Flipped Classroom Instruction Using Virtual Simulation Laboratory

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***Abstract*— In this paper effectiveness of the devised framework to implement flipped classroom in engineering educational laboratory using virtual laboratory is explained based on the observation made through controlled and experimental group. It is observed that the laboratory learning can be enhanced by providing learning material such as video, audio, simulation and testing manual and which can be accessed anywhere and at any time. Incorporating simulation laboratory with formative assessment in the learning resource materials, attracts the students to practice it before attending the real laboratory and it is more effective when compare to just a traditional reading material/manual. Thus, virtual laboratories facilitates the learning due to effectiveness of constructivist pedagogy. In general the main focus of educational laboratory is to provide better understand of the fundamentals behind each experiments and the skill required to perform it in accordance to the codal provision. Integrating flipped classroom in laboratory instruction helps the students to perform experiments through simulation in a structured manner and in turn actively engage in the laboratory for further refinement of the concepts learnt. The in-class activities during laboratory involve significant focus towards quizzing, problem solving and other active learning activities which engage students to recognize, recollect, retrieve, apply and extend the learning to real laboratory. Based on the study, it is observed that the administered pre and posttests results indicated that the accuracy increased and conceptual understanding of the laboratory procedures is improved with the flipped instruction. During the formative assessments students learned through virtual laboratory performed better in the handling and performing the experiments when compared to the traditional groups. Both treatment groups performed in a similar manner for experiments of low complexity and flipped group scored higher on items of moderate and higher complexity. The results categorically shows the effectiveness of flipped classroom with higher accuracy on the post test than the instruction. This study highlights the importance of the need in paradigm shift in the laboratory instruction and this new mode of teaching learning requires both a holistic institutional planning approach and technological support by the educational technologists. This paper concludes with a discussion of the implications associated with implementation and follow up.**

Keywords—Blended learning; flipped classroom; Learning Centric, Laboratory instruction; Technology enabled classroom.

I. Introduction

Flipped classroom is an instructional technique which promotes and enhances the learning of students as a part of blended classroom instruction. In this mode, the classroom environment is basically redefined to promote more discussion and questioning and it leads to further enhancement of knowledge. It is best suited to inculcate conceptual learning to the students and how to customize it for the laboratory classroom instruction is explained through this research study. It is found that, if this technique adopted appropriately for the laboratory instructions in a structured manner, it will enhance the learning capability and provide a better understanding of the concepts to the students. The role of the faculty member is transformed to facilitator and mentor from the instructor.

In the case of technical education, laboratories play an important role for the students to visualize the abstract concept, enhance their creative skills and promote the innovations. In general, the engineering laboratories can be grouped into three different categories (a) educational laboratory (b) research laboratory and (c) development laboratory [1]. But educational laboratory instruction in the technical institutions of developing countries faces several problems due to lack of a sufficient number of equipment's / instruments for the student learning, lack of professionally trained technician to handle the instruments and lack of interest to invest in the laboratory infrastructure. Hence it is appropriate to adopt blended classroom instruction for developing better knowledge society. In this study, virtual simulation laboratory is coupled with an individualized real practice session for understanding the improvement in learning capability. It is observed that in the traditional laboratory teaching, students are carrying out experiments in groups and their involvement in performing the experiments is not meeting the expectation envisaged. Thus, the graduated engineers are not meeting the requirements of clientele system, due to the existing gap between the obtained knowledge and skill. The literature review also revealed, there is a limited evidence on the impact of reform efforts in engineering education and what exists to be of largely poor

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quality is due to the increase in student enrolment without augmenting the laboratory infrastructure facilities. In addition to this, the current generation students are completely oriented towards securing marks/grades rather than accruing the fundamentals principles of the subject. One of the reasons attributed to such prevailing condition is due to the lack of the innovation in teaching-learning methodology and it is widely recognized that the teaching approach needs a paradigm shift from the teacher centric to student centric. The current millennial learners need to be instructed through an inclusive approach. There is a need to infuse more responsibility to the learners and teachers in turn act as mere facilitators. It is the time to restructure the classroom instruction through the techniques such as problem-based learning, inquiry-based learning, activity based learning and flipped classroom. It is highly imperative to incorporate different techniques in the classroom instruction in order to enhance the student learning. Our focus in this paper is towards redefining teaching-learning technique in the educational laboratory.

At present, students follow step by step instruction provided in the cookbook style laboratory manual. The main focus of the student in the laboratory is towards completing the experiments within the stipulated hours rather than understanding the underlying principle behind the procedure. If the interest of students in the laboratory is kindled through blended technique and adopting flipped classroom instructional strategy, it will be a great reform in the technical education system. The active involvement of the student in the educational laboratory can provide more opportunity for them to comprehend the difficult concepts. Thus, it will also provide enough scope for the students to apply their knowledge and understanding to the real world situations. In addition to this problem solving, individual and teamwork, communication, and other relevant graduate attributes are also acquired.

Thus in this research study, two experiments viz., estimation of dissolved oxygen and measurement of pH in the environmental engineering laboratory are instructed to the undergraduate students through two different techniques viz., one batch of undergraduate students taught through traditional instruction format and the second batch of undergraduate students taught using virtual laboratories.

II. CONCEPTUAL FRAMEWORK

In this study, it is ensured that the instructional design and delivery strategies follow the principle of constructivism and connectivism, where students are provided with the fundamental principle behind each laboratory experiments and nurtured to interconnect the new knowledge with the existing knowledge. The instruction technique provided an opportunity to authenticate the facts, theories, and principles through well-structured virtual laboratory experiments, prior to the actual practice in the educational laboratory. To be specific, well-structured laboratory instruction provided to the students to perform their designated experiments with concrete objects and concepts and in turn enhance their cognitive, affective and psychomotor domains. When the laboratory activities are performed in a group, it promotes creative thinking skills, individual and teamwork skills, problem-solving ability, communication skills, and other relevant attributes which are essential for holistic professional development of the students and it forms the core pedagogical practice [2], [3], [4].

The laboratory learning experience should constitute five components (as shown in Figure 1) viz., the student engages in scientifically oriented questions, the student gives priority to evidence in responding to questions, student formulates explanations from evidence, the student connects explanations to scientific knowledge, and student communicates and justifies explanations.

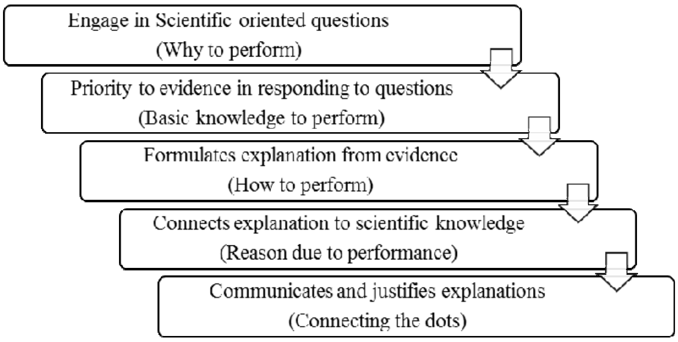

Fig. 1. Five components in laboratory learning.

Laboratory environment, especially virtual laboratory provides more scope for the students to scaffold inquiry during the learning process. Scaffolding makes the learning more tractable for students by changing complex and difficult tasks in ways that make these tasks accessible, manageable, and within student's zone of proximal development [5], [6].

III. STUDY DESIGN

In this study, two batches of undergraduate civil engineering students with 35 members in each group, have been taught with two experiments in the environmental engineering laboratory. The pedagogical strategy adopted was to infuse scientific inquiry at its teaching and learning phase. It is ensured students are completely involved in questioning the importance and need of the testing, collecting the sample, devising the investigation plan with think, pair and collaborate strategy which nurtures inquiry-based learning. The instructional manual is designed in such a manner it provides necessary information that fully explains the concepts and procedures that student will learn. The manual also provides the procedure to perform the experiment in a pictorial format (figure 2).

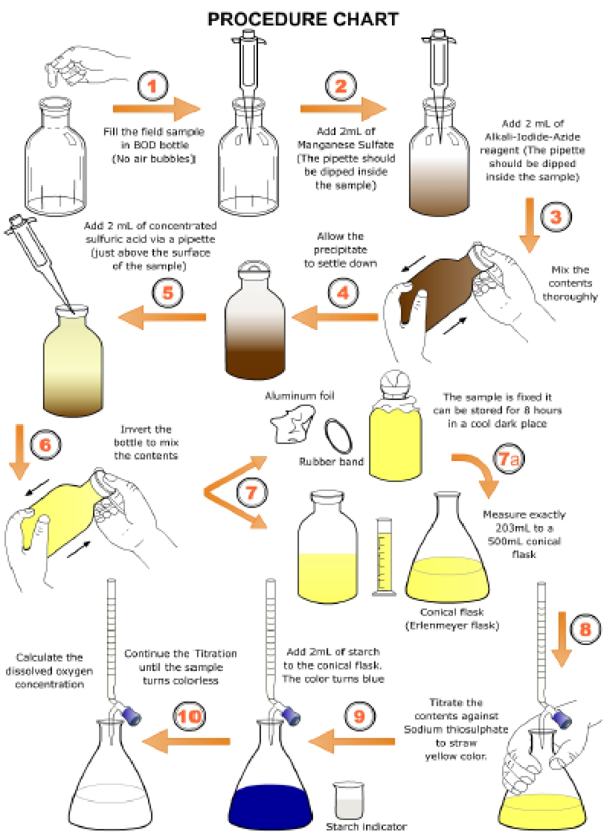

Fig. 2. Procedure to determine Dissolved Oxygen

In addition to what had been provided to the first batch, the second batch of students had complete access to the virtual laboratory. They will be learning the procedure by performing virtual laboratory experiments before coming to the educational laboratory. Few screen shots of the experiment is provided in the figure 3.

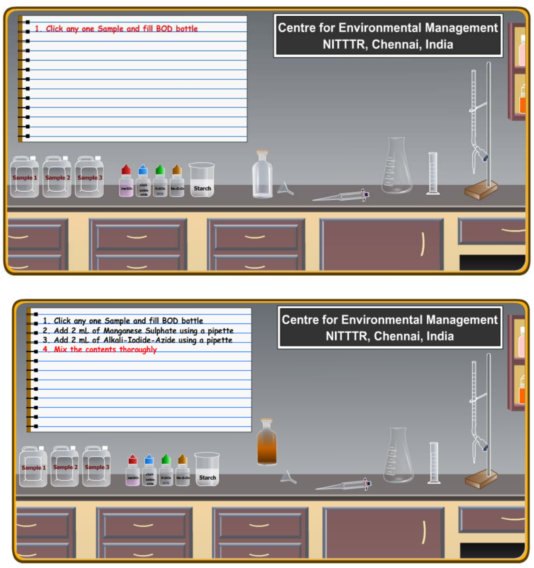

Fig. 3. Virtual simulation for the determination of dissolved oxygen.

The main purpose of this virtual laboratory focused on

(1) the students understanding of concepts involved in determination of pH and dissolved oxygen and its applications and

(2) their perception of the environment of the laboratory unit, the research questions are as follows:

(a) Can the virtual laboratory unit assist the students in understanding concepts and its applications during laboratory session?

(b) What are the student's perceptions of the classroom environment of the laboratory unit?

(c) How the virtual laboratory influence the understanding of students in learning?

In this experimental study, both the batches of students have access to good laboratory environment to perform their experiments in accordance with APHA standards. Student's entry behaviour is assessed through online questionnaire and consent for the study is also obtained. Both the batches undergone a lecture session about the experimental procedures along with their environmental significance. The essential role of factual knowledge and conceptual framework in understanding is evaluated through the questionnaire during the study. In the traditional laboratory, students worked in groups and performed the experiment after reading the procedure stated in the instructional manual. It is ensured that the students completed the pre-laboratory quiz and assignments before the class and also completed the lab report and short quiz after the laboratory class. After learning the experiments in the laboratory, students are engaged in specially designed situations, Students were provided with the opportunity to solve the particular problem by devising their own strategy in performing experiments and inferring the results. Students were asked to apply what they had learned from the pre-lab homework assignment to design their own experiments. The students were exposed to real-time problems in the field for assessing the quality of water.

For the second batch of students, in addition to the pre-laboratory quiz and assignments, they were supposed to finish the experiments through virtual laboratory uploaded in the course learning management system (LMS). It is decided to assess how the virtual laboratory scaffolds their learning. Virtual laboratory guides the learners to perform the experiments individually and understand the complexities of the task before executing in the laboratory. Scaffolding through virtual laboratory articulates the learners with better reflection on the progress of performing experiments and productive engagement with the task, tools, and peers. Based on the survey it is observed more than 85% of the students expressed, virtual laboratory facilitated them in obtaining the conceptual knowledge and in turn better retention of the procedures.

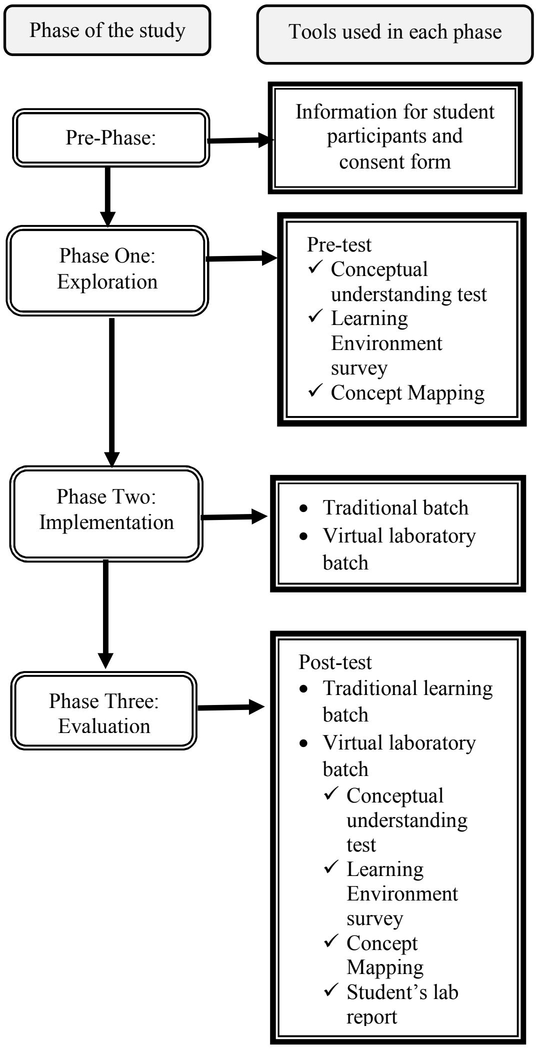

Fig. 4. Framework for the study design (Adopted and modified from Watcharee Ketpichainarong et.al., 2010)

IV. DATA COLLECTION AND ANALYSIS

In this study five tools were used to collect data from the students during the three phases: conceptual understanding test, laboratory group report, questionnaire, and student interviews. An online questionnaire with five open-ended questions is used for studying the conceptual understanding of the experiment conducted before and after the teaching-learning process and to ascertain whether the virtual laboratory facilitated the better learning. The test was developed based on objectives of the laboratory in the determination of pH and Dissolved oxygen. The questions were verified by the content experts for reliability and validity. This tool was used to answer the first research question on whether the flipped approach coupled with virtual laboratory can assist the students in understanding the fundamental concepts. The depth of conceptual knowledge about the experiments is studied using the concept mapping, both the batch of students was instructed to submit concept map. The effectiveness of the approach is evaluated using the rubrics with the input on the number of connections. Using the interviews, student's perception about the relevance, uncertainty, interpersonal negotiation, and attitude were assessed through recording. It provided a great hindsight about the student's perceptions of the constructivist classroom environment. It is observed that students experienced better understanding when they performed the experiments through the virtual laboratory. During the laboratory session, the students clarified the queries through questioning and discussion. For example, during the calibration of pH electrode, the student obtained a better understanding, why to calibrate and how to calibrate. In what order the standard buffer solution needs to be used for calibration. It facilitates in the retrieval of information from long-term memory. The student's involvement in the flipped classroom with prior virtual laboratory practice helped them to create greater relationships between fragments of knowledge and facilitate in correcting disorganization of content knowledge. Virtual laboratory provided comprehensive utilization of all the learned process skills. In the project, quasi-experimental control group design two batches of students provided Pre intervention and post intervention test and questionnaire to understand their learning. This study basically employed the use of a control group (without virtual laboratory) and special group (with virtual laboratory) to determine the impact on the virtual laboratory based learning due to different instructional approaches. Based on the concepts maps developed by the student in the learning of understanding and the report submitted along with the interview helped to gauge the in-depth information mostly on understanding the impact on affective domain.

V. RESULTS AND CONCLUSION

Based on the study, it is clearly observed that the post-test scores were significantly higher than those of the pre-test. Higher gains were observed on the blended learning approach coupled with virtual laboratory. The second batch students could figure out how to perform experiments at ease in both field and laboratory condition. The student's laboratory reports were evaluated using the Rubrics with five major criteria (a) Introduction, (b) procedure for testing, (c) data and results, (d) discussion and conclusion and (e) comfort and time for performing the testing. The second batch of students benefited a great deal from the blended based environmental laboratory in knowledge construction, reasoning, communicating and explanation and increased motivation. The students exposed to virtual laboratory exhibited better learning and obtained increased scores in the conceptual understanding test, better clarity in laboratory reports and concept mapping. Flipped classroom based virtual laboratory seemed to foster more enthusiasm for performing experiments in the laboratory. The students reacted positively on the inquiry experiences, practiced working as a team, and incorporated what they have learned into the laboratory report. The key success factors in this study are in both the context and methodology, both the methods inculcated inquiry but virtual laboratory was more beneficial.

Based on the concept map evaluation was conducted before and after the learning process. Each criterion had a maximum score of 4. For the first criterion, the maximum score was given to the concept maps that made all relevant links, similar to the reference map constructed by the experts. Logic and understanding were looked as second criterion and clarity, legible and easy-to-follow links were made into third criteria. The results showed that the mean scores of the students' concept map after using virtual laboratory significantly improved after the learning process according to the three criteria on content, logic, and understanding, and presentation of the concept maps. The results thus depict that this flipped classroom instruction strategy coupled with virtual laboratory helped the student to construct and conceptualize the knowledge on pH evaluation and DO measurement from basic principles to applications.

Based on the paired t-test it is determined the overall post-test scores were significantly higher than those of the pre-test. These results show that the flipped classroom instruction is more constructive than that in the traditional laboratory. The higher scores of the post questionnaire suggested that students perceived the flipped classroom instruction environment coupled with virtual laboratory aroused their enthusiasm and critical thinking. The students perceived that the experiences from the learning unit were more relevant to their everyday interests and activities than the traditional classes.

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