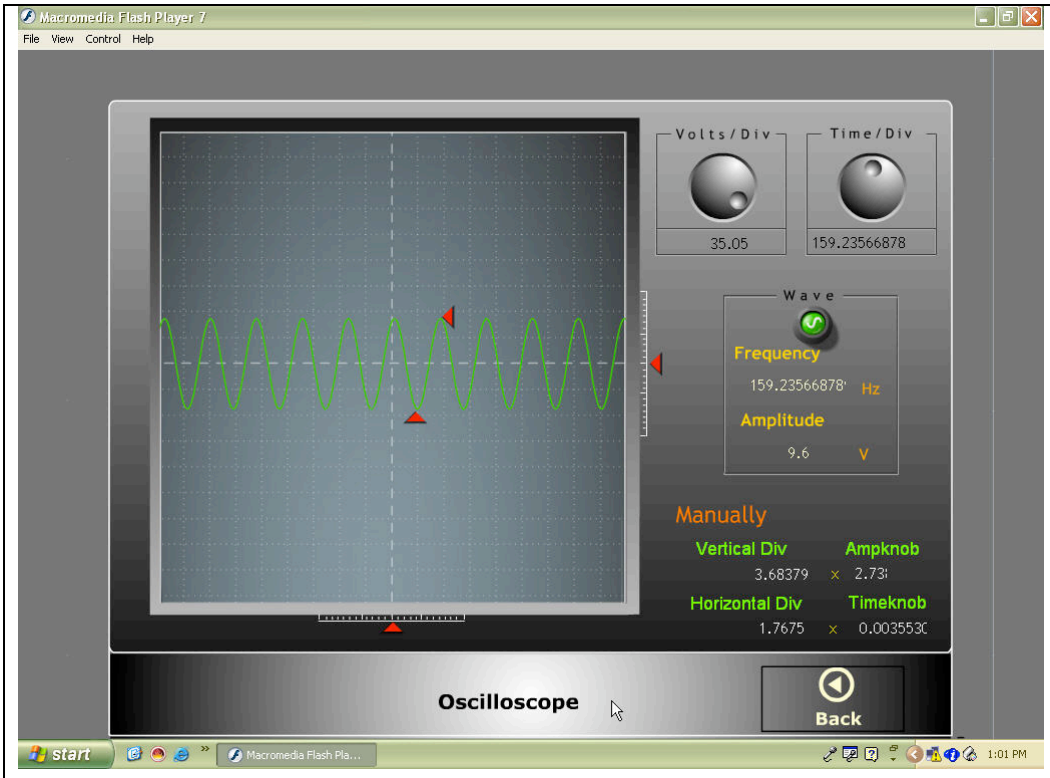

Figure 2: Simulated oscilloscope which displays the circuit performance for given set of the component values

Chetana Kamlaskar is lecturer at School of Science and Technology, Yashwantrao Chavan Maharashtra Open University, Nashik. She has done her M.Tech (Communication) from IIT, Powai, Mumbai. Her area of interests is in electronics and eLearning content development.

Office Address:
Lecturer, School of Science and Technology, Yashwantrao Chavan Maharashtra Open University, Dyangangotri, Near Gangapur Dam, Nashik, MS, India- 422222. Phone: 91-0253-2231473, Fax: 91-0253-2231716, Cell: 09422946482 Email: Chetana.Kamlaskar@gmail.com