CHAPTER 1: INTRODUCTION TO EXPERIMENTAL METHOD

1.1 Importance of experiment in science and engineering

In all engineering field, whether in the past, now and future, solution for the problem in engineering can be divided into two approaches:

- Theoretical method (physical principle / mathematics)
- Experimental method

Between these two methods, research becomes a 'bridge' for them. Usually, theoretical person works on explaining or forecasting the result of an experiment based on analytical model and physical concept regarding on some phenomenon. While in experiment, the theory suggested will be tested, measurement of quantity, deciding conclusion, or may be will be used for building a good exercise in conducting an experiment. When the data gathered from the experiment are not comply with the condition needed fro the analytical model or physical concept, the first checking that been will be implemented is on the data, follows by the theory related to the model. In all situations, all physical concepts will be relying on the experiment for verification.

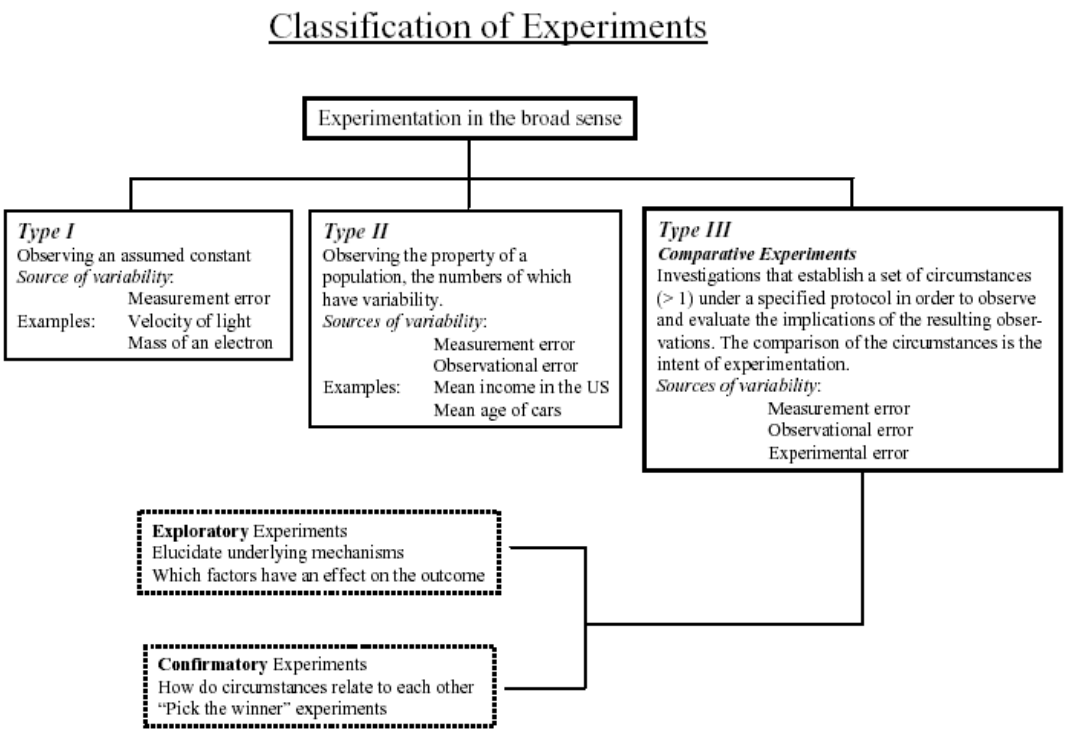

Figure 1: Classification of an experiment

So that, in solving problem related on engineering, combination of ***theoretical method*** and ***experimental method*** is the way that usually used by engineers and scientists. As a problem solver, the knowledge regarding on these two methods must be built:

Table 1: Knowledge needed to solve engineering problem

Theoretical Method	**Experimental Method**
Basic Concept	Measurement System
Main Principle	Apparatus System
Analysis Method	Hard Ware / Software

The following table explains the criteria between theoretical method and experimental method:

Table 2 Problem solution technique in engineering

Theoretical Method	**Experimental Method**
Mathematical model analysis on real world, where assumption is needed.	Analysis on real situation; assumption is not needed.
Give general results for all type of problems.	Give specific result.
Relaxation in assumption lead to complexity of mathematical model.	Measurement devices with high accuracy are needed, if used apparatus is more complex.
Not need to have many accommodations. (trained person, pen, pencil)	Complete and expensive laboratory accommodation is needed.
Research can be started immediately.	Time delay is needed for equipment's preparing and testing.

For researchers who has broad experiences, experiment that been conducted aims to find an explanation regarding on the theory that not been known, or to verify a new theory, or to prepare the data for the theory that will be suggested. Whether the experiment is conducted by a student or researcher, scientific method that been used is basically same, which is:

- change only one variable at one time
- to test the method of experiment in order to prove that it is applicable through measuring an effect from the experiment
- to test the reproducibility if an experiment (where the result can be regenerated by an expert tester and it is independent from an error).

Generally, a scientist who testing the theory by experiment will try to design an experiment that be used to prove that the theory that been tested is wrong. But for engineer, the aim of experiment is to find the differences between result that been gathered from theory and experimental results.

1.2 Generalized experimental procedure

To make an experiment successful, overall process related to the experiment must be divided into several stages:

i. Objective and preliminary planning of an experiment
   a. Establish the need for the experiment
   b. Establish the optimum budgetary, manpower, and time requirements including time sequencing of the project. Modify scope of the experiment to actual budget, manpower and time schedule which is allowable.

ii. Begin detail planning for the experiment, clearly establish objectives of experiment (verify performance of production model, verify theoretical analysis of particular physical phenomenon, etc.). if experiments are similar to those of previous investigators, be sure to make use of experience of the previous workers. Never overlook the possibility that the work may have been done before and reported in the literature.

iii. Continue planning by performing the following steps:
   a. Establish the primary variable that must be measured (force, strain, flow, pressure, temperature etc.)
   b. Determine as nearly as possible the accuracy which may be required in the primary measurements and the number of such measurements which will be required for proper data analysis
   c. Set up data reduction calculation before conducting the experiments to be sure that adequate data are being collected to meet the objective of the experiment
   d. Analyze the possible errors in the anticipated results before the experiments are conducted so that modifications in accuracy requirements on the various measurements may be changed if necessary

iv. Select instrumentation for the various measurements to match the anticipated accuracy requirements. Modify the instrumentation to match budgetary limitations if necessary.

v. Collect a few data points and conduct a preliminary analysis of these data to be sure that the experiment is going as planned.

vi. Modify the experimental apparatus and/or procedure in accordance with the findings in item 5.

vii. Collect the bulk of experimental data and analyze the results.

viii. Organize, discuss and publish the findings and results of the experiments, being sure to include information pertaining to all item i ~ vii, above.

1.3 Storing an experiment record

Main attention for experiment must be given to record each procedure in steps as the next analysis can be implemented without many problems. This is due to each experiments have different level and observation techniques, where some experiment is easy but need to use sophisticated tools, while some experiment use a simple tools but the level is difficult. So that, during an experiment, there may be required to change a procedure, improvement of procedure or change in setting of equipment etc. According to these facts, it is needed for us to record what that being happened during an experiment so that it

make us easier to do a report, presenting findings or conclusion from the experiment that been done. One way to record a work is using log book, or in other name, laboratory journal. This logbook must be used to record all the processes in the experiment. Logbook also has their role as:

- tools for arrangement and references when writing a report
- main record in patent law
- preparing the record for overall experiment
- information storage regarding on the procedure that is difficult to find from journal articles
- as a note that explain the success or failure of an experiment

If the logbook is used fro verify some findings, technique to insert necessary information must be developed. At least, the following information must be included:

- design concept, date and name
- first drawing or sketch
- first explanation (writing)
- first test on design
- information regarding on first announcement to outside world

The logbook must be:

- binding; piece of paper are not allowed
- all the pages must be numbered

1.3.1 Log book for engineering student

As you plan your project and do your experiments, you must keep a record of everything you do. The science research logbook is simply the notebook in which you keep this record. Each page must be dated and describe the work you have done. It should include a description of the equipment used and the setting, particularly if the setting can influence the outcome. Whenever you do field work you need to carefully describe the location and the weather conditions for that day. Diagrams and sketches may be used to clarify your descriptions. They should be completely labeled so the identity of equipment, distances, etc. is clear. Your notebook needs to include the procedures you followed in carrying out your research/experiments. Data should be organized into tables and all variables should be named and labeled with the units used. Graphs and other types of analysis should be done and preliminary conclusions written. Any changes in procedures should be noted when they are made.

For engineering students, usually the experiments that been conducted are for

- to understand a concept in textbook
- to implement a standard test e.g. hardness test, tensile test
- to check performance of a machine
- to find physical coefficient e.g. gravitational acceleration, elastic modulus for a metal etc.

It is recommended that you use a bound notebook (either stitched or stapled) for your log. Information should be recorded in the logbook as you do the work. For this reason, logbooks are not normally typed on a computer, but are handwritten. An exception might

be if your research is primarily on the computer or if you use a handheld PDA to keep your records.

Students who work with human subjects should include consent forms in their log. They must also include copies of any tests, surveys, etc., that they have used in their research. For that reason, students working with human subjects might want to use a 3-ring binder for their science log.

The logbook is a start to finish, dated RECORD of the research that went into producing the science project. Expectations of completion and effort should be high and consistent to the grade level. Logbooks should include personal thoughts, interviews and reading notes for background information. Entries should include recorded plans, actions, raw data, observations and results. The logbook is worth up to 15 points. Bolded items should receive greater emphasis. (*Special needs students who cannot handwrite a logbook should have a statement at the beginning stating such.)

- Handwritten* log entries are dated, no names or identifying information (student, parent, teacher/mentors, etc.)
- Detailed research notes from articles, books, and interviews.
- Notes should include the bibliography of each resource
- Includes detailed reasons for choosing the topic, especially WHY.
- Discussion of focus on a problem statement and defining of hypothesis.
- Discussion of selection of variables (IV, DV, and standard of comparison-control group).
- Development of the step by step procedures (includes Safety if applicable)
- Observations of TRIAL RUN and refinement procedure.
- Completed data tables as they happened.
- Interpretation of the results from the data tables (reliability of data, trends show in graphs).
- Reflection upon the results of the project, what could have affected the results and any possible future explorations.

As a summary, for the experiments that aims to train a student, student logbook must contains:

- date of experiment
- objectives
- apparatus that been prepared; take note regarding on how to use the apparatus, preparation etc.
- create a table for the reading that been taken, together with their unit
- record all the information needed to decide an overall experimental errors
- make a necessary decision in order to evaluate an effectiveness and level of success for an experiment. Plot a graph required together with their estimation error
- give a comment regarding on the experiment and discuss the result that been gathered through critical thinking.

1.4 Conclusion

Experimental design can be concluded as:

- Objective
- Planning
- Evaluation
- Uncertainty analysis
- Cost
- Calibration
- Data gathered
- Data reduction