Analysis of Industry based Experiential Learning for Undergraduate courses in Civil Engineering

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***Abstract*— Increased levels of communication and automation process indicates the onset of fourth Industrial Revolution. Production of industry ready professionals especially for the dynamic Civil Engineering domain will be an outcome of continuous implementation of interactive teaching-learning methods. Incorporation of industry-based experiential learning to supplement the classroom sessions have been attempted for two undergraduate courses in Civil Engineering programme namely Surveying and Computer Aided Building Drawing for first year learners. Simultaneously, conventional and standalone classroom teaching was implemented for the second year learners with respect to these two courses. This study attempts to compare and analyse the learner perceptions and measure the learning outcome attainment of the Industry based Experiential learning and conventional teaching method. The selected courses provided ample space and scope for the working of industrial methodologies such as use of modern laboratory equipment (Total Station) and software (AutoCAD) for real-time problems. The assessment patterns varied extensively between the two teaching methods as the first year learners had experimental assessments for solving critical scenarios in the construction site. The results and analysis of learners' perception obtained through the internal assessments provided an insight that Industry based Experiential Learning was well ahead in the development of Industry ready professionals. However, the challenges in this novel method are also accounted for future adaption for other courses. Hence, this study provided a unique opportunity to compare and contrast the learning environments and identify specific benefits for both the teaching methods.**

Keywords: Industry based Experiential learning, Surveying, Computer Aided Building Drawing, Civil Engineering

1. INTRODUCTION

India's population is among the youngest in an ageing world. With the nations' current demographic statistics, youth population is excessive which seems to be opportunistic for the growth of the country. As per Economic Survey'19, additional jobs need to be created to keep in track with the ageing population which will turn out to be well-educated and skilled. India stood with 34.33% of youth population by 2020. The World Economic Forum predicts that by the year of 2025, around 50% of the workforce requires reskilling due to the increased usage of new technology (Li 2022). In this scenario, it is the responsibility of the teaching community to mould and prepare the youngsters (learner community) for the future challenges. Engineering graduates need to be competent for solving issues that arise as a result of socio-economic, environmental and engineering factors (Das 2021). The Program Outcomes (PO) which serves as the guideline for Engineering Education need to emulate the needs for an Industry oriented teaching process.

"When one teaches, two learns". These words of Robert Heinlein stand as a testimony to the teaching community. Our teaching philosophy is to pave way for an interactive learning scenario. With the advent of several modes of learning and teaching, learner community is provided with abundant resources. But the prospect of identifying an appropriate content lies with a good facilitator. The aspect of supervision prevails more than guidance in today's teaching scenario.

Today's learners are called to be modern as they understand, analyse and implement the acquired skills in a complex and energetic environment. Such 21st century skills (Rotherham and Willingham 2010) also enable the learners to collaborate effectively with their peers and respond to evaluators healthily. Problem solving, communication, ethical responsibility, accountability for decision making are key roles of a professional. These are the integral components that result in fruitful outcome through 21st century skills. The incorporation of Technology-Organization-Environment (T-O-E) is highly imperative for implementing Industry 4.0 skills among the learners (Srivastava et al. 2022).

A. Conceptual beginning

Our Institution, Saveetha Engineering College has been highly instrumental in exposing us (as a facilitator) to several active learning tools and methodologies. Right from Multiple Interactive Learning Algorithm (MILA), Inquiry Based

Learning (IBL), Active Learning (Senthil 2020), several models of teaching-learning were implemented time and again. Conventional teaching was gradually replaced with interactive teaching and that resulted in a state where a model like Industry based Experiential Learning was taken up.

Civil Engineering courses are of great importance as they pave way solving real-time engineering problems that cater to the basics needs of a society such as housing and infrastructure (Das 2023). For effective teaching in the initials days, for a course like Surveying that involved both theoretical and practical components, we adopted Attention, Relevance, Confidence and Satisfaction (ARCS) model (Li and Keller 2018) for structuring the teaching content. Later, several online tools (Mielikäinen 2022) along with Moodle enabled us to implement the interactive learning for a laboratory cum theory course like Surveying. Virtual laboratories (Hong and Lv 2022; Muslim et al. 2022)established by Government of India through Indian Institute of Technology (IITs) were instrumental in depicting the experimental set up and working during online classes.

However, still we felt there needs to be a call that could make us assess the capability of learner to implement the teaching content in his work. Every learner is a professional who needs to be aware of the objective of his learning process. Without this realization, teaching and learning never comes to a fulfilment. At the right time, we were introduced to the history of Problem Based Learning (PBL) initiated by the Aalborg University (AAU) in Denmark and Regional Research Symposium on PBL hosted by Indo Universal Collaboration for Engineering Education (IUCEE). In addition, the certification course obtained through International Engineering Educator Certification Program (IEECP-IUCEE), guided us in taking up this work.

The PBL model was extended as Industry Based Experiential Learning in forthcoming days with the guidance of our Institution's Architect. Industry-Institute collaborative teaching model was experimented in several countries like Australia (McLennan and Keating 2008) and South Africa (Das 2023). Several researches cite that Industry based model teaching is an effective and potential for inculcating the ethics of work environment among graduates (Lee 2008; Nandi et al. 2015; Agrawal and Harrington-Hurd 2016; Stephen and Festus 2022).

II. INDUSTRY BASED EXPERIENTIAL LEARNING

A. Process for implementation

At the initial stage, from a bucket of listed core courses, the Industry expert ensured to choose an appropriate course for the incoming first year Civil Engineering learners (2022 batch) by observing the presentation of important topics. Further, we made it possible to offer the chosen courses in conventional way of teaching for second year learners (2021 batch) simultaneously.

After three sessions of meeting with Industry expert, courses namely 19CE402-Surveying and 19CE417-Computer Aided Building Drawing (CAD) was selected for experimentation.

1) Strategies developed in the Industry Based Learning implementation of Surveying

Step1: The entire course consists of five units, and in Industry based experiential learning, these units are converted to problem statements. Hence, the timeline of the course (75 hours-Surveying; 60 hours – CAD) was taken into a single timeline for merging the courses. It was observed that there is a deep and fundamental relationship between these courses where Industry does not differentiate them as separate entities. Hence first year learners were educated at the beginning about the integration ideology and the course outcomes are outlined very clearly to them. Thus, they were introduced to two laboratories namely Survey and CAD during the session.

Step 2: At the onset of the class, learners are introduced to the backward learning system where the entire integrated course itself is modeled as a problem. For example, we have started with our first problem – 'Develop a plan for a given area by adopting suitable modern method of surveying'. To accommodate the learners to answer this problem, they were introduced to only the required components of syllabus. Hence, it was expected from the learners to identify the needs for answering this problem statement by gathering and implementing the appropriate parts of the course.

Step 3: This step involves the introduction of the leaners to the stepwise process that would assist them in completing the project or problem. For example, the Industry expert along with the respective faculties gave them a detailed introduction to the concept of Field Measurement Book (FMB) sketch and State Building Rules and Regulations. These topics were not explicitly mentioned in the syllabi; however, it was a revelation that these are required as utmost from the Civil Engineering graduates in the field work. Instead of expecting the graduates to relate the conventional topics with their work environment, the Industry way of teaching enables them to experience the actual requirement of a dynamically changing field like Civil Engineering. Further, each first year learner on the suggestion of Industry expert were provided with safety jackets, helmets, measuring tape for their own to facilitate their real-time visits to building under construction in the premises of the Institution.

Step 4: A detailed evaluation of the developed solution and mapping the attainment of the course outcome with relevance to the learners' performance was carried out. Industry expert was instrumental in giving apt assignments which were monitored and assessed online (through Moodle). Each of the assignments were not tedious like a conventional write-up. Instead, real-time residential plans, FMB sketches and survey land records were shared among each learner to answer the problem statement.

Step 5: Reflective Analysis of the implemented Industry based model for further revision was taken up after the completion of the entire timeline of the integrated course.

As shown in Figure 1, the learners were taken predominantly for construction site to experiment the topics and later completed the drafting of plan in CAD laboratories.

B. Creation of Lesson plan

The lesson plans (Table 1) are developed to track the timeline of course outcomes, projects planned and requirements for the curriculum design. The lesson plan is uploaded in Moodle platform for the learners to identify the learning objectives and course outcomes that could be attained by solving a problem that solely identifies a subject.

Table 1. Plan and implementation of the topics based on Industry Expert's guidance (for first ten sessions)

Planned session	Planned topics	Date & Session	Topics covered
1	Introduction to Civil Engineering	10.11.2021 (8 am - 9 am)	Introduction to buildings (display of examples), explanation of terms like plot, extent and layout. Display and discussion of FMB sketch. Linear Measurements - A glimpse of Chain and accessories was given.
2,3	Introduction to Field Measurement Book (FMB)- Basics of Surveying & Computer Aided Drawing (CAD), Linear Measurements and Ranging	10.11.2021 (9 am - 10 am)	Introduction to basic tools in CAD software. Explanation of function keys in CAD along with demo. Drafting of FMB sketch in CAD (two examples). Assignment: Manual drawing of FMB sketch based on a given FMB ladder. Discussion of Assignment-1 answers. Units conversion (Linear and Area measure)- detailed discussion of conversion within feet, inches, metre with examples. Introduction to calculator in CAD software.
4	Unit Conversions in FMB	11.11.2021 (11 am - 12 pm)	Solving of examples in Unit conversions, Drawing of FMB sketch in CAD (one example), Introduction to drawing commands (Line and Circle) in CAD, Summarisation of the class was done. Assignment 2- Unit conversion of area parameters (feet - sq m and metre to sq.ft)
5,6	Introduction to Basic Tools & Commands in CAD (AUTO-CAD)-TN Building Plan Rules-High-rise, Non High-rise, Residential, Commercial and Industrial Buildings	12.11.2021 (8 am - 10 am)	Review of Assignment 2. Introduction and detailed discussion of Tamil Nadu Combined Development and Building Rules (2019). Introduction to terms: High-rise and non-High-rise buildings, floor space index, floor height. Examples drawn in CAD. Drawing of a plot layout (two examples). Setbacks and offsets. Calculation of plot area. Information on installation of AutoCAD. Assignment 3-Drafting of a plot layout of an Educational/School building for given parameters.
7,8	Drafting the Plot with Dimensions (Feet & Inches), Computation of Area in Square meter & Square Feet – Unit Conversions	15.11.2021 (10 am - 12 pm)	Review of Assignment-3. Detailed discussion of TN building rules for school buildings. Structures in setback spaces- Calculation of parking space - Design of staircase- and Special regulation for schools- Unit conversions done parallely.
9,10	Building Setbacks based on guidelines of National Building Code (NBC) Moodle Assignment on TN Rules for Building Drawing	17.11. 2021 (8 am - 10 am)	Experiment 1 - Determination of area of FMB plot layout in the field

C. Involvement of resources for implementation

The details of the learners, course, subject handled in the 2021-22 (ODD) semester involved in the Industry based Experiential Learning is displayed in Table 2.

Table 2. Involvement of course, subject, learners, faculty members, lab resources

Academic Year	Title of the course	No. of Learners	No. Faculty Members	No. of Labs	Status
2021-22 (ODD Semester)	19CE412- Surveying 19CE417- Computer Aided Building Drawing	47	2+1	2	Completed
2021-22 (EVEN Semester)	19CE401 Mechanics of Materials	47	1+1	2	Completed

Note: +1 indicates the Industry Expert

A glimpse of the differences that Industry Based Experiential Learning brought into my teaching pattern for Surveying is shown in Table 3.

Table 3. Learner perceptions before and after the introduction of Industry based Experiential Learning

Second Year Learners (Conventional teaching)			First Year Learners (Industry model)		
Q1	Q2	Q3	Q1	Q2	Q3
Determine the horizontal and vertical angle between two points using theodolite.	Distinguish between microwave and electro-optical total station.	Discuss in detail the segments of GPS.	Develop a plan for the college playground using theodolite.	Develop a profile for the college roads using Total Station.	Develop a spatial system for classrooms using GPS.

Figure 1. Learners' in the construction site during the Industry based teaching model

D. Effective Assignment and Assessment

At the end of the session, learners were assigned with a real-time work testing their drafting skills in CAD software. An example of learners' submission of drafted plans is displayed in Figure 2. At this frontier, it is to be noted that such drafts are generally assigned to them at a higher semester. But the Industry oriented teaching exposes them directly to the ultimate objectives of a course at the initial stage like first year. Also, the potential portfolio while specializing these courses are exhibited to them through the experiences of the Industry expert. The assessment questions (Figure 3) were not prescribed for a limited duration or marks. The rubrics were designed as per the requirement of the Industry needs.

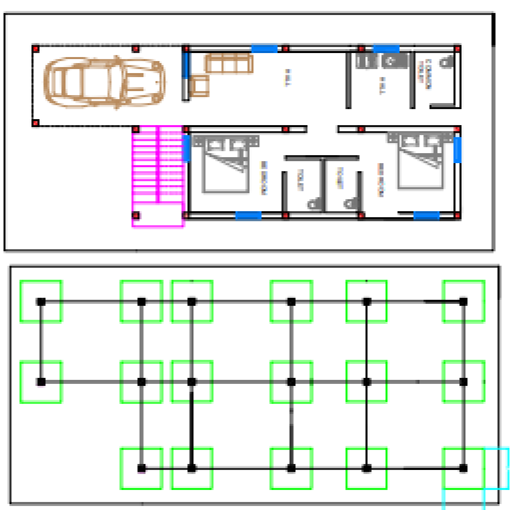
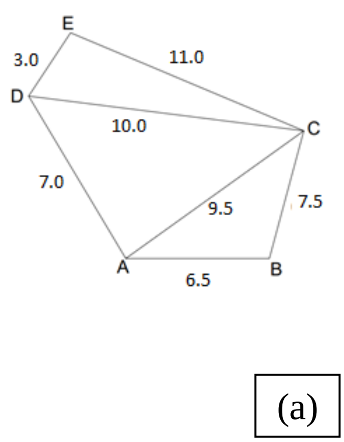


Figure 2. Learner's submission on an assignment related to drafting and design

In addition, each assignment was assessed iteratively based on standard rubric (Table 4) designed for the field work related to the problem: 'Develop a plan for a given area by adopting suitable modern method of surveying'.

<table>
<tr><th>Sl. No.</th><th>Question</th><th>CO</th><th>Bloom's Taxonomy Level</th><th>Rubrics</th></tr>
<tr><td>1.</td><td>Using the given FMB data, plot the given dimensions in the field and compute the setbacks and area.
<table>
<tr><td></td><td></td><td>A (28)</td><td></td><td></td></tr>
<tr><td></td><td></td><td>20</td><td>15</td><td>E</td></tr>
<tr><td>D</td><td>7.5</td><td>17.5</td><td>7.5</td><td>F</td></tr>
<tr><td></td><td></td><td>12.5</td><td>4.0</td><td>G</td></tr>
<tr><td>C</td><td>3.5</td><td>5.7</td><td></td><td></td></tr>
<tr><td></td><td></td><td>B</td><td></td><td></td></tr>
</table></td><td>CO1
CO2</td><td>Level 2 - Understand
Level 3 - Apply</td><td>Reading the FMB Data – 1 Mark
Plotting the data in the field – 6 Marks
Calculating Setback – 6 Marks
Calculating Area – 2 Marks
Viva – 5 Marks</td></tr>
<tr><td>2.</td><td>Refer the FMB sketch, plot the given dimensions in the field and compute the area.

</td><td>CO1
CO2</td><td>Level 2 - Understand
Level 3 - Apply</td><td>Reading the FMB Data – 1 Mark
Plotting the data in the field – 15 Marks
Calculating Area – 1.5 Marks
Unit Conversion – 1.5 Marks
Viva – 10 Marks</td></tr>
</table>

PART – A **05X02 = 10**

1. Examine the possibilities of the kinds of special measurements that could be done using a total station while updating a past survey record.
2. Define the concept of Selective Availability.
3. List the softwares used in GPS data processing.
4. Explain the terms spherical triangle and spherical excess in astronomical surveying.
5. Identify the significance of Mean Sea Level (MSL) in surveying.

PART –B **02X13 = 26**

6. (a) Explain in detail the working and measuring principle of total station.

(or)

6. (b) Explain in detail about the different segments of GPS.

7. (a) Find the shortest distance between two places A and B, given that the longitudes of A and B are 15° 0' N and 12° 6' N and their longitudes are 50° 12' E and 54° 0' E respectively. Find also the direction of B on the great circle route. Radius of earth = 6370 km.

(or)

7. (b) Calculate the hour angle and declination of a star from the following data.
Altitude of the star =22° 36'
Azimuth of the star = 42° W
Latitude of the place of observation = 40° N.

(b)

PART –C (Case Study/Applications) **01X14 = 14**

8. (a) Justify the requirement of a total station as a modern surveying equipment by listing its functionalities, parameters, merits and demerits.

(or)

8. (b) Assess the role of Global Positioning System (GPS) for location-based services in the city with appropriate examples.

Course Outcomes	
After successful Completion of the Course, the Students should be able to	
CO4	Develop a plan for given area by using modern surveying equipments
CO5	Explain the various streams of advanced surveying

Part	**Part - A**				
Question No.	1	2	3	4	5
Course Outcome	**CO4**	**CO4**	**CO4**	**CO5**	**CO5**
Knowledge Level	**K4**	**K1**	**K2**	**K2**	**K3**

Part	**Part - B**				**Part - C**	
Question No.	6. (a)	6. (b)	7. (a)	7. (b)	8. (a)	8. (b)
Course Outcome	**CO4**	**CO4**	**CO5**	**CO5**	**CO4**	**CO4**
Knowledge Level	**K2**	**K2**	**K3**	**K3**	**K5**	**K5**

Figure 3. An example of the Assessment questions and rubrics (a) Industry model and (b) Conventional model

Table 4. Assessment Rubric (Tested for a sum of 30 points)

Criteria	Excellent	Average	Poor
Set-up and Equipment Care (5 points)	Equipments are accurately placed. Temporary adjustments are done precisely and zero setting made at a lesser duration. (4-5)	Equipments are placed in position and preliminary adjustments done to some extent. (2-3)	Setting up of equipment is not done accurately. Details about adjustments is not known. (1-2)
Data Collection (5 points)	Learner demonstrate good knowledge of the lab procedures. Coordinates with others to follow procedures. Carefully follows each step before moving on to next step. (4-5)	Learner demonstrates good knowledge of lab procedures. Obtains help from peers to solve problems in procedures. Follows each step. (2-3)	Learner lacks appropriate knowledge of the lab procedures. Requires help from the facilitator to even complete basic procedures. (1-2)
	Measurements are both accurate and precise. Observations are in order and errors may be found for correction. Includes appropriate symbols, units and significant digits. (4-5)	Measurements are accurate with reasonable precision. Observations are not in order. Includes symbols, units and significant digits. (2-3)	Measurements are incomplete and inaccurate. Observations are incomplete or not included. Symbols, units and significant figures are not included. (1-2)
Ethics (5 points)	Observations and procedures are ethically noted. Usage of instruments are done with care and responsibility. (4-5)	Observations and procedures are noted properly only to some extent. Usage of instruments need to be taken care. (2-3)	Observations and procedures are not reliable. Usage of equipments are not done with care and responsibility. (1-2)
Corrections (5 points)	Errors were identifiable, minimal and adjustable. (4-5)	Errors were identifiable, systematic but requires some procedures to adjust. (2-3)	Errors were random and unidentifiable to some extent. Correction procedures need to be well-read to implement. (1-2)
Understanding of concept (5 points)	The inference drawn out from the experiment is a reflection of a good understanding of various interrelated concepts. (4-5)	The inferences are approximate and are not related properly with the learner's understanding of the concepts. (2-3)	The inferences are vague and are not relatable with the learner's understanding. (1-2)

III. CHALLENGES DURING IMPLEMENTATION

1. **Handling of learners:** With a newer method of teaching arise the effective issue of handling learners. Initially, there were 60 member classes. With the emergence of innovative learning methods, the classes functioned with 30 members. Slowly, the one to one teaching and learner interactive evolved in the classes. In the current scenario with 'Choice Based Learning', the learner has the role of choosing the course and facilitator which clearly depicts his aspirations. In the present case, first year of 47 learners were taken up

and two faculties along with an Industry expert catered to their needs arising from the course. Initially, learners were comparing this way of teaching with other courses that were implemented in a conventional mode. Time and again, their involvement and knowledge levels were improvised by field visits and innovative assignments.

2. **Adaptation of teaching community:** The initial days were ones where facilitators had dilemma in shifting from conventional teaching. Even though the shift was based on 'trial and error' methods and gradual sessions, the process by itself demanded a large quantum of dedication and belief from the teaching community. Right from the assimilation and preparation of activities, the facilitators had a great role in reaching the current status under the guidance of Industry expert. As mentioned by (Deed et al. 2014), 'personalized learning spaces' are need of the hour where both the learning facilitator and learner can accommodate themselves into open-up classrooms in both face-to-face and virtual modes.
3. **Learners' willingness:** The methods of a new way of teaching is always a boon to the learners. However, we realized that is not possible to obtain the same positive response from all sectors of learners. The heterogeneous learners team always provided mixed response to the methods of teaching. However, the consistent efforts of teaching community made the learners understand the effectiveness of realistic learning.
4. **Time-consumption:** This challenge could even be a myth mostly, as continuous experiments with Industrial connections lands us at several conclusions on time management. For example, managing a field visit within a two-hour session was tedious. Most of the experiments required durations exceeding the prescribed course hours. However, the nascent experience with this model is giving us hope to overcome this challenge. In this industry based teaching model, there should be a good balance between time and cost involved in the process (Chryssolouris et al. 2016; Mavrikios et al. 2018). These authors in their 'Teaching Factory' concept elaborated on the nature of time and overlapping time involved in the learning process,
5. The cyclic process of online and offline (face to face sessions) that occur due to the pandemic situations posed a challenge which requires detailed planning. However, continuous engagement through resources like MOOCs and virtual tools resulted in a constant collaboration with learners. (Cohen 2018) stated that consistent involvement of industry experts shall be maintained through virtual meets.

IV. COMPARATIVE ANALYSIS

The academic results of the first and second year learners with respect to the experimented courses were assessed to be 100%. Hence the Industry model and conventional teaching are in par with the attainment of academic results. However, though they match quantitatively, the qualitative status of first year learners' understanding of Surveying and CAD course through Industry oriented teaching is found to be effective as they can relate with real-time requirements of the Civil Engineering Industry. This reflection can be substantiated with the findings of (McWilliam 2008), where the author stated the ways to unlearn how to teach conventionally. The authors stressed on lessening the time for giving instructions and insisted on the involvement of facilitator in the experiment mode. In our case, with the industry expert in the academic session, the facilitator was able to take the role of both a 'collaborative critic' and an 'authentic evaluator'.

A mock interview session related to a placement process for the positon of a Quantity Surveyor and CAD Engineer in a Core company was conducted to assess the first and second year learners. As expected, second year learners performed well on theoretical questions but were found to be slow in grasping the field oriented questions. The panel members gave an appreciable feedback for the first year learners as they were able to relate with the summative and formative assessments while answering the panels' queries on real-time environment of an quantity surveyor or a CAD Engineer. This improved performance was a result of evaluating the learners based on authentic assessment which were assessed for meeting up the real-time industry expectation. As mentioned by (Ajjawi et al. 2020) in their research 'Work Integrated Learning', authentic assessments are important in aligning the curriculum with the needs of the industry.

V.SCOPE FOR IMPROVIZATION

As of now, there are no external collaborators except the Industry Expert (Architect) of our Institution. But at frequent intervals, experts from the domain of Surveying and Design related studies are invited for guest lectures and webinars. (Clarke 2021) stated that a balance between industry scenario and academic environment need to be reached for a successful collaboration. Similarly, our experience with industry expert gave us few reflections on bring a consensus between these work scenarios namely Institution and Industry. Further, internship opportunities in their concerns are communicated to collaborate and expand the problem solving method. In addition, Memorandum of Understanding (MoU)are in progress with Ministry of Micro, Small and Medium Enterprises (MSME) backed start-ups in the Surveying field. The requirement for robotic total stations were identified as they are used in the real-time field instead of the semi-automatic total stations available for study purpose. The purchase of such high-end equipments are in progress.

As already stated in Table 2, the compatibility of Industry based teaching model is extended to another core course 19CE401- Mechanics of Materials for the same set of learners. As mentioned earlier, the outcomes of the current Industry based Experiential learning plan will be analyzed, reflected positively and revisions will be made in forthcoming semester.

As per UNESCO report (2019), atleast 47% of Indian youngsters are not in track for quality educations and skills necessary for employment in 2030. This is the perfect time to take up PBL to simultaneously impart knowledge and work skills for learners. (Almeida and Simoes 2019) in their study reflected about 25 innovative projects carried out by the Portuguese learning model where learners were transcended to a higher order of education by dealing with such problem solving methods. Trailing behind such studies where solving critical scenario at academic level tends to bring the ‘top-bottom’ approach in learning and promotes the implementation of backward curriculum.

VI. CONCLUSIONS

Our Institution upholds quality education, always planned to produce industry ready professionals. We firmly believed that any graduate from this Institution should be a product that accommodates to the realistic expectations of the Industry and promotes ethical standards in the society. We were able to realize the ardent motivation of IUCEE in making us realize a real-time scenario of implementing problem based learning for Surveying. The learners’ involvement in positively approaching each tasks within a problem are encouraging to widen the scope of the process.

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