AC 2012-3742: FACILITATING GROUP WORK: TO ENHANCE LEARNING IN LABORATORY BASED COURSES OF ENGINEERING EDUCATION IN INDIA

Dr. Sujatha J., Mission10X, Wipro Technologies

Sujatha J. is academically qualified with a Ph.D. in signal processing, from Indian Institute of Science, Bangalore, India, and has more than 24 years of academic and industry experience. Over the years, Sujatha has participated in not only academic teaching and research but also in academic counseling for students, professional development programs, curriculum development, industry-institution relationship activities, and prototype development and team building. Currently, Sujatha is a core member of Research Center, Mission10X, Wipro Technologies, India, and takes active role in conducting workshops, designing course contents as well as various other Mission10X projects in addition to several research activities in various aspects of engineering education. As a technical faculty of Mission10X, she is a certified master trainer for the various training modules of Mission10X for engineering college faculty in INDIA. In addition, she is qualified with the "Cambridge International Certificate for Teachers and Trainers (CICIT),” Cambridge University, U.K.

Dr. Rajshri Jobanputra

Rajshri Jobanputra brings with her more than 15 years of experience of teaching, training, and research. Academically qualified with a Ph.D. in philosophy, from Indian Institute of Technology, Bombay, Mumbai, India, Jobanputra has been actively involved in academics through various roles of visiting faculty, trainer, and counselor across esteemed institutions of India like IIT Roorkee, IIM Ahamadabad, IITM Chennai And Mission10X, and Wipro Technologies. This paper has evolved as a result of a study conducted. At the time, Jobanputra was working as a consultant to Mission10X, Wipro Technologies, India.
Facilitating Group-Work: To Enhance Learning in Laboratory Based Courses of Engineering Education in India

Introduction

Quality of engineering education, which is essential for the economic growth of the nation, has emerged as a factor of paramount importance in India, today. This has led to several discussions on reforms in teaching-learning processes in engineering classrooms. In particular, laboratory courses form an integral part of the degree programs in engineering. Concepts taught through lectures are often complemented by laboratory experiments which are critical to enable learners to further develop their knowledge and skills. Student participation, however, in these laboratory based courses has been largely disappointing. It is often times a teacher’s experience that students are either not very interested in their laboratory classes or that they carry out mediocre efforts when involved in completing their laboratory experiments. Educators have regularly expressed their concerns with regard to their laboratory practices and ways in which one can significantly enhance the effectiveness of the same. A root cause analysis of such an existing apathetic attitude towards laboratory sessions that have been experienced and expressed can be traced to the lack of clarity of learning objectives as well as suitable facilitation in terms of appropriate pedagogy of laboratory instructions.

In this context, the present study is towards enhancing the learning in laboratory courses through appropriate design and facilitation of the popularly used pedagogy of ‘group work’. Group-work is one of the most commonly used pedagogy for laboratory sessions in engineering curriculum. However, though commonly used, it is often marred by improper planning and inadequate definition as well as assessment of learning objectives. Based on this premise, this paper aims to support the claim that while the use of “Group-Work” doubtlessly entail several positive learning outcomes through collaborative and cooperative learning, it has to be facilitated appropriately to earn higher dividends as an active-learning technique. Good facilitation is fundamentally a result of good planning. When a session is diligently planned, execution of the same becomes effortless and increases the likelihood of a session being successful is terms of involving the learner and increasing their knowledge and skill level.

In continuation, an attempt is made to understand the typical manner in which ‘group-work’ is actually carried out during laboratory sessions by way of making and recording observations of such sessions, simulated in the context of our faculty empowerment workshops. These observation records serve as our database upon which we identify and analyze key aspects relevant to group work specifically in the context of conducting laboratory sessions. Having thus identified some of essential group work aspects the paper seeks to warrant the claim that while facilitating groups, it is fundamentally essential to heed to vital aspects of group work and group dynamics during the planning phase. Facilitators who meticulously plan on how to conduct the session using active collaborative pedagogy such as group work are far more likely to positively impact a learner’s attitude towards laboratory session than those who do not. What is offered in this paper are thus some signposts which facilitators can use to effectively plan their group work and thereby enhance learner engagement in during laboratory session.
Laboratory courses in engineering education – existing scenario in India

In engineering education, concepts taught through lectures are often complemented by laboratory experimentation. The purpose of laboratory work is well articulated as it is a place to learn new and developing subject matter as well as insight and understanding of the real world of the engineer. This includes model identification, validation and limitations of the assumptions, predication of performance of complex systems, testing and compliance of specifications and exploration for new fundamental information.

However, in practice, approaches to preparation of laboratories are limited by various factors. Large class sizes lead to splitting of students of the same class into convenient number of groups and each group undergoes a given laboratory session typically once a week, in an allocated slot. This also means that labs are not synchronized with lectures many a times. Some students conduct the experiments before the theory has been covered while others do the same after some considerable time.

Typically the preparation starts with a short talk by the laboratory supervisor on the conduct of the experiment. The equipment is set up before the students arrive or students use many a times laboratory kits built for easier conduction of the experiments. There is mostly a prescribed routine of making adjustments and taking readings or noting down observations. The supervisors offer some pointers during the conduction of the experiment/procedure.

There is a common practice to support all laboratory exercises by short handouts or laboratory manuals. However, typically such handouts do not specify the objectives though these are usually implicit either in the procedure or analysis of results section. An outline of methodology, apparatus to be used and schematic of equipment may be included and for the numerical results, reading and number of sets are indicated and brief guidance on how to analyze the readings are also provided. However, it is to be noted that the student’s approach to conducting the experiment is not taken into account for evaluation normally and a written report is normally the sole basis of assessment.

It is further observed that most students do little preparation for the session. Also, though the students are split into small groups for the conduction of the experiment/procedure, teamwork is largely unplanned. Little attempt is made to ensure that all are participating or gaining an understanding of all aspects of the given complex procedure or experiment.

In a scenario such as the one described above, undergraduate laboratories are perhaps the weakest links in the chain of engineering education today. The students view laboratories as boring, not intellectually challenging and involving a lot of cookbook-style chores. To a teacher, laboratory teaching is a second-rate job that does not contribute to his professional development. Many institutions complain of the lack of resources, modern equipment, and infrastructure as the factors responsible for the malaise. However, the root cause of the problem is the lack of clarity of the objectives and the resultant poor design of the pedagogical content of laboratory instruction. Any sustainable improvement in laboratory teaching can be obtained not through acquiring state-of-the art equipment, but by seriously considering and improving the pedagogical design of the laboratory courses.
Thus the present day laboratory experiments seem to be largely aimed at reinforcing the lecture material and not to imbibe exploratory learning, which should ideally be the logical aim of a laboratory course. It must be understood that familiarity of standard equipment, measuring techniques and use of standard calculating procedures are essential, though they are of lower-order learning.

In order to understand and analyze this aspect further, a study was conducted through a number of faculty empowerment workshops for engineering college faculties across India wherein the participants actually plan and demonstrate an active learning session for their own subject matter to be taught. Several of these sessions were to demonstrate achieving active learning in the different scenarios corresponding to laboratory classes such as experimentations, computer simulations and use of hardware kits. The observations and experience of these simulated laboratory sessions are discussed in the following section.

Observations and inferences through Case Studies

A set of faculties belonging to different engineering colleges were invited to demonstrate the ‘Practical Work/Experimental Work’, for teaching a particular topic of their engineering discipline, in the context of a faculty empowerment workshop conducted by our group. This involved typically, demonstration by a team of 5 to 6 faculty members belonging to a given engineering discipline. The present work stems from an in-depth qualitative analysis of observations, interactions and case-study experiences recorded during 20 such sample demonstrations, held across different regions of India, of which the authors have been the main facilitators.

The purpose of this study was to observe, analyze and infer effective ways of facilitating active learning in scenarios of laboratory courses, equivalently demonstrated as “practical work” as mentioned above. In particular, a number of important aspects as illustrated in Table 1 were considered and corresponding observations recorded in detail by the authors during the study.

With primarily the six points mentioned in the Table 1 as the observation agenda, there were two arrangements for recording the observations. In addition to the observations recorded by the authors themselves, after every demonstration, the audience (which comprised of the fellow faculty members of the demonstrating team) was invited to provide their observations regarding the same. Inferences drawn from the collected reports/feedback specific to this study were later consolidated.

Specifically, as a result of the study, it was observed that in most cases, no objectives or expected outcomes were listed/ formulated. Further, the facilitator did not seem to plan specifically for any particular pedagogy/ execution strategy for the session. It is to be noted that especially in the context that laboratory courses it can become complex with several aspects of the tools/software/apparatus involved, to achieve specific learning objectives. Further, attention to the pedagogy and the execution strategy clarifies specific roles and responsibilities of both the facilitator and the learner and this in turn can lead to measurement of learning outcomes as well as the effectiveness of the teaching-learning session. Most importantly, as the laboratory courses are typically carried out by groups of students, an underlying skill that the facilitator needs to
possess is to make “group-work” effective so that collaborative active learning happens during the laboratory session. In absence of such effective group-work the laboratory sessions are reduced to mere passive learning sessions.

<table>
<thead>
<tr>
<th>Sl No</th>
<th>Observation criterion</th>
<th>Description of the observation criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Learning objectives</td>
<td>Were the learning objectives for the given practical session identified/listed explicitly during the demonstration?</td>
</tr>
<tr>
<td>2</td>
<td>Learning Methods</td>
<td>Did the faculty member use any specific pedagogical method during the practical work session? If yes, what are the details?</td>
</tr>
<tr>
<td>3</td>
<td>Learning Levels</td>
<td>Against Bloom’s Taxonomy⁶, what levels of learning did the faculty member achieve post the demonstrated session of “practical work”?</td>
</tr>
<tr>
<td>4</td>
<td>Roles and Responsibilities</td>
<td>What were the roles and responsibilities of the faculty and the learners during the session involving practical work?</td>
</tr>
<tr>
<td>5</td>
<td>Execution strategy</td>
<td>What prior planning and preparation did the faculty members have to make before engaging the demonstrated “practical work” session?</td>
</tr>
<tr>
<td>6</td>
<td>Learning outcomes</td>
<td>What kind of mechanism was adopted, if any, by the faculty to determine and measure the learning outcomes?</td>
</tr>
</tbody>
</table>

Table 1: Format of the Observation Record

While there was no doubt that learners benefited far more when faculty members were able to integrate the practical work session with active-collaborative pedagogy, it also surfaced from the various observation feedbacks that were collated, that much of the success in terms of learning depended on the concerned faculty member’s facilitation skills. Without some of the crucial facilitation skills exhibited by the facilitator it is unlikely that learners will either develop their required learning levels ⁶ or inculcate various skill sets ⁷. Thus, based on our detailed analysis of the experience mentioned above, enumerated below are some vital facilitation traits that any facilitator must possess as well as a design procedure to make a given laboratory course effective using ‘group-work’.

**Designing Group-Work for effective learning in laboratory courses**

It has been emphasized over and again that collaborative learning through group-work in engineering education is of great significance as this would lead the students to acquire various skills as well as achieve objectives in collaboration with others ⁸. However, creating such a collaborative environment in the context of laboratory session requires two important aspects as illustrated in Figure 1; on one hand it is essential that the facilitator formulates in detail the
relevant learning objectives as well as execution strategy to ensure achieving the same. At the same time, effective facilitation here also requires rigorous and thoughtful design of the group-work.

The important learning objectives that are relevant to a laboratory course typically are the ability to:

- **Measure**: Measuring various physical quantities as relevant to engineering domain using appropriate sensors, instrumentation and/or software tools.
- **Model**: Establishing or validating relationship between measured data and underlying physical principles.
- **Experiment**: Devising an experimental approach and interpreting the results to characterize an engineering system.
- **Design**: Developing system specifications from requirements, testing and debugging a prototype, system, or process using appropriate tools to satisfy requirements.
- **Analyze**: Collecting analyzing and interpreting data to form and support conclusions. Make order of magnitude judgments and use measurement unit systems and conversions.
- **Evaluate**: Competence in selection, modification and operation of appropriate engineering tools and resources.

**Figure 1**: Aspects of Facilitating Collaborative Learning in Laboratory Session
• **Communicate**: Communicating effectively both orally and in writing at levels ranging from executive summaries to comprehensive technical reports.

In parallel, the success rate of generating maximum learner involvement, leading to active learning, is likely to increase if the facilitator also chooses to pay sufficient attention to the following important aspects of group work:

a) **Group Formation**:
   - Making each member responsible and dependent on all others
   - Choosing an optimum group size (typically about 6-7 members per group)
   - Ensuring group size that actively and easily involves all

b) **Group Task**
   - Creating group tasks that require interdependence
   - Ensuring fair division of labor within the group
   - Setting up competitions among groups or using an alternative strategy if groups are not working well
   - Devising strategies such that group succeeds only if each member contributes

c) **Group Performance Evaluation**
   - Awarding prizes/ incentives helps keeping the group spirit high
   - Adhering to democratic mechanisms to deal with uncooperative members
   - Ensuring the evaluation of both individual as well as group performance
   - Offering students the opportunity to evaluate the effectiveness of their own group
   - Giving formative feedback on how each member of the group is performing

Further, in order to facilitate the implementation of such an effective group-work, a format of a session plan was offered to the faculty members that helped them to reflect and develop ideas on every aspect of their session like *methodology of teaching-learning, role of faculty, involvement of learners and learning outcomes* achieved. In particular, incorporating active learning strategies like “effective questioning”, “group discussion”, “debate” etc as a part of the execution, enhanced the learner involvement to a great extent. The same is illustrated in Figure 2 and the faculty members were very appreciative of such a tool towards diligent planning and execution so as to achieve higher learning during the laboratory session.

Also, to experience and substantiate the role of facilitation skills as discussed, a comparative case-study was conducted between two scenarios – one was a conventional laboratory session while the second was facilitated with well-formulated objectives and suitable execution strategies so as to achieve active learning the using session plan as shown in Figure 2. The two were compared with respect to effectiveness of learning, which is depicted in Table 2 and the same clearly illustrates the benefits of the second scenario in terms of higher level of learning as well as multiple skills achieved. In continuation, these facilitation techniques have been made part of our faculty development workshops so that the faculties are able to take it forward to their laboratory sessions and enhance the culture of active learning.
Session Name

Objectives

At the end of this session, the learner will be able to:
1.
2.
3.

Session Plan

<table>
<thead>
<tr>
<th>Time (in min)</th>
<th>Content</th>
<th>Learning Aid and Methodology</th>
<th>Faculty Approach</th>
<th>Typical Student Activity</th>
</tr>
</thead>
</table>

Execution Details of the Methodology

<table>
<thead>
<tr>
<th>Procedure of conduction in steps</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Relevant information before/during conduction</td>
<td></td>
</tr>
<tr>
<td>Significant Debrief points</td>
<td></td>
</tr>
</tbody>
</table>

Learning outcomes measured

- 
- 
- 

Figure 2: Sample Session Plan
<table>
<thead>
<tr>
<th>No</th>
<th>Laboratory Session</th>
<th>Learner Role</th>
<th>Faculty Role</th>
<th>Level of learning</th>
<th>Skills Imbibed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Conventional</td>
<td>Following instructions</td>
<td>Preparation for the demonstration in content and infrastructure, Monitoring, evaluating</td>
<td>Understanding</td>
<td>Not sure</td>
</tr>
<tr>
<td>2</td>
<td>Well-formulated objectives + facilitation of collaborative group- work</td>
<td>Listening, Observing, Interaction with other learners/peer teaching and learning, Discussing, Analyzing, Defining the problem, Justifying solution, Presentation</td>
<td>Design of the entire pedagogy, detailing interactions between the facilitator and learners planning and preparation, measuring learning outcomes</td>
<td>Understanding, Applying, Analyzing, Evaluating</td>
<td>Logical, Interpersonal, Visual, Linguistic, ICT skills</td>
</tr>
</tbody>
</table>

Table 2: Comparison of two scenarios

Conclusion

The existing scenario of engineering colleges of India shows that, the laboratory courses in engineering education, are typically engaged in a general way to support existing ‘conventional’ pedagogical practices which seem to be not so effective in developing the knowledge as well as skill of the learners. The root cause for the same could be lack of clarity in objectives and poor pedagogy of laboratory instructions. The systematic study and experience presented here has lead to the inference that these laboratory sessions have the potential and can be made most effective through appropriate pedagogic design and facilitation. As most of the laboratory sessions of the engineering curriculum are typically structured as to be carried out by groups of students, facilitating “group-Work” becomes very important in leading the learners towards several positive learning outcomes through collaborative and cooperative learning. The study presented here has offered pointers, suggestions and resources in this direction on how to make effective use of group-work in the given context. Further the same has been incorporated as a vital component of our faculty development workshops conducted for the faculty of engineering institutions across India. With this, it is anticipated that faculty members will be able to strengthen their facilitation skills to enhance the effectiveness of laboratory courses in engineering education so as to take their learners to higher levels of learning as well as develop the requisite skills for the engineering profession.
3. www.mission10x.com