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On Instilling Research Paradigm in PG Engineering Students through Guided Open Ended Lab Component Implementation

Dr. Joshi Manisha Shivaram
Department of Medical Electronics Engineering, B.M.S. College of Engineering, Bangalore 560019, India
msj.ml@bmsce.ac.in

Abstract— Creating interest and involvement of engineering students into the domain specific research work is indispensable for the future technology developments. Original intellectual and creative contribution through experimentation to the discipline can bring new developments significant for societal reforms. This paper presents an effort to nurture research interest among postgraduate students of Biomedical Engineering. In order to nurture a research attitude, a Lab component for the course Biomedical Image Analysis was modified with practical reflection-based learning style. The impact analysis of this exercise is studied objectively. The newly designed Lab component included more practice-based learning, demanding additional time from students and teacher, for the discussion and reflection-based learning. Assessing students on the basis of critical thinking, focused efforts and the right approach in devising the solution for real-life problems played a critical role in this pedagogy. The impact of this exercise on students learning is analyzed by comparing course outcomes and program outcomes attainment for two batches with batch size 14 and 16 respectively. The assessment was based on rubrics devised for various phases. The course outcomes were improved by 6 to 12% for the experimental Batch. This is also reflected in increase in PO attainment in the same proportion. Particularly, attainment of course outcomes related to handling complex real-life problem and to develop solution showed considerable improvement. The results revealed individual student's ability in implementing and analyzing the open-ended experiment. The major conclusion from this educational experimental work is that the conceptual, practical, and interpretational skills necessary for research can be inculcated by devising innovative pedagogy. This work also reports positive sideways of this practice and the difficulties faced during the entire exercise.

Keywords— Research Paradigm, Reflection based learning, Open ended Lab component, Industry readiness

Dr. Joshi Manisha Shivaram
Department of Medical Electronics Engineering,
B.M.S. College of Engineering, Bangalore 560019, India
msj.ml@bmsce.ac.in

1. Introduction

For the impending technology developments, creating interest for domain specific research work among postgraduate students is very essential. Original and creative involvement through experimentation can bring new advances for societal transformations. This paper presents an effort to nurture research interest among postgraduate students of Biomedical Engineering. In order to foster a research attitude, a Lab component for the course Biomedical Image Analysis was modified with practical reflection-based learning style. Typically, an integrated course in the engineering curriculum consists of a lab component along with classroom-based learning.

During the conduction of Lab experiments common practice is, students are provided with the cook-book. If a course involves programming, then students follow the instructions given by teacher and use a cook book experiment scripts to get the output. This practice to handle Lab components creates an illusion of practical learning and limits students' critical thinking skills [1]. Project based lab component implementation is, where students are given the liberty to design their own experiments, instead of merely following the already set procedures from a test guide or elsewhere [2-5]. In comparison with traditional approach of conducting lab, during Open-ended laboratory classes, students are encouraged to formulate experimental methodology. While doing this, student need to go back to theory concepts explained and then devise the methodology. With this attitude, students thought process is instigated while implementing the concepts. In the process, they use reflection-based learning attitude to decide the correctness of the process used during the study. This experience will certainly be beneficial to PG students during internship or the project work when they are expected to work independently. In the open-ended practice, the problem can be solved in many different ways and student need to endorse the best possible solution among few favorable, based on quantitative analysis. This offers freedom to students to explore their ideas to design experiments and analyse the best possible solution [6-9]. Numerous factors influence engineering student's inclination towards research: exposure to research article reading and knowledge of writing research article. This study presents an effort towards making PG students inclined towards research.

2. Methodology

The methodology and results presented in this paper are part of pedagogics designed for the course 'Biomedical Image Analysis'. This is a four credit integrated course, in the first semester of a PG program Biomedical Signal Processing and Instrumentation. This course has weekly three hours classroom learning and two hours of Lab component. Earlier, experiments in this course were designed to understand algorithms in digital image processing, applied to medical images. During interaction with students when they were asked questions like, why this algorithm is suitable? Did you compare the results by changing the flow of the process used? students did not respond. With no thought process about suitability of the algorithm and reflection-based learning, the need of transformation needed in conducting the lab component was realized. Besides, the problem-solving skills using modern software tools is another essential component in making students industry ready. Therefore, in the new course design for this course, implementation of Lab component was changed from the traditional practice to an open-ended style. The experimental batch of PG students (Batch1) had 14 students admitted from the diverse UG programs. The proposed teaching learning methodology has been tested for Batch-1 with 14 students and results are compared with a previous PG batch (Batch 2 with16 students) where this pedagogy was not experimented. The course design was very thoughtfully organized, to conduct the lab component as a guided open-ended project-based implementation. The need of a greater number of contact hours with students was recognized during the course design itself. As a general practice, in the first class, course design was discussed with the students to provide outline of pedagogy, schedule for completion of the various tasks involved, and skill enhancement thereafter. Course outcomes and its mapping with Program Outcomes (PO), assessment and rubrics devised for the evaluation were also discussed. Students were enlightened about why this change is desirable and how it will be expedient to them when they complete the PG program. In the continuous internal evaluation (CIE) for this course, considering the efforts and the time requirements, open ended lab component was specified with more weightage (60%) compared to internal tests (40%). Being a PG course, this kind of autonomy has been granted to teacher in the academics by the institution. The Bloom's Taxonomy was considered while setting the test question papers. Question paper had three sections. One of the sections was completely based on problem-based learning to assess the higher order thinking. Table-1 describes course outcomes and their mapping with Program Outcomes for the PG program. Table- 2 represents Program Outcomes based on NBA guidelines.

While mapping the course outcomes with program outcomes the level in terms of number 1 to 3 refers to low, medium and high respectively. PO mapping level-3 indicates the high contribution of the course learning outcome in achieving a particular PO of the PG program. This weightage is based on the marks assigned for the specific activity and its importance in course learning outcome.

Table 1: Course Outcomes (CO) for the course and its mapping to Program Outcomes (PO)

Course Title: Biomedical Image Analysis			
Course Outcomes (CO)	Course Outcomes (COs) statement	Program Outcome (PO) mapped	PO Mappin g level
CO1	Apply the fundamental concepts of Image processing for Biomedical Image analysis.	PO3	3
CO2	Design and implement open ended experiments for medical image analysis using modern tools	PO1, PO3	3
CO3	Develop Graphical models to understand medical image enhancement and segmentation	PO1, PO3	3
CO4	Write a technical document on reflection-based learning as an outcome of open-ended experiment designed.	PO2	3

Fig.1. represents the methodology conceived for the guided open ended lab component-based learning.

The following section gives details of various phases in this Teaching Learning Process (TLP). The implementation of open-ended project had the following main tasks:

a. Development of medical image segmentation algorithms:

- Through research-based knowledge assimilation, define the problem statement to work on identified medical image database.
- Reflection based learning to decide appropriateness of the algorithms developed.

b. Writing a technical report on the open-ended experiment conducted

- Discuss various algorithms and their comparative analysis
- Reflection based discussion about suitability of the algorithm

Table 2: Programme Outcomes for PG program based on NBA guidelines

PO #	Program Outcomes (POs)
PO1	Ability to independently carry out research /investigation and development work to solve practical problems
PO2	Ability to write and present a substantial technical report/document
PO3	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program

Each student was directed to select different medical image dataset of 10 images of various qualities in a specific medical imaging modality. These medical image datasets are available online for the research purpose. This phase took a little more time as students were not familiar to this sort of activity. Also, search for medical image database and reading related research papers anticipated additional time. During this phase, students had many queries like, how to initiate the lab component work, where to search for medical image database and technical papers etc. They were guided to decide on a problem definition for their open-ended experiment. During this step, their interest in learning this novel research-based technique was prominently noticed. Students were communicated to use their free time apart from the scheduled lab time for completing the given tasks. According to the schedule, all the students presented the problem definition and was evaluated based on devised rubrics. During this session, few students were advised to change the problem definition so as to reach the objective. Table-3 provides various phases of this entire exercise, activities scheduled during this experiment, along with expected output and POs addressed. Before starting the tangible implementation, students must have the knowledge of different algorithms in this course. This was taken care

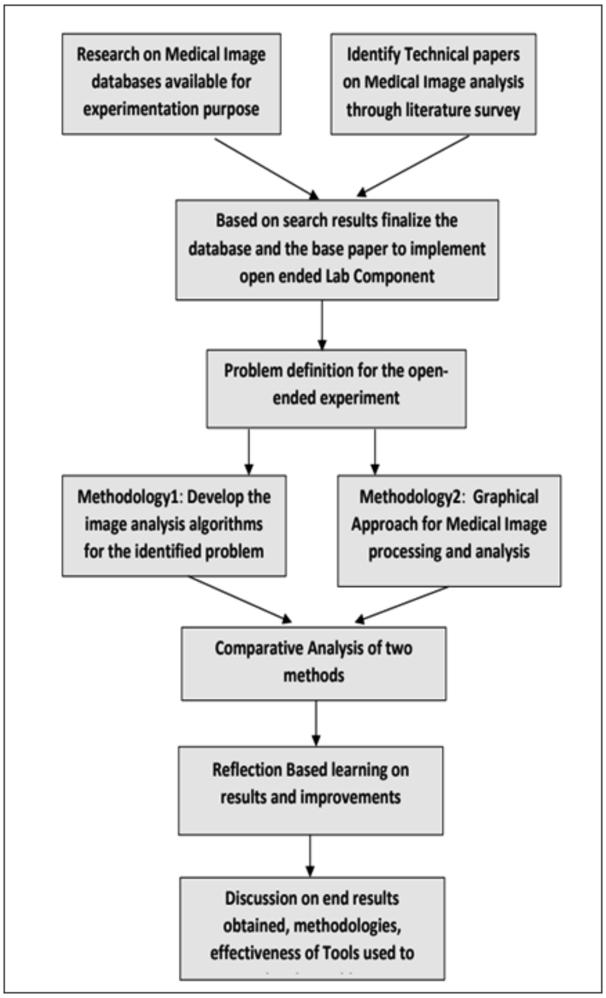

Fig.1 : Flow of Proposed Teaching Learning Process

during the classroom teaching. Generally, in initial class hours algorithms for digital image pre-processing were discussed. The students were guided to start with these basic algorithms. With this exercise, they could verify results of various algorithms to identify specific and appropriate process for pre-processing of selected medical images. In the regular classes while teaching, they were exemplified the applicability of various image segmentation algorithms. For this kind of pedagogy smart classroom facility has been utilized during teaching hours to show related activities through demonstration. With today's developments in the technology, there are many resources available on the internet related to programming aspects; students were allowed to refer such resources and acknowledge them in the presentation and in technical report to understand the ethical and professional practices. As per the curriculum, the number of contact hours for this course is 5 hrs. /week (3 Hrs. theory and 2 Hrs. of Lab). But for this activity-based learning, additional 2-3 contact hours/week have been dedicated depending upon the requirement. Problem solving using modern software tools is expected from the students, when they are ready to work for industry. Students were told to use modern tools like MATLAB Simulink and Open CV Python libraries for the experimentation

3. Experimental Findings

The present-day education is slowly transforming to student centric approach. Many teachers are experimenting with new practices to actively engage the students during teaching hours and try to impart skills through hands on activities. The best way to make engineering graduates industry ready is to work on an industrial problem or to give them practice on how to work with real life problem. Course design with doable activity-based learning and its implementation plays significant role in Outcome Based Education (OBE). As discussed in the methodology, this guided open ended lab experiment implementation had three milestones, namely, problem definition through research-based knowledge assimilation, use of modern tools in implementing digital image processing algorithms & reflection-based understanding thereon and technical report writing. Assessment of the students was through separate rubrics designed for each of the activity given in Table 4. The rubrics were shared with the student during the course design presentation and they were clarified about each criterion.

No separate weightage was specified for assessing presentation skills of the students as the main purpose of this activity was to impart innovative practical skills using modern technology. Students were told to use two modern tools for their experiment, Open Computer Vision (CV) with Python and MATLAB Simulink. Selection of these tools was based on its usage in the industry and availability. In recent days, use of Open CV python for machine learning of images has been increased in industry and research practice. For using these modern tools, demonstrations were given to exemplify how various image processing algorithms affect the results. The advantage of CV libraries is, students can directly use the available open-source libraries. But while using them, they must know how the algorithm works at the back-end, mathematics operations involved in each algorithm, parameters to be assigned and change as per the requirement during the analysis. MATLAB Simulink is a Graphical approach to solve a problem.

Here, students can develop a model-based solution by selecting necessary blocks and choosing required parameters. Initially student started with this tool for the implementation of image pre-processing algorithms to decide the best suitable algorithm for their image dataset. After this, they were guided to work on image segmentation process. In segmentation, students worked on three broad types of segmentation algorithms,

- Thresholding Based Image segmentation
- Region Based segmentation and
- Development of Customized Algorithm

Table 3:Different Phases of Guided Open-Ended Project Based Pedagogy for the course Biomedical Image Analysis

Activity	Time allotted	Expected Output	PO addressed
Phase1			
Identify medical image database for the open-ended project-based learning. Select 10 images with diverse quality for the experimentation purpose. Identify 10 research papers in previous 3 years to assimilate domain specific information	Duration- 1 week. Commitment of 4 -6 Hrs. in a week by the student.	Ground work for the problem definition	PO1
Problem Definition: Presentation and Discussion with the course instructor about the activity performed and conclusion	20-25 mins. for presentation and discussion for each student. activity to be completed in a week.	Identification of students learning through presentation and discussion	PO1
Phase 2			
Implementation of application specific Medical Image processing algorithms using Open-source tool. Discussion on the results obtained	Regular Lab hours (2 Hrs.) Additional work as a home work during free hours	Development of algorithms and reflection-based learning	PO1, PO3
Develop Graphical models to understand medical image enhancement and segmentation for the proposed open-ended experiment	Regular Lab hours (2 Hrs.) Additional work as a home work during free hours	Development of algorithms and reflection-based learning	PO1, PO3
Progress Presentations to know advances in algorithm developments	20-25 mins. for presentation and discussion for each student. Duration- 1 week	Identification of students learning through presentation and discussion	PO1, PO3
Identify the flow of algorithms based on results obtained. Analyze which algorithm is the best suited	Regular Lab hours (2 Hrs.) Additional work as a home work during free hours	Development of algorithms and reflection-based learning	PO1, PO3
Phase 3			
Capstone project presentation	Presentation and demonstration	Output of the open -ended experiment through reflection-based learning	PO1, PO3
Technical document preparation on the open-ended experiment formulated	Submission of the technical document	Research based technical document	PO2

Table 4: Rubrics for the assessment of various components of guided open-ended experiment

Assessment component	**Parameter considered for the assessment**	**Range Scale**				**POs addressed**	**Weightage**
		Exemplary 10-8	Proficient 7-5	Satisfactory 4-2	Poor 3-0		
Problem definition	Literature Review and Medical Image database search	Refers to understand current literature for precise problem definition Good number of technical references listed	Refers current literature to understand define problem Few Good number of technical references listed	Refers few technical papers and needs improved literature review for precise problem definition technical references not listed according to requirement	Do not refer to current literature and vague problem definition technical references not listed in proper way	PO1	20%
Design of the experiment	Design a process using image processing algorithms discussed during classroom base learning	Innovative ideas, skill s of proposing various solutions, convincing the proposed solution with the clarity on fundamental concepts	The concepts are well understood and able to frame appropriate the algorithms	Fair understanding of concepts but not presented clearly, needs improvement	Insufficient for adequate understanding	PO3	20%
Implementation using modern tools	Development of image processing algorithms using modern tools	Result oriented development of algorithms and analysis Confidence in using tools	Few algorithms implemented and analysed Confidence in using tools	Needs improvement on using new tools and developing algorithms Can use few libraries and functions	Not satisfactory understanding of al gorithms and use of tools Needs more hands-on practice to use the tools	PO3	20%
Results and reflection-based learning	Excellent Analysis and reflection-based learning to achieve the results	Good analysis and justification of applicability of algorithms	Fair analysis and reflection-based learning to get few results	Can analyse very few results and applicability of algorithms without understanding need of parameter usage	Lags in justifying us e of algorithms and learning from variations in parameters	PO3	20%

Technical Report writing	Integration of Knowledge Focussed technical discussion Reflection based comparative analysis, Spelling & Grammar, Sources and Citations	Very well understanding and has applied concepts learned in the course, focused In - depth discussion No spelling &/or grammar mistakes Cites all data obtained from other sources.	Good understanding of concepts Well focussed discussion & Very few spellings &/or grammar mistakes Cites all data obtained from other sources.	Fair understanding of applied concepts and discussions of the algorithms few spellings &/or grammar mistakes mostly Cites all data used from various resources	Poor understanding of applied concepts without focussed discussion Many spellings &/or grammar mistakes Do not Cite all data used from various resources	PO2	20%

In the medical image analysis, success rate of the segmentation algorithm is image specific. Therefore, while deciding the sensitivity and specificity of the algorithm it is necessary to check the results for each image and then conclude about the performance of the algorithm. Considering the time constraint, students were advised to work on 10 images only. In development of customized algorithm, students need to decide the suitable pre-processing step and then work on mathematical operations to combine the results with thresholding or region-based segmentation algorithms. Finally, they need to verify which of the image processing algorithms are suitable for their problem, based on subjective analysis initially and then objective analysis. All steps of this exercise were exemplified during the classroom-based learning. During lab hours students were monitored for the progress, they were encouraged to discuss the difficulties and were directed by suggesting alternate methods. During available free time (for student and course instructor) students approached to show intermediate results and for the guidance. Initially, some students had difficulty in usage of the tools. Few students expressed the non-availability of resources; for them dedicated work stations were allotted in the PG lab. Interest was picked up by students after few labs and practice sessions. During this entire exercise, learning through peer conversation and how it creates interest and boosts the confidence among others was prominently noticed [13]. Table 3 shows the various phases involved, time allocation and anticipated output at the end for each activity. Nevertheless, students were given the guidelines about how to organise the slides and flow of the presentation. Evaluation was done by the course instructor and two randomly selected students from the same class. This approach made students to actively participate during the entire process and was also helpful to understand how peer evaluation can be done based on the rubrics. The findings as a result of this activity-based learning are motivating to introduce this kind of tools in Lab based subjects.

The analysis presented here is for the registered students of two batches. (Batch-1, 14 students, Batch-2, 16 students of previous year). The entire activity was evaluated for 50 marks and later scaled down to 30 marks. CO attainment was calculated through Continuous Internal Evaluation (CIE) with 70% weightage, 20 % weightage for CO attained through semester end evaluation (SEE) and 10% weightage for CO attained through course end survey (CES). If marks scored by a student is greater than 50% (threshold) of the total allotted marks, it is considered that the specific course outcome has been attained. Rubrics are used for Continuous internal Evaluation with weightage 70% which is major part of this pedagogy. The guidelines for the mentioned weightage have been given at the institutional level.

Table 5 represent the CO attainment for 2 bathes. Increased attainment for CO1 through CO4 can be noticed for Batch-1 who executed guided open ended lab component, as represented in Fig.2.

Table 5: CO attainment for the Batch-1, Experimental Batch and Batch-2

Course Outcomes (CO) #	70 % weightage of CO attainment through CIE (direct)	20 % weightage of CO attained through SEE (direct)	10 % weightage of CO attained through CES (indirect)	Overall CO attainment
Batch-1				
CO1	47.60	18.50	2.0	68.10
CO2	60.80	18.50	2.0	81.30
CO3	60.33	18.50	2.0	80.83
CO4	61.60	18.50	2.0	82.10
Batch-2				
CO1	41.23	17.0	1.8	**60.03**
CO2	51.59	17.0	1.8	**70.39**
CO3	55.81	17.0	1.8	**74.61**
CO4	52.17	17.0	1.8	**70.97**

**Note: Batch1 (open ended experimental batch)

Batch2 (students of previous year who did not undergo this experiment)

In this experimental study students acted like "researchers". They individually defined experimental design and obtained coherent results. They also exhibited their ability to analyse results. It can be linked to authentic student achievement, so that students can actively experience the feelings of practising professionals. During this entire experiment, it was observed that, students need to be self-motivated and focussed throughout the experimental study. Students with weak learning attitudes need more support and guidance to encounter the technical problems of the open-ended experiment. At the end of the activity student presented their capstone project. The technical report was submitted by the students with discussion on algorithms developed and their reflection-based learning. This experiment has strongly conveyed that, hands on based learning is an effective learning approach for students. This could be mainly because of students 'interest developed during the experimentation and impact of peer group discussions during the activity. The main findings from this activity exhibited progressive outcome about creative thinking, learning, organizing and time management. Considering the weighted average, overall PO attainment for the two years is as represented in Table 6, which denotes sound improvement for all POs.

Table 6: Contribution of COs in PO attainment

CO	PO Attainment					
	PO1		PO2		PO3	
	Batch 1	Batch 2	Batch 1	Batch 2	Batch 1	Batch 2
CO1	--	--	--	--	68.10	60.03
CO2	81.30	70.39	--	--	81.30	70.39
CO3	80.83	74.61	--		80.83	74.61
CO4	---	---	82.10	70.97	---	---
PO Attainment	81.065	72.50	82.10	70.97	76.74	68.34

Experiential learning provided a concrete platform for stimulating the learners' intuitiveness to be more methodical, inquiry-based with specific aim in mind. It created opportunities for the learners to be more engaging intellectually, creative, and taking initiative while making decision on the results obtained to reach the final goal. Few students were lagging in the implementation, they were motivated and guided to complete the project with additional peer support. Students appreciated understanding of the core concepts of medical image processing compared to theoretical and traditional experimentation. During classroom-based interaction to exemplify the results, readiness of the course instructor and time management are very crucial. This activity was constructive efforts towards preparing students to work on research project and industry assignments in computer vision. Following factors contributed for the effective implementation of the open-ended experiment,

- Consistent efforts from students in implementing concepts taught during theory class hours
- Constant motivation, timely inputs and supervision by the course instructor
- Willingness of the students and course instructor to spend additional hours during the implementation to see the results are correctly obtained and discussion thereon.
- cooperative learning through peer interaction

Note: Batch1 (open ended experimental batch), Batch2 (students of previous year who did not undergo this experiment)

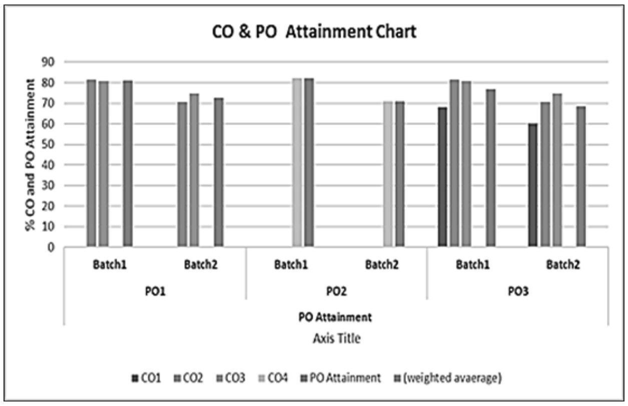

Fig. 2 : PO attainment through Course Outcomes

4. Conclusion

This academic research on pedagogy reports implementation of Lab component as a Guided open ended experimental learning for Biomedical Image Analysis, an integrated course in a PG program. This course is a core course having applications in the field of computer vision and extensively used in by industry. This methodology of implementing lab component has been experimented to nurture research attitude among post graduate students and also making them industry ready to work in the area of artificial intelligence. Students were guided to define open ended lab experiment which included implementation of various image processing algorithms for medical image segmentation problem defined by the student for selected medical image database. This included reflection based learning and technical report writing after its completion. The entire activity was planned during the course design stage. The assessment was done by the course instructor along with students in the same batch, based on rubrics devised. The effect on the overall students' learning and grade analysis was verified. The impact of this exercise on students learning is analysed by comparing the course outcomes and program outcomes attainment for the two batches. Batch-1 is with sample size 14, is the experimental batch. Students of this batch were part of this pedagogy. The Batch-2 with sample size 16 is the previous batch, who conducted Lab experiments with the traditional approach. The course outcomes were improved by 6 to 12% for the experimental Batch-1. This is also reflected in PO attainment showing increase in the same proportion. Particularly, attainment of CO2 and CO3 (81.30% and 80.83%) which are related to handling complex real-life problem and to develop solution for that showed considerable improvement. CO4 attainment related to technical document writing exposed the skills imparted for lifelong learning ability. The results revealed individual student's ability in implementing and analysing the open-ended experiment. More number of contact hours, dedicated efforts by the students were the significant aspects of this innovative pedagogy. In such a TLP, students with weak learning attitudes revealed additional support and guidance was required to meet the challenge of the open-ended experiment. Constant motivation, timely inputs and supervision by the course instructor are essential factors for students to accomplish the objective of the experiment. The attainment of program outcomes through designed course outcomes exhibited sound improvement. Assessing students on basis of critical thinking, focussed efforts and right approach in devising the solution for real life problem play a critical role in this type of training. Conceptual, practical and interpretational skills were exposed by the students throughout the experimental course. This entire experiment was motivational to continue it for the forthcoming PG students.

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