THE IMPORTANCE OF LABORATORY EXPERIENCE IN THE ENGINEERING CURRICULA

G. Kuppuswamy [1] and R. Natrajan [2]

1. Introduction :

It is generally accepted that the quality of laboratory instruction is of considerable significance in engineering education. Laboratory-oriented studies include the research required to improve this process,. the use of laboratory instruction as a teaching method, characterization of the equipment and facilities, and other aids to this educational process. It should be noted that the student is actively involved in the form of participatory education.

Laboratory instruction plays a vital role in any engineering education programme. In addition to being a means of verification of theory, laboratory experience puts reality into theory, indicates the limitations of theory in actual situations, develops familarity with instruments and equipment, teachers techniques and procedures and aids the student in creating the motivation to reason and to analyse.

2.0 Role of Laboratory Instruction

The basic functions of any experimental work performed by engineers can be described as below :

a) Familiarisation of principles and concepts;

b) Model identification of devices and systems; quantitative information being obtained.

c) Validation of assumption to assu... the designer that he is within the realm of reality.

d) Prediction of performance of complete systems by simulation using computers, models or mock-ups, if the system is too large, complex, or non-linear.

e) Testing for compliance with specifications; includes acceptance tests, reliability, quality control and failure trend analysis.

f) New fundamental information that may include properities of materials, other co-efficients or transfer functions for an analytical model of a problem.

The primary goal of instructional laboratories

[1]Asstt. Professor, [2]Professor, Department of Mechanical Engineering, I.I.T., Madras.

is to inculcate in the student the theory and practice of experimentation to perform the above six functions. It should provide him with the basic tools for experimentation with the needed instrumentation and measurement theory.

3.0 Types of Laboratories :

The various laboratories found normally may be categorized as below :

a) The ***Set Laboratory*** with specified experiments using detailed instructions and equipment. The experiments are repeated each semester with minor changes or in some cases, major changes.

b) The ***Take-HomeLaboratory*** in which a significant part of the work is done by the student away from the institution, and the results of work reported to instructor. The laboratory may be used on a scheduled or non-scheduled basis.

c) The ***Problem Laboratory*** in which a student is given a specific well-described task to undertake.

d) The ***Project Laboratory*** in which the project to be undertaken may be somewhat general in description and broad in scope.

Each of the different types of laboratories is used for instruction in all of the different aspects of experimental studies. The characteristics of any one laboratory are usually strongly tied to the individual responsible for its organisation and operation, and the actual set-up is limited by many factors; institution, instructor, facilities, capital equipment available etc..

Also, the type of experimental activities carried on can be generally categorized as :

a) *Demostration Experiments :*

These encompass a wide range of specific activities. Included are live classroom demonstrations carried out by the instructor; group demonstrations guided and led by the instructors; also student-operated demonstrations which are more properly referred to as self-demonstrations.

b) *Student participation experiments/ Projects :*

In these investigations, the goal of developing the student capability as an experimenter is clearly implied.

Although most laboratories employ student participation experiments, many place a strong emphasis on demonstration.

Similarly, in the administration and operation of instructional laboratories, a variety of methods and techniques are normally found. The programme of laboratory instruction has to be geared to the total curriculum either as a separate function or integrated to serve as a service role for the remainder of the curriculum. The faculty may be full-time senior faculty, part-time research/post graduate assistants, or some mixture of the two. Methods of scheduling laboratory classes, size of the laboratory group, and policies affecting the availability of laboratory facilities for both faculty and students are some of the factors which vary widely from place to place.

4.0 Objectives of Laboratory Instruction

The objectives of the laboratory programme are mainfold, but the prime objective is to teach an engineering approach to real problems. The lecture and the laboratory are treated as separate parts of the curriculum. It is intended that each be utilized to its full extent to educate the students. Of course, the laboratory work is used to bolster the theoretical classroom work, but it is directed at developing the student rather than a particular experimental phenomenon.

The laboratory is an ideal place to develop student initiative and responsibility. It is an excellent place to develop the art of communication. These items are all interrelated and may be developed at the same time. For instance, by scrapping all experimental sheets, procedure outlines and report forms, the teacher can put the student in the position where he must use his own initiative in a responsible manner to obtain anything to report. Furthermore, much more factual material can be covered if the experiment is all laid out ahead of time.

The student must be taught how to approach problems which are new to him, and which he may believe are unavoidable. However, if he has the experience of being guided by the instrucvtor to a reasonable solution, he will learn the general approach and will be in a much better position to attack new problems. The student should be reminded constantly that if the problem has been solved many times before, it is not engineering. The engineer's task is to solve new problems. The student can be taught the accuracy of instruments and measurements without spending valuable time in refining a technique. Most technicians will be much more adept with actual instruments than the professional engineer needs to be. Thus accuracy should be taught as an educational item, not a technique of manipulation.

The broad objectives of the laboratory programme can be summarized as follows :

1. (a) Initiative,
   (b) Responsibility,
   (c) Art of Communication,
   (d) Engineering Judgement;

2. Teaching Measurement;

3. Teaching the engineering method of analysis.

Also the laboratory programme is a very important part of the curriculum and can not be relegated to the young and inexperienced teachers. Teaching a laboratory course is a challenge for any good teacher.

The question of whether the Mechanical Engineering laboratory is an important part of the curriculum is determined by its method of presentation more than by any other factor. The course presentation must grow in sophistication with the maturing of the student, but the increase in complexitv of the problem and the demand for more initiative on the part of the student do not alone make a vital course. In the competition for student's time, the laboratory may face extinction in the undergraduate curriculum unless we utilize every innovation that can draw from the laboratory its full potential.

Pressures are continuously being exerted to reduce laboratory time to make way for more basic course material, upgraded courses in the fundamentals, and the undebatable desirability of free time for students to ruminate and digest. At the same time, the laboratory can perform pedagogical functions not duplicated in any other learning situation.

Nowhere else can we develop in the student competence in the investigation of a problem by direct measurement and observation, and by the analysis of his own test results. Nowhere else is there the same opportunity for emphasis, clarification and expansion of lecture course material. The first hand study of instrumentation, the opportunity for the student to report his own findings in his own way, the encouragement of discussion, contemplation and self expression are all a part of a dynamic laboratory course.

5.0 Some Guiding Principles for Design of Laboratory Experience

Some principles governing engineering laboratory education are suggested below :

1. Student engineering laboratories should provide students with a worthwhile educational experience in a relaxed atmosphere and provide a proving ground for subsequent industrial research after graduation.

2. Laboratories, where feasible, should be interdisciplinary in nature, eliminating artificial departmental boundry lines. For example, the experiments in the Materials Laboratory involve a wide variety of mechanical, electrical, thermal, electro-chemical, fluid, optical and metallurgical properties. This contrasts with conventional materials laboratories, which are usually limited to a number of mechanical properties. The Measurements Laboratory should emphasize instrumentation systems and the experiments employ mechanical, electrical, electronic, thermal and radiation measurements.

3. Students should be presented with challenging experiments that will stimulate their interest and tax their ingenuity.

4. Students should receive their experimental information in the form of problems requiring experimental solutions, in the manner that the research engineer receives his project in industry.

5. Experiments should be so selected that they will foster and develop creativity in the student. These experiments must also show the interrelationship between the experimental and analytical approaches in the solution of problems.

6. If possible, equipment should be small, table-mounted without bolting, portable and selfcontained. Not only is this less expensive but more instructive and requires less time for operations. The student also develops a feel and appreciation for the equipment because he can see by inspection what makes the equipment function. In addition, materials used will be small, less expensive and easier to fabricate.

7. The instruments required for the experiments must be of the type encountered in industrial research. It is more difficult to train students for laboratory work on crude instruments, which are lacking in precision and accuracy, than on the professional type. There should be no problem selecting the desired instruments, as a large variety of fine instruments are commercially available. The instruments purchased should also have research potential.

8. In setting up an instrumentation system, the emphasis should be on simplicity rather than intricacy for the sake of sophistication. To illustrate, when measuring a displacement under static

conditions, there is no need to go to a linear differential transformer with its associated electronics when a simple dial gauge would do.

9. Experiments should be so designed that no more than two or three students should be required to operate the experimental system, measure and graphically display the information in the laboratory.

10. Students should be trained to prepare professional reports similar to those required in industry. To accomplish this, a format for report writing is essential. A format can be developed for engineering laboratory courses from formats used in industry. A sample report should be prepared and distributed to the student, so that there can be no misunderstanding of the instructor's requirements. In grading reports, simply marking up the reports with constructive criticism is not sufficient from the teaching point of view. The errors that are made are usually repeated, creating an unhappy situation for both student and instructor. The reports should be graded in the presence of the student so that he can question the instructor's comment and obtain other helpful information. This method of grading, together with the use of the sample report as a guide, can greatly improve the quality of reports.

11. It is highly desirable to add new experiments each year or make major revisions to existing experiments, so that there is a complete turnover in a set period of time. The experiments that are replaced, but are considered good, can still be used in alternate years.

12. A special experimental project in which the student can explore a chosen area in greater depth should be required. In addition to the prepared experiments, the student (individually or with his group) should select a special project that will occupy a substantial number of laboratory sessions. The special project requires the students to initiate and design an experiment, of his own choosing, design any necessary special equipment, select and purchase the material, construct the apparatus, perform the experimental work, and submit a polished report -- with minimal guidance. The special project tends to develop student self-confidence and independence.

The further goals of laboratory education should primarily emphasis the needs of the students. Since learning must be done by the learner, research and experimentation in laboratory education should be directed towards the development of sutiations and activities that contribute to learning. The directions that should be explored include -

a) More extensive and effective use of educational technology. This will involve the use of such devices as audiotape players, video tape systems, and integrated experimental systems. Each device can make a major contribution to the learning process when the device is properly inserted in a sequence of learning events which have relevance to the educational objectives.

b) The use of audio-tutorial systems of individualised laboratory education.

c) More extensive use of independent study. This could take the form of special problems in a laboratory course, one credit paper courses, or an undergraduate thesis.

6.0 Results of a UCLA STUDY :

The American Society of Mechanical Engineers describes the laboratory component of the mechanical engineering curriculum as follows :

"Laboratory experience in mechanical engineering has several possible goals :

(a) to develop a student's ability to design experiments and analyze experimental results;

(b) to familiarize him with modern measurement methods, instrumentation and equipment;

(c) to enhance his knowledge of physical phenomena and the behaviour of engineering components and systems;

(d) to introduce him to the use of experimentation as part of the design process; and

(e) to develop his ability to report on his work and his findings."

In an effort to identify the relative importance of individual objectives, a study was made in 1974 in the University of California in the US. Some of the interesting results are summarized below :

(i) Under "subject matter content" a strong emphasis was desired for the relations between theoretical studies and experimental studies. That is, laboratory instruction is simply not designed for just the efficient transmission of information on experimentation. Indeed there is little reason to expect laboratory teaching to be effective through simple communication of information. Thus, topics such as laws, principles, theories, facts, definitions and the like are probably more effectively covered in non-laboratory instructional formats.

(ii) There is an emerging development of laboratory instruction from an equipment - centered hardware base to an instrumentation - centered hardware base. There is a great need for emphasis on "the operating characteristics of specific equipment, the operating characteristics of specific instrumentation and the function and use of specific instrumentation".

(iii) Regarding "student attitudes and habits", the following require strong emphasis :

- practice in synthesis
- engineering judgement
- ability to organise the relationship of specific cases to general principles or laws.
- competence in compiling a neat presentable report
- appreciation for planning and preparation

and competenece in conveying information by use of the written word.

Other items include the following non-behavioral objectives :

- conbfidence in his ability, as an engineer,

- ingenuity and creativity,
- a heightened interest in the field of engineering,
- an appreciation for some of the skills of the cragftsman, and
- heightened safety conscious ness.

(iv) The essential function of laboratory instruction is to teach the theory and process of experimentation. Also increased attention should be directed towards instrumentation on "procedures for designing an experiment to accomplish a given task". The implementation of this objective increased opportunity for the student to learn on his own in the laboratory; stated conversely, at least some experimental activity should be non-cookbook.

One of the functions that subjectively stated listing of objectives can serve is to provide a logical basis for establishing a course or course sequence which is designed along behavioral lines. Highly specific, behaviorally stated instructional objectives for laboratory work are best developed within the confines of a particular instritution, discipline or course.

7.0 Implementation of a Good Laboratory Programme :

The quality of laboratory courses should not be underemphasized in these days of increasing enrollments and scarce resources. An understanding of a programme's needs can best be obtained by defining the objectives of the laboratory, relating the available resources to the objecvtives, and motivating students to relate to the experiments.

Several distinct problems exist in laboratory development and these lower the efficiency and effectiveness of laboratory instruction. Atleast three specific problems are as below :

* Communication of ideas and methodology,
* Laboratory instruction aids,
* Laboratory facility.

These problems have to be well tackled and continuous improvement has to be attempted for a successful implementation of the laboratory instruction.

In this context, it may be relevant to list some notable innovations tried elsewhere and reported successful :

* Audio-Tutorial Techniques.
* Laboratory Slide Presentations
* Guided Discovery Teaching
* P.S.I.,
  (Personalised System of Instruction) or Self-paced method for lab. courses.

Concluding Remarks :

Laboratory instructions plays a significant role in engineering curriculum and the objectives served are many and varied. Some guidelines for the design of laboratory experience have been outlined above. Successful implementation requires a scientific approach and continuous improvement.

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