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Effective Virtual Laboratory Content Generation and Accessibility for Enhanced Skill Development through ICT

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Abstract. In this era of knowledge economy, it is desirable to make technical education of good quality accessible and affordable to all using latest distance learning technology available. The growth of distance learning has been associated with Information and Communication Technologies (ICTs) in recent years. The focus of this paper is to emphasize on enhancement of skill development through ICT, using standard virtual laboratory content generation and making them easily accessible across all the student population. The aim is to develop simulation based experiments through demonstration videos as productive learning tool similar to real time hands-on equipment. Further, on-line quizzes and project based assignments in each virtual experiment will scale-up conceptual understanding and discovery based learning, unlike verification based conventional experiments. Currently, only feedback of our own students is available which is encouraging. The students welcomed the task based experiments to design a virtual system and found them to be more productive.

Keywords: ICT, distance learning, virtual lab, simulation.

1. Introduction

In this era of knowledge economy, all the countries depend on development of their educational sector. Technical education Institutes across India falls under different categories. Among these Institutions, there is a vast difference in availability of infrastructure, skilled staff as well as teachers. Hence it is only desirable to make technical education of good quality accessible and affordable to all using latest distance learning technology available.

Distance and open education schemes that have until recently relied mainly on the mailing of written materials, videos, cassette recordings, and radio or TV broadcasting techniques can be augmented, enhanced or replaced by new on-line tools and technologies which have the power to transform the learning environment. The growth of distance learning has been associated with Information and Communication Technologies (ICTs). The focus of this paper is to emphasize on enhancement of skill development through ICT, using standard virtual lab contents and making them easily accessible across all the student population. It provides a unified, completely flexible system of learning where learners can access any kind of resources, at any time, from anywhere. The aim is to engage students actively in learning process, to enhance their conceptual understanding and make the laboratory more discovery-based rather verification-based. Each experiment is designed so as to provide basic learning and bring-in challenge to design real-life like industrial system as assigned task. Self-learning brings out capacity of lateral thinking and creativity. For the purpose, on-line quizzes and assignments in the form of design projects are kept to scale-up the knowledge gained.

2. Issues in ICT based Education

2.1 Digital Divide

A digital divide exists between the technologically advanced and technologically backward system. It brings setbacks at many fronts, like economic, social and psychological. Aim of ICT is to bridge the gap in appropriate manner and convert it into digital opportunity. Distance learning platform also provides opportunities to working population to continue their studies, empower themselves with state-of-the-art knowledge. It brings better paid job and ultimately lead to economic growth. It provides a great opportunity for women and girls due to flexibility of access and study times. Also people with disabilities can access learning opportunities hence allowing them to be part of mainframe.

2.2 Challenges and Strength

With a growing middle class having a high priority for education and a number of world class institutions of learning and research, India dreams to be a knowledge superpower by 2020. Table 1 lists the challenges and inherent strength of ICT to tackle them, to achieve the goal.

Table 1: Challenges and strength with regard to ICT.

Challenges, India faces	Strength of ICT
Abundance of un-nurtured talent	Nurturing of scholars and learners, any time, any where
Lack of timely and easy availability of knowledge resources to all	ICT not only provides availability of resources but also resource persons if planned
Opportunities lost because of difficult access to information and guidance	Extensive leveraging of the advancements in the field of ICT for taking the knowledge resources to the door steps of the learner
Mismatch between demand and supply of knowledge and skills	Capability to handle the huge user base in the long term
Lack of collaborative learning	Knowledge enhancement at any age, any place, any time, any direction
Questionable quality of teaching at various places and lack of motivated teachers	Technological and Communication backbone to take their advantage in the field of knowledge empowerment of the mass of learners.
Lack of encouragement to excel	Support to all the learners / workers for any of their perceived learning needs.

2.3 Objectives

Institution like ours set up by MHRD puts emphasis on IT driven education system. IT is sitting at the core of learning, teaching and management process. Objectives of ICT enhanced learning are

- Providing connectivity, along with provision for access devices, to institutions and learners;
- Standardized Content generation;
- Management of resources and learning;
- Online Evaluation and testing system.

The objectives will be achieved through

- Standardization and quality assurance of contents to make them world class;
- Research in the field of pedagogy for development of efficient learning modules for disparate groups of learners;
- Making available of e-knowledge contents, free of cost across all population;
- Field trials of the developed contents from remote locations;
- Development of Online evaluation procedure;

- Device ways of interaction between author and learner.

The aim is to sustain a high growth rate of our economy through the capacity building and knowledge empowerment of the people and for promoting new, upcoming multi-disciplinary fields of knowledge. ICT enables individuals to customize the learning to fit their own needs and abilities. In conventional learning model such customization is not feasible.

2.4 The Problems

Web enabled learning modules suffer from absence of teacher and peer interaction. The authors develop content based on their own student's understanding level instead of considering average level of receptivity. The concept grasping power of students would vary based on their surroundings and the perceptions that the students have derived over a period of time. It presents a continuum of challenge to develop content that is pedagogically the most suitable for any given learner. Thus, it is imperative that increased research is made in this area to derive new techniques for enhancing the effectiveness of the content being developed.

3. Concept of Virtual Lab

In India through a national mission of knowledge empowerment, vast base of lecture material has been created by mostly premier technical education Institutions. National Programme on Technology Enhanced Learning (NPTEL) provides this material in the form of Video or Web based content for each theory course in Engineering Sciences. NPTEL, using the Internet as a medium facilitates lecture materials to a large audience through ICT based distribution.

However, technical education is not complete without appropriate hands-on sessions where students put their acquired knowledge into practice. It brings two-fold advantage: 1. Strengthening knowledge base through enhanced conceptual understanding, 2. Applicability of theory as per the need of the industry. In India, thousands of technical education Institutions has come up, but very few are having quality teachers and state-of-the-art infrastructure to provide hands-on training to students. Sometimes exorbitant cost of laboratory equipment makes it impossible to provide the much needed facility at all locations.

Web technology can be a powerful tool for learning concepts and developing skills of measurement, analysis, and processing information. In view of the necessity of laboratory practice as important part of technical education and associated problems with providing necessary support, Cost effective virtualization of laboratory sessions with the aid of simulations, videos and demonstrations may be thought of as solution to the problem. Virtual labs and simulations may not be a substitute for real time laboratory experience, but may be used to supplement and extend such experience.

Project on Development of Virtual Laboratories by the Ministry of Human Resources Development (MHRD) is one such initiative to provide hands-on support to theory courses. Setting up of virtual laboratories will play very important role in that the learners in the distance education system and those in remotely located educationally backward areas can be benefitted from quality and relevant education, through ICT. These laboratories shall provide a platform for the students to conduct experiments in a virtual environment and enhance their capabilities.

3.1 Curriculam Standardization

Technical education Institutions across India are quite varied in category. In most of these Institutions, on one hand, curriculam structuring usually does not fulfil the requirement at the world level to make the students competent enough to face challenges of the era world-over; on the other hand, teaching quality is also varied. There is a need to standardize the curriculum and learning material across the country and keep them in tune with the latest trends world over. The accessibility of good teachers and quality teaching to the students of many Institutions is a far cry. Teacher-independent and infrastructure-independent nature of modules brought up by NPTEL and virtual laboratory respectively, therefore may be used with advantage in remote areas where the learner does not have access to quality teaching or wants to study independently.

3.2 Development of Virtual Lab Experiments

A conventional laboratory consists of about 12 experiments across the semester. It is meant to support a theory course learning, which is well defined in any curricula. Similar to this, in a virtual laboratory course, target group has to be well defined, in addition to the list of courses pre-requisite to the lab. Each laboratory will have a list of 10-12 experiments. Background knowledge on each of the experiment has to be given as supporting material to learn theory behind each experiment as well as its significance/usefulness. Each of such material is followed by example questions. To engage learner actively in the learning process and to enhance conceptual understanding, an on-line quiz has to be solved at the end of each module. Upon clearing the quiz only the learner is allowed to go through virtual experiment. Similarly, on-line quiz will also be provided at the end of each virtual experiment, followed by assignment in the form of design project. On-line quiz development and testing is currently in progress. The flow chart shown in Figure 1 provides stages of development of virtual laboratories. For a defined target group, it starts from standard content generation and go upto e-testing.

Virtual Labs when developed will work in a complementary fashion to theory courses (NPTEL) in the sense that they teach the student the basic concepts, as well as trigger their imagination and inquisitiveness. Virtual Lab will be effective as an instructional tool as well as a self-learning tool. However, it can never truly replace an actual laboratory, where learning starts with selection of components, their assembly in the form of experiment set up, followed by carrying out experiments to better understand physical phenomenon, to analyse behavioural pattern in terms of effect of various variables on the system as a whole or prediction of system behaviour. To counteract this difficulty, hands-on design project on each experiment will be assigned on-line. Instead of repetitive kind of verification based experimental work, it will require learner to put-in conceptual understanding and creativity of mind to carry out design projects successfully. The exercise will bring self-understanding of knowledge gained.

The following points have to be kept in mind in finalizing the virtual lab.

- Is this lab a good candidate for virtualization?
- Does it fit into a standard UG/PG curriculam at the defined level?
- Are the objectives of the experiments clearly defined?
- Will it provide supportive learning to theory course? Or Can it be used to compliment a theory course?
- What is the category of virtual lab?
- Will the student gets a feel similar to real time experiment?

3.2.1 Virtual Lab Models

Therefore, the conceptualization and development of Virtual Labs would require more effort, planning and coordination than the theory courses such as NPTEL. Flow chart in Figure 2 shows steps that go into creating virtual experiments for a lab course, till it reaches to the learner. Virtual labs may fall under different categories, but in principle creation of each experiment follows the same steps. Virtual Labs may be designed by one of the following methods (or possibly a combination):

- **Pure Simulation based Model:** Modeling the physical phenomenon by a set of equations and carrying out simulations to yield the result in terms of parameter effect prediction. This can, at-best, provide an approximate version of the real-time experiment.
- **Hardware-in-the-loop Simulation:** Experiments are designed on software. Hardware is then integrated and simulation is carried out at the laboratory having real-time experiment setup. Software simulation may be carried out at remote location, providing results of simulation to analyze with. While hardware simulation may only be demonstrated through Videos of real time experiment run by the designed algorithm. This will provide design details but lack in any feel of real time experimentation.

- **Providing a corresponding measurement data for the Virtual Lab experiment:** Experiment set up is demonstrated through videos, followed by providing vast data of measurement of experiments previously carried out on an actual system. This will be closer to the real-time experiment.
- **Remotely Triggered:** Student may access real experiment setup from remote location. Experiment is carried out from remote location in an actual lab, on real-time basis and providing the student the measurement data of real experiment through the computer interface. This would entail carrying out the actual lab experiment remotely.

3.3 Standard Content Generation

A virtual lab template needs to be evolved. Each experiment of all the virtual labs will follow the template. The following may be considered the minimum requisites for the template:

- Objective of experiment: Clearly defined
- Standard Apparatus required: Providing photograph of the components will give the feel of components with which the system is made of.
- Block Diagram/Circuit Diagram: Explaining the arrangement of all the components and the flow of information.
- Theory: It may be supported by link to relevant NPTEL courses.
- Procedure of Experimentation: Detailed procedure has to be listed along with photographs of crucial stages during experiment. Video of full experiment conduction helps in understanding the procedure.
- Results and Analysis of observed data: Need to be elaborated for conceptual understanding and information processing, in the form of discovery of concepts and their relevance to physical system behaviour.
- Evaluation Quiz: In the form of standard questionnaire. To enhance project based learning, it may be followed by assignment projects to be carried out at remote location by assembly of locally available components.

3.3.1 Model vs Content

There might be marginal changes required in the template while building up content under various virtual lab models. In case of category 3 lab., a vast set of measurement data is made available from real time experiments. A sample analysis is also made available for understanding of the learner. Learner can see the animated results of experiments. Further analysis of available data has to be carried out at remote locations by each learner so as to understand behaviour of the system on which experiment was carried out. In the category 4, the measurement data is obtained directly by conducting experiment from a remote location through computer interfacing.

In the virtual experiment of taper turning on lathe machine, setting of cross slide to cut taper and other requisite settings are demonstrated through still photographs of machine tool as well as video of complete setting process. By studying these stills and video, learner gain complete understanding of how requisite taper cut is set and cutting operation is performed on the machine. Through interactive mode of experiment, user may set variable taper cut and see the results of taper turning operation in the form of photographs of final cut piece and relevant analysis.

In category 2 of virtual lab all the experiments are predominantly simulation based. The experiment is designed on software. Simulation is then carried out with two-fold objective. 1. Correctness of the developed algorithm as per the desired logical flow of information, and 2. Modification required in the designed system based on study of resulting system behaviour. This step is iterative and may be carried out by each learner at remote location so as to bring understanding about designing a system for the desirable logical flow of information. Hardware is then integrated in the loop and procedure of hardware integration with the designed algorithm is explained. Hardware simulation is carried out in real time and made available in the form of video and stills of experiment setup and simulations.

In the virtual lab experiments on industrial automation, learner is first engaged in making ladder diagram on programmable logic controller (PLC). The processing of information from input signal to PLC to generating actuation is then tested by simulating the designed algorithm for correctness of the logical flow of information as desired.

3.4 Extensive Field Trials for Accessibility

Even the best e-content may not have any significant impact unless it reaches the vast majority of learners with ease, as and when they need it. Benefits of ICT for all learners require high level of computer ownership and broadband connectivity across the country. Unlike NPTEL course, virtual laboratory course will be successful only if learner at his remote location could download simulation videos, animations and be able to run it on his own system. The following details should be listed with regard to simulation based experiments at each website.

- How to get simulation — Click to go to the download page
- Does it require specific software — No
- What simulations are installed — All
- What application it needs to run the simulation — Java/flash, etc
- How large is the download — Approximately 45 MB
- Is an internet connection required to run simulation — No

3.4.1 Evaluation

During the field trials, the following points required to be evaluated. 1. Ease of content accessibility, 2. Evaluation of conceptual understanding through quizzes and 3. Confidence gained through videos and assigned projects towards feel of carrying out real-time experiment. It will not only help in easy learning through ICT but will also make the system effective.

Hands-on learning may be promoted by giving task in the form of projects and innovative systems building through readily available off the shelf components or specifically designed low cost kits. The availability of chosen components in the local market has to be given priority in building the task. Through these simulation kits, learners would conduct experiments and enhance their design skills in the relevant field.

4. Conclusions

It is obvious that emphasis on ICT is a crying need as it acts as a multiplier for capacity building efforts of educational institutions without compromising the quality. Owing to the extraordinary pace of software development; enriched teaching and learning with enhanced graphics, interaction, animation and visualisation is made possible. Based on the experience gained by developing two virtual labs, the study summarizes the choices available for developing virtual laboratory courses. A properly designed virtual experiment of any category, with standard content, demonstration methodology and proper evaluation strategy can even replace real time experimentation and brings in the benefit of enhanced understanding of concepts and requisite hands-on. However, the concept of virtual laboratory is still new and more research should go into designing the content and evaluation procedure based on feedback and field trials.

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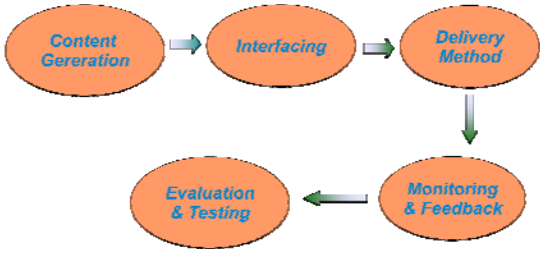

Figure 1

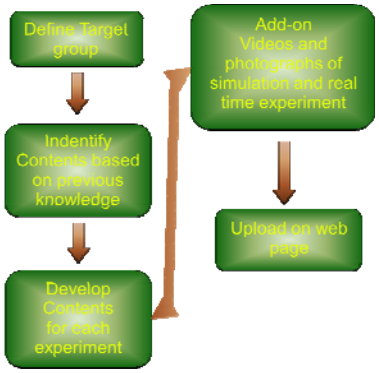

Figure 2