Enhancing the Attainment of Environmental Engineering Laboratory Course Outcomes through Virtual Laboratories

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ABSTRACT

In this global era, innovation in engineering may hold the key to the economic growth and prosperity, security, and competitiveness of the country growth. Hence, the students who hails to the engineering profession, should understand the nuances of the discipline to meet the needs of human resources in the society. At present in the engineering courses, there is a proper blend of theoretical and laboratory courses to achieve the stated outcomes and objectives. In general, laboratory instruction plays an important role in providing better understanding of the knowledge taught and in turn it exemplifies their conceptual learning through inquiry based laboratory activities. It is the only place where students get trained in all the three domains cognitive, affective and psychomotor. Hence laboratory acts as a breeding ground where students, either directly or indirectly acquire the graduate attributes as listed in the Washington State Accord. At present, there is an increase in the number of engineering student's enrolment and hence it is a difficulty in providing separate facility for each student in the laboratory to practice, but it is highly imperative to redefine the teaching learning process, and provide equity in practicing the laboratory. Although, the group work has an advantage of inculcating team spirit and collaborative learning to the students, but it is not providing avenue for individualistic inquiry based learning. This paper provides the in depth view about this laboratory instruction framework with an environmental engineering laboratory as an example. This model ensures that the students obtain better understanding of concepts, good opportunity to each individual in handling equipment's, optimum utilization of the laboratory resources and in turn attain the listed course outcomes.

Keywords: Virtual Laboratory, Learning Outcomes, Procedural and Conceptual Knowledge.

INTRODUCTION

Laboratory practice constitutes an indispensable part in the engineering course. The knowledge gained by theoretical study coupled with experiments in laboratory will enhance the thought process of the students in better understanding of the concepts and in turn apply the same, in a sustainable manner. Different course outcomes are used as criteria for judging the laboratories: Hands-on practice increase the ability to design and investigate (engineering knowledge, design skills), collaborate and articulate the purpose of laboratory test findings with fellow students (Individual and team work, ethics and communication), equipment handling, safety, safe disposal of testing waste (Environment and sustainability, engineer and society). Thus important programme outcome and course outcome attainment is assessed through well-defined rubrics which encompass all aspects of laboratory practice with an exposure to theory. Thus well-structured laboratory instruction will facilitate in achieving eight to ten graduate attributes. Theoretical-practical fusion into a singular body of knowledge enables them to apply collaborative and experiential learning and in turn become trained professional beneficial to the society. This paper outlines laboratory instruction framework has been developed by coupling both virtual simulated and real hands on laboratories.

LABORATORY INSTRUCTION

The engineering laboratories could be grouped into three different categories (a) educational laboratory (b) research laboratory and (c) development laboratory (Feisel and Rosa, 2005). The nature of educational laboratories has transformed a lot in recent years and started to explore the use of information and communication technology for laboratory instruction. In general educational laboratories is classified into three types (a) Hands on practice laboratory; (b) virtual simulated laboratory and (c) Remote operated laboratory (Elawady and Tolba, 2009). In the traditional hands on practice laboratory, students are typically tasked with performing experiments and taking measurements, analyzing the data, often in the context underlying theory in the curriculum, and reporting the findings. This laboratory requires high demand of space, experimental infrastructure, financial cost and faculty time. It is suitable and manageable for limited students with dedicated equipment else group work is involved. In the case of virtually simulated laboratory, they are mimic of real laboratories. It provides opportunity for each and individual students to understand the procedural knowledge in detail. All the infrastructure required for laboratories is not real, but simulated on computers. Some note that the cost of simulation is not necessarily lower than that of real labs (Canizares and Faur 1997). Hands-on labs involve a physically real investigation process. Two characteristics distinguish hands-on from the other two labs: (1) All the equipment required to perform the laboratory is physically set up; and (2) the students who perform the laboratory are physically present in the laboratory. Hands-on labs put a high demand on space, instructor time, and experimental infrastructure, all of which are subject to rising costs. Table 1 list the difference between hands on practice laboratory vs simulated laboratory. As per National Board of Accreditation (NBA), criteria stipulated for evaluation requires real laboratory facilities and technical support fetches 80 points during the evaluation process. It is presumed if the infrastructure is established teaching learning process will ensure the effective usage of laboratory. However, the current generation of students lost their charm in exploring the laboratory. Students' assessments suggest that students are not satisfied with current hands- on labs (Dobson et al. 1995). Hence it is highly imperative to couple both hands on practice laboratory and virtual simulated laboratory for effective teaching learning process. Moreover it is appropriate time to tap the potential of Information and Communication Technology (ICT) towards teaching and learning process. ICT based teaching learning process facilitate scaffolding effect to the learners. This instructional scaffolding is an instructional tool that provides support, extends the range of the learner, and permits the completion of tasks not otherwise possible. It accommodates the learner pace in achieving the outcomes listed for the programme.

Table 1: Advantages and Disadvantages of Hands-on Labs and Virtual Simulated Laboratory

	Hands-on Labs	*Simulated Labs*
Access Mode	Physical access to lab.	Virtual access to experiments using simulation programs.
	Advantages 1. Realistic data 2. Interaction with real equipment 3. Open ended experiments are possible. *Disadvantages* 1. Limited to available physical environment 2. Inflexible lab room (needs schedules).	*Advantages* 1. Good for concept validation 2. No time and physical restrictions. *Disadvantages* 1. Idealized data 2. No interaction with real equipment.
Infrastructure	HW components and computers if required	Simulation SW programs.
	Advantages 1. Offer students the sense of the reality 2. Help students to connect the experiment under staff supervision. *Disadvantages* 1. Finite lifetime of the HW components 2. Needs maintenance of the HW components 3. Vulnerable to damage (misuse, theft……).	*Advantages* 1. Good for conceptual understanding 2. Secure if safety precautions are taken into account. *Disadvantages* 1. Need SW update.
Pedagogical	*Advantages* 1. Nothing like real experiment 2. Interaction with supervisor 3. Offer students to collaborate 4. Offer students to learn by trial and error *Disadvantages* 1. Students may not complete experiments in lab period 2. Supervision required	*Advantages* 1. Have more Pedagogical adv. than other labs 2. Provide safe learning environment for experimentation with dangerous equipment 3. Flexible and easy to use SW tools 4. Enhancement through animation and virtual reality software. *Disadvantages* 1. Supervision of academic staff not available 2. No sense with real equipment of the experiment.
Economical	1. Expensive (Disadvantage)	1. Low cost (Advantage)

VIRTUAL LABORATORY

The Government of India funded flagship project, National Mission on Education through Information and Communication Technology (NMEICT). Under this mission, there is increase in number of virtual simulated laboratories and remote laboratories for student learning. As a part of NMEICT project, Centre for Environmental Management (CEM) National Institute of Technical Teachers Training and Research Chennai (NITTTR) developed this virtual laboratory for the course "Environmental Engineering Laboratory". In general, laboratories can motivate students, provoke active learning, and convey practice of fundamentals. Current generation are digital savvy and spent maximum time with digital tools. Hence it is appropriate to scaffold learning through computer based learning tools. Virtual simulation laboratory is developed and uploaded in the course learning management system (LMS) and it is ensured each student completes all the virtual experiments prior to the laboratory course. Virtual simulation experiments will provide proper procedural knowledge and in turn conceptual knowledge is obtained in the real laboratories by performing the experiments within the stipulated time duration.

The main purpose of this paper is to integrate the virtual laboratory with real laboratory. There are different type of learners and in outcome based education, it is the learning matters rather than the time taken for learning. In hands on practice laboratory, due to increase in number of students and paucity in the equipment for testing, attention is limited. Hence, the students gets only glimpse of procedural knowledge and there is only little scope for enhancing the conceptual knowledge. A laboratory instruction framework has been developed by coupling both virtual and real laboratories. It is neither the replacement of real laboratories nor switching to the virtual laboratories. It is the proper blend of virtual and real laboratory, where there is more scope for the students to work in both the laboratory at ease and enhance their procedural and conceptual knowledge. This method of instruction, is completely based on the pedagogical value and ensure that the student acquire both procedural and conceptual knowledge through this instructional material. It also provides more meaningful in the learning, by providing good opportunity to the student for manipulating the equipment and materials and in turn construct new knowledge by properly connecting with existing knowledge.

However in this theoretical framework, it is decided to couple both virtual and real laboratory. Environmental engineering laboratory is uploaded in course learning management system (LMS), which ensures student must finish and practice the virtual laboratory before commencing the real laboratory. In the LMS it is ensured and cross checked whether students finished the course or not and moreover it is assessed the time taken for their understanding. In this situation, students get good opportunity to practice the laboratory virtually and understand the meaning of each steps followed in the experiment. During the real laboratory practice, students may work individually or in group to clarify and authenticate the procedure learned in the simulated condition. Since the virtual laboratory is simulated, complete user intervention is required for the completion of the same. During the laboratory session, students will discuss during the each step and interact in better manner which help them to clarify their doubts and enhance their learning process. Virtual laboratory acts as an instructional scaffolding to augment the students and motivate them for better involvement during the laboratory. In addition to this there is lot of scope for getting more clarity in the laboratory. It also acts as a flipped classroom, where learning take place outside laboratory and more conceptual clarification during the real laboratory. Figure 1 to 4 shows the virtual laboratory developed for the environmental engineering laboratory. Interactive screen experiments contain within themselves significant technological interest. However, this is of no value if these resources deliver no educational benefit and couple with real laboratory.

Fig. 1: Environmental Engineering Virtual laboratory – Main Menu

Fig. 2: Environmental Engineering Virtual Laboratory – Example of Particular Experiment

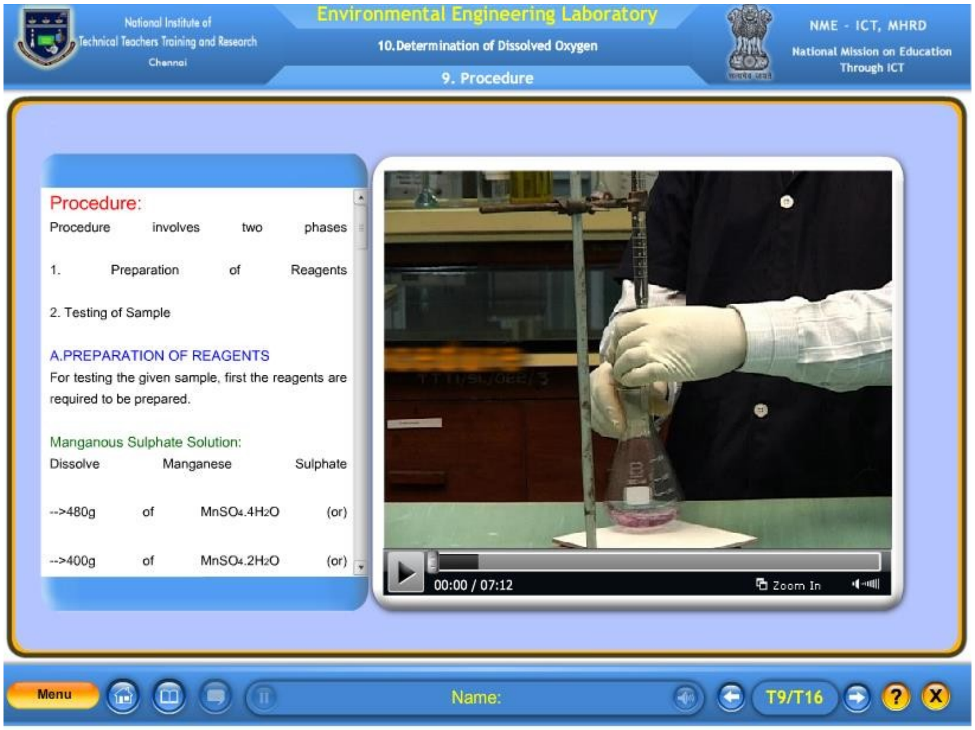

Fig. 3: Environmental Engineering Virtual Laboratory – Example of Testing Procedure

Fig. 4: Environmental Engineering Virtual Laboratory – Example of Virtual Simulation

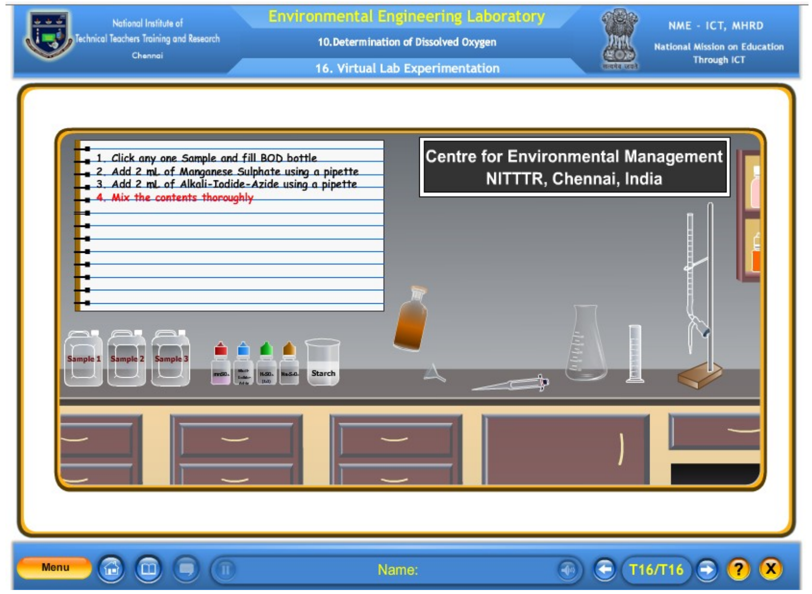

Fig. 5: Environmental Engineering Virtual Laboratory – Example of Virtual Simulation

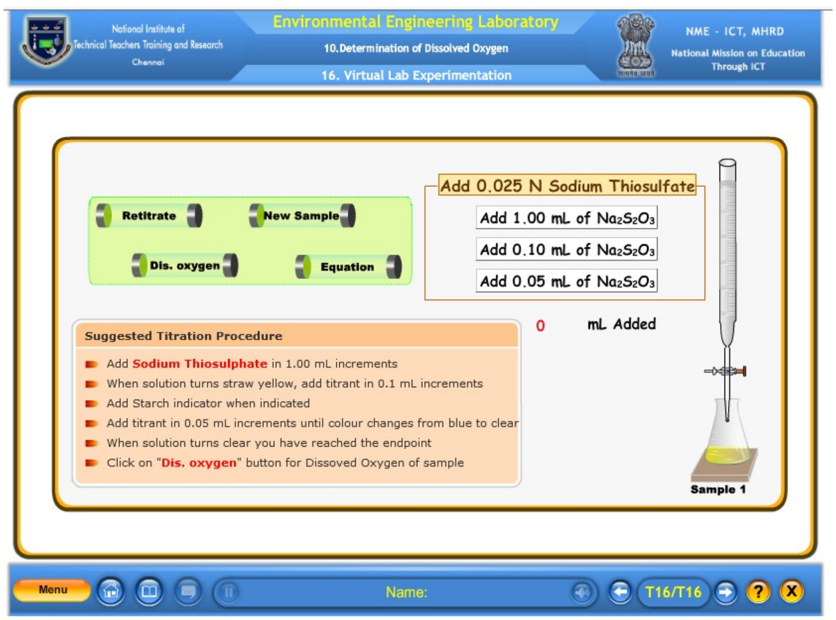

Fig. 6: Environmental Engineering Virtual Laboratory – Example of Virtual Simulation

CONCLUSION

With the current generation of students, the roles of teachers are changing, and there are undoubtedly ways of learning not yet explored to the fullest extent. However, with the advent of ICT based teaching learning, the student learning can be enhanced and instructional scaffolding is possible. The major improvement can be made through virtual laboratory in explaining the conceptual knowledge in addition to the procedural knowledge. In engineering the full-course (lecture laboratory component) may replace the existing lecture-based courses, and the virtual instruments may provide a highly interactive user interface and advanced analysis facilities that were not deliverable in the conventional methods. Proper blend of hands on laboratory and virtual laboratory helps the students to achieve the course outcome in a better manner. To cater for students who are coming from increasingly diverse backgrounds, and whose learning is best achieved in a contextual setting, is provided through this mode of instruction. It is clear that change is necessary because many of the things that we are doing can be done better with the help of technology. The Government of India, virtual laboratory developed under NMEICT could be utilised and integrated with the existing system. If the size and the complexity of the system increase, organisations and universities may undertake hands on laboratory developments in partnership with other universities and/or commercial partners and provide necessary procedural skills through virtual laboratory.

REFERENCES

[1] Feisel and Rosa, 2005, "The Role of the Laboratory in Undergraduate Engineering Education" Journal of Engineering Education, Vol. 94, Issue 1, pp. 121–130, January 2005.

[2] Elawady, Y. H and Tolba, A. S. 2009, "Educational Objectives Of Different Laboratory Types: A Comparative Study". International Journal of Computer Science and Information Security, Vol. 6, No. 2, 89–96.

[3] Canizares, c. A. and Faur, z. T. 1997, "Advantages and disadvantages of using various computer tools in electrical engineering courses" IEEE Trans. Education 40, 3, 166–171.

[4] Dobson, E. L., Hill, m., and Turner, J. D. 1995, "An evaluation of the student response to electronics teaching using a CAL package" Computer and Education 25, 1–2, 13–20.

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