UNIT –III

ENGINEERING AS SOCIAL EXPERIMENTATION

Syllabus: Engineering as experimentation - engineers as responsible experimenters - codes of ethics – Industrial Standards

ENGINEERING AS EXPERIMENTATION

What is Experimentation?

Experiment- means a scientific test done carefully to study what happens and to gain new knowledge.

Experimentation refers to activity, process or practice of making experiments.

Experimentation plays an important role in the process of designing the product. When it is decided to change a new engineering concept into its first rough design, preliminary tests or simulation should be conducted. Using formal experimental methods, the materials and methods of designing are tried out. These tests may be based on more detailed designs. The test for designing should be evolved till the final product produced. With the help of feedback of several tests, further modification can be made if necessary. Beyond these tests and experiments, each engineering project has to be viewed as an experiment.

ENGINEERING EXPERIMENTS WITH STANDARD EXPERIMENTS:

There are many similarities and differences between engineering experiments and other standard experiments.

Similarities to Standard Experiments

There are many aspects of engineering that make it appropriate to view engineering projects as experiments. The three important aspects are as follows:

1. Engineering projects, like the standard experiments, are carried out in **partial uncertainties**. The uncertainties may include in the,
   - ✓ Design calculation
   - ✓ Exact properties of raw materials used
   - ✓ Constancies of material processing and fabrication
   - ✓ Nature of working of final products
2. The final outcomes of engineering projects are also generally **uncertain** like those of other experiments for example, a nuclear reactor may reveal unexpected problems that endangered the surrounding people.
3. Similar to standard experiments, engineering experiments also requires **thorough knowledge** about the products at the pre-production and post-production stages. Thus engineering, like any other experimentation, requires constant monitoring, alertness, and vigil on the part of the engineers at every stage of the project.

   Contrast with standard experiments: The study of knowing differences between engineering and other standard experiments is helpful to the engineers to realize their special and moral responsibility.

Some aspects of these differences are given below:

1. Experimental control: Experimental control is the most important difference between engineering and other standard experiments.

✓ In standard experiments, experimental control involves selecting members for two different groups randomly. The first group members are given the special, experimental treatment, whereas the members of another group are not given that special treatment. Even both the groups are subjected to same environment; the group that was not given the special treatment is called "**control group**".

✓ While, in engineering experiments, usually there is no control group. Sometimes the control group is used only when the project is limited to laboratory experiments. Because the engineering experiments involve human beings are experimental subjects. In fact, clients and customers have more control, as they own the authority of that project. So here the experimental subjects say clients or end users are out of experimenter's control. In this type, it is not possible to select the member from various group randomly. Instead, the engineers should work with the available historical and fair data about various groups randomly. Instead, the engineering should work the available historical and fair data about various groups that uses the end product.

The above discussion also justifies the view of engineering as a social experimentation.

2. Informed consent: It is well known that there is always a strong human interface in the use of the engineering experiments' result; and also, the beneficiaries are invariably humans. Therefore, engineering experiments are also viewed at par the medical experiments. When a medicine or an engineering product is to be tested on a person, then the moral and legal rights is to get "informed consent" for him.

   Informed consent consists of two main elements:

   A. **Knowledge**: The human subjects should be given all the information to make a reasonable decision.
   B. **Voluntariness**: The human subjects should show their willingness to be a human model voluntarily. The person should not be forced, deceived, fraud, etc. Moreover, the manufacturer should give all the information about the potential risks and benefits of their products to their customers and users.

      The characteristics of a "valid consent" (The informed consent is called as _valid consent 'when the following three conditions are met):

      I. The consent should be given voluntarily and not by force.
      II. The consent should be based on all information needed for the rational person to make reasonable decision.
      III. The consentient should be physically and mentally fit; then he should be major i.e., above 18 years.

Learning from the past

It has been expected that the engineers have to learn not only form their own design and the production system but also the results of others. Due to lack of communication, prejudiced in not asking for clarification, fear of law and also mere negligence, these things can happen to the continuation of past mistakes.

The following are some of the examples:

1. The tragedy of „Titanic" happened because of the insufficient number of life boats. The same disaster took place in the steamship "the Arctic" some years before, because of the same problem.

2. The fall down of "the Sunshine Skyline Bridge" in the bay of Thamba at Sweden in 1980, on a moving ship due to improper matching of horizontal impact forces in mind. This could have been avoided of the engineers had known about the striking of the ships with the Maracaibo Bridge at Venezuela in 1964 and the Tasman Bridge of Australia in 1975.

3. The nuclear reactor accident at Three Mile Island on March 1979, was due to malfunctioning of the valves. Valves though minute items, are being among the least reliable components of hydraulic systems. It was a pressure relief valve and lack of information about its opening or closing state contributed to a nuclear reactor accident at Three Mile Island. This malfunction was already happened because of the same reasons at other locations.

4. The disaster of Tettron Dam in Los Angles was due to rapid flow of water and sudden break down. The builder didn't consider the case of the Fontenelle Dam, which was also collapsed due to the same problem. So, to say that engineers should not fully depend on handbooks and they should have some review of the past cases relating to their current task.

Comparisons with standard Experiments

Engineering is entirely different from standard experiments in few aspects. Those differences are very much helpful to find out the special responsibilities of engineers and also help them in knowing about the moral irresponsibilities which are involved in engineering.

Experimental Control

Members for two groups should be selected in a standard experimental control, i.e. Group A and Group B. The members of the group "A" should be given the special experimental treatment. The group "B" does not receive the same though they are in the same environment. This group is called the **'*control group*'**.

Though it is not possible in engineering but for the projects which are confirmed to laboratory experiments. Because, in engineering the experimental subjects are human beings who are out of the control of the experimenters. In engineering, the consumers have more control as they are the selecting authority of a project. Therefore, in this field it is impossible to follow a random selection. An engineer has to work only with the past data available with various groups who use the products.

Consequently, engineering can be viewed as a natural experiment which uses human subjects. But today, most of the engineers do not care for the above said Experimental Control.

Informed Consent

Engineering is closely related to the medical testing of new drugs and techniques on human beings as it also concerned with human beings.

When new medicines have been tested, it should be informed to the persons who undergo the test. They have moral and legal rights to know about the fact which is based on "informed consent" before take part in the experiment. Engineering must also recognize these rights. When a producer sells a new product to a firm which has its own engineering staff, generally there will be an agreement regarding the risks and benefits form that testing.

Informed consent has two main principles such as knowledge and voluntariness.

First, the persons who are put under the experiment has to be given all the needed information to make an appropriate decision.

Second, they must enter into the experiment without any force, fraud and deception. The experimenter has also to consider the fundamental rights of the minorities and the compensation for the harmful effects of that experiment.

In both medicine and engineering there may be a large gap between the experimenter and his knowledge on the difficulties of an experiment. This gap can be filled only when it is possible to give all the relevant information needed for drawing a responsible decision on whether to participate in the experiment or not.

In medicine, before prescribing a medicine to the patient, a responsible physician must search for relevant information on the side effects of the drug. The hospital management must allow him to undergo different treatments to different patients and finally the patient must be ready to receive that information from the physician. Similarly, it is possible for an engineer to give relevant information about a product only when there is a better co-operation by the management and quick acceptance from the customers.

The following conditions are essential for a valid informed consent

A. The consent must be given voluntarily and not by any force.
B. The consent must be based on the relevant information needed by a rational person and should be presented in a clear and easily understandable form.
C. The consenter must be capable of processing the information and to make rational decisions in a quick manner.
D. The information needed by a rational person must be stated in a form to understand without any difficulty and has to be spread widely.
E. The experimenter's consent has to be offered in absentia of the experimenter by a group which represents many experiments.

Knowledge Gained

Scientific experiments have been conducted to acquire new knowledge. Whereas engineering projects are conducted as experiments not for getting new knowledge. Suppose the outcomes of the experiment is best, it tells us nothing new, but merely affirms that we are right about something. Meanwhile, the unexpected outcomes put us search for new knowledge.

ENGINEERS AS RESPONSIBLE EXPERIMENTERS

The engineers have so many responsibilities for serving the society.

1. A primary duty is the safety of human beings and respect their right of consent. [A *conscientious commitment* to live by moral values].

2. Having a clear awareness of the experimental nature of any project, thoughtful forecasting of its possible side effects, and an effort to monitor them reasonably. [A comprehensive perspective or *relative information*].

3. Unrestricted free personal involvement in all the steps of a project. [*Autonomy*]

4. Being accountable for the results of a project [*Accountability*]

5. Exhibiting their technical competence and other characteristics of professionalism.

Conscientiousness

Conscientiousness implies consciousness (sense of awareness). As holding the responsible profession with maintaining full range moral ethics and values which are relevant to the situation. In order to understand the given situation, its implications, know- how, person who is involved or affected, Engineers should have open eyes, open ears and open mind.

The present working environment of engineers, narrow down their moral vision fully with the obligations accompanied with the status of the employee. More number of engineers are only salaried employees, so, they have to work within large bureaucracies under great pressure to work smoothly within the company. They have to give importance only to the obligations of their employers. Gradually, the small negative duties such as not altering data by fraud, not violating patent right and not breaking confidentiality, may be viewed as the full extent of moral desire.

As mentioned, engineering as social experimentation brings into light not only to the person concerned but also to the public engineers as guardians of the public interest i.e., to safeguard the welfare and safety of those affected by the engineering projects. This view helps to ensure that this safety and welfare will not be affected by the search for new knowledge, the hurry to get profits, a small and narrow follow up of rules or a concern over benefits for the many and ignoring the harm to the few.

The social experimentation that involved in engineering should be restricted by the participants consent.

Relevant Information

Without relevant factual information, conscientious is not possible. For showing moral concern there should be an obligation to obtain and assess properly all the available information related to the fulfilment of one's moral obligations. This can be explained as:

1) To understand and grasp the circumstance of a person's work, it is necessary to know about how that work has a moral importance. For example, A person is trying to design a good heat exchanger. There is nothing wrong in that. But at the same time, if he forgets the fact that the heat exchanger will be used in the manufacture of an illegal product, then he is said to be

showing a lack of moral concern. So, a person must be aware of the wider implication of his work that makes participation in a project.

2) Blurring the circumstance of a person's work derived from his specialization and division of labour is to put the responsibilities on someone else in the organization. For example, if a company produces items which are out of fashion or the items which promotes unnecessary energy wastage, then it is easy to blame sales department.

The above said means, neglecting the importance of a person's works also makes it difficult in acquiring a full perspective along a second feature of factual information i.e., consequence of what one does.

So, while giving regard to engineering as social experimentation, points out the importance of circumstances of a work and also encourage the engineers to view his specialized activities in a project as a part of a large social impact.

Moral Autonomy

This refers to the personal involvement in one's activities. People are morally autonomous only when their moral conduct and principles of actions are their own i.e., genuine in one's commitment to moral values.

Moral beliefs and attitudes must be integrated into an individuals' personality which leads to a committed action. They cannot be agreed formally and adhered to merely verbally. So, the individual principles are not passively absorbed from others. When he is morally autonomous and also his actions are not separated from himself.

When engineering has seen as a social experimentation, it helps to keep a sense of autonomous participation in a person's work. An engineer, as an experimenter, is undergoing training which helps to form his identity as a professional. It also results in unexpected consequence which helps to inspire a critical and questioning attitude about the current economic and safety standards. This also motivates a greater sense of personal involvement in a person's work.

Accountability

The people those who feel their responsibility, always accept moral responsibilities for their actions. It is known as accountable. In short, „accountable" means being culpable and hold responsible for faults. In general, and to be proper, it means the general tendency of being willing to consider one's actions to moral examinations and be open and respond to the assessment of others. It comprises a desire to present morally convincing reasons for one's conduct when called upon in specific circumstances.

The separation of causal influence and moral accountability is more common in all business and professions and also in engineering. These differences arising from several features of modern engineering practices are as follows:

1. Large – scale engineering projects always involve division of work. For each and every piece of work, every person contributes a small portion of their work towards the completion of the project. The final output us transmitted from one's immediate work place to another causing a decrease in personal accountability.

2. Due to the fragmentation of work, the accountability will spread widely within an organization. The personal accountability will spread over on the basis of hierarchies of authority.

3. There is always a pressure to move on to a different project before finishing the current one. This always leads to a sense of being accountable only for fulfilling the schedules.

4. There is always a weaker pre-occupation with legalities. In other words, this refers to a way a moral involvement beyond the laid down institutional role. To conclude, engineers are being always blamed for all the harmful side effects of their projects. Engineers cannot separate themselves from personal responsibilities for their work.

CODES OF ETHICS

The codes of ethics have to be adopted by engineering societies as well as by engineers. These codes exhibit the rights, duties, and obligations of the members of a profession. Codes are the set of laws and standards.

A code of ethics provides a framework for ethical judgment for a professional. A code cannot be said as totally comprehensive and cover all ethical situations that an engineer has to face. It serves only as a starting point for ethical decision-making. A code expresses the circumstances to ethical conduct shared by the members of a profession. It is also to be noted that ethical codes do not establish the new ethical principles. They repeat only the principles and standards that are already accepted as responsible engineering practice. A code defines the roles and responsibilities of professionals.

Roles of codes and its functions

1) ***Inspiration and Guidance***

Codes give a convinced motivation for ethical conduct and provide a helpful guidance for achieving the obligations of engineers in their work. Codes contribute mostly general guidance as they have to be brief. Specific directions may also be given to apply the code in morally good ways.

The following engineering societies have published codes of ethics.

AAES - American Association of Engineering Societies

ABET - Accreditation Board for Engineering and Technology (USA)

NSPE - National Society of Professional Engineer (USA)

IEEE - Institute of Electrical and Electronics Engineering (USA)

AICTE - All India Council for Technical Education (India)

Most of the technological companies have established their own codes such as pentagon (USA), Microsoft etc. These codes are very much helpful to strengthen the moral issues on the work of an engineer.

2) ***Support***

Codes always support an engineer who follows the ethical principles. Codes give engineers a positive, a possible good support for standing on moral issues. Codes also serve as a legal support for engineers.

3) *Deterrence and Discipline*

Codes act as a deterrent because they never encourage to act immorally. They also provide discipline among the Engineers to act morally on the basis of codes does not overrule the rights of those being investigated.

4) *Education and Mutual Understanding*

Codes have to be circulated and approved officially by the professionals, the public and government organizations which concern with the moral responsibilities of engineers and organizations.

5) *Contributing to the profession's Public Image*

Codes help to create a good image to the public of an ethically committed profession. It helps the engineers in an effective manner to serve the public. They also give self-regulation for the profession itself.

6) *Protecting the Status Quo*

Codes determine ethical conventions which help to create an agreed upon minimum level of ethical conduct. But they can also suppress the disagreement within the profession.

7) *Promoting Business Interests*

Codes help to improve the business interests. They help to moralize the business dealings to benefit those within the profession.

Limitations of Codes

1. Codes are restricted to general and vague wordings. Due to this limitation, they cannot be applicable to all situations directly. It is also impossible to analyze fully and predict the full range of moral problems that arises in a complex profession.

2. Engineering codes often have internal conflicts. So, they can't give a solution or method for resolving the conflict.

3. They cannot be treated as the final moral authority for any professional conduct. Codes represent a compromise between differing judgments and also developed among heated committee disagreements.

4. Only a few practicing engineers are the members of Professional Societies and so they cannot be compelled to abide by their codes.

5. Many engineers who are the members of Professional Societies are not aware of the existence of the codes of their societies and they never go through it.

6. Codes can be reproduced in a very rapid manner.

7. Codes are said to be coercive i.e., implemented by threat or force.

A BALANCED OUTLOOK ON LAW

A balanced outlook on laws stresses the necessity of laws and regulations and their limitations in directing engineering practice.

In order to live, work and play together in harmony as a society, there must be a balance between individual needs and desires against collective needs and desires. Only ethical conduct can provide such a balance. This ethical conduct can be applied only with the help of laws. Laws are important as the people are not fully responsible and because of the competitive nature of the free enterprise system which does not encourage moral initiative.

The model of engineering as social experimentation allows for the importance of clear laws to be effectively enforced.

Engineers, ought to play an effective role in promoting or changing enforceable rules of engineering as well as in enforcing them. So, the codes must be enforced with the help of laws. The following are the two best examples.

1. Babylon's Building Code: (1758 B.C.)

This code was made by Hammurabi, king of Babylon. He formed a code for builders of his time and all the builders were forced to follow the code by law. He ordered

"If a builder has built a house for a man and has not made his work sound, and the house which he has built was fallen down and so caused the death of the householder, that builder shall be put to death. If it causes the death of the house holder's son, they shall put that builder's son to death. If it causes the death of the house holder's slave, he shall give slave to the householder. If it destroys property, he shall replace anything it has destroyed; and because he has not made the house sound which he has built and it has fallen down, he shall rebuild the house which has fallen down from his own property. If a builder has built a house for a man and does not make his work perfect and the wall bulges, that builder shall put that wall in to sound condition at his own cost".

The above portion of Babylon"s building code was respected duly. But the aspects find only little approval today. This code gives a powerful incentive for self-regulation.

2. The United States Steamboat Code: [1852 A.D]

Steam engines in the past were very large and heavy. James Watt, Oliver Evans and Richard Trevethik modified the old steam engines by removing condensers and made them compact. Beyond careful calculations and guidelines, explosions of boiler happened on steam boats, because of the high speed of the boats. The safety valves were unable to keep steam pressure up causing explosion. During that period in 18 th century, more than 2500 people were killed and 2000 people were injured because of the explosion of boilers in steam boats.

Due to this, the ruling congress in USA passed a law which provided for inspection of the safety aspects of ships and their boilers and engines. But his law turned out to be ineffective due to the corruptions of the inspectors and also their inadequate training regarding the safety checking. Then Alfred Guthiro, an engineer of Illinoise had inspected about 200 steam boats on his own cost and found out the reasons for the boiler explosions and made a report. His recommendations were published by a Senator Shields of Illinoise and incorporated in senate documents. With the help of this, another law was passed. Now it is in the hands of the

American Society of Mechanical Engineers who formulated the standards for producing steam boats.

THE CHALLENGER CASE STUDY

The world has known about many numbers of accidents. Among them the explosion of the space shuttle „Challenger‟ is the very familiar one. In those days this case had been reviewed vigorously by media coverage, government reports and transcripts of hearings. This case deals with many ethical issues which engineers faced. It poses many questions before us. What is the exact role of the engineer when safety issues are concern? Who should have the ultimate authority for decision making to order for a launch? Whether the ordering of a launch be an engineering or a managerial decision?

Challenger space shuttle was designed to be a reusable one. The shuttle mainly consisted of an orbiter, two solid propellant boosters and a single liquid-propeller booster. All the boosters were ignited and the orbiter was lifted out the earth. The solid rocket booster was of reusable type. The liquid propellant booster was used to finish the lifting of the shuttle in to the orbit. This was only a part of the shuttle which has been reused.

The accident took place on 28th January 1986, due to the failure of one of the solid boosters. In the design of the space shuttle, the main parts which needed careful design of the fields joints where the individual cylinders were placed together. The assembly mainly consists of tang and clevis joints which are sealed by two O-rings made up of synthetic rubber only, not specifically hat resistant. The function of the O-rings is to prevent the combustion gases of the solid propellant from escaping. The O-rings were eroded by hot gases, but this was not a serious problem, as the solid rocket boosters were only for reuse initially for the few minutes of the flight. If the erosion of the O-rings could be in a controlled manner, and they would not completely burn through, then the design of the joint would be acceptable, however the design of the O-rings in this shuttle was not so.

In the post flight experiment in 1985, the Thiokol engineers noticed black soot and grease on the outside of the boosters due to leak of hot gases blown through the O-rings. This raised a doubt on the resiliency of the materials used for the O-rings. Thiokol engineers redesigned the rings with steel billets to withstand the hot gases. But unfortunately, this new design was not ready by that time of flight in 1986.

Before launching, it was necessary to discuss the political environment under which NASA was operating at that time. Because the budget of NASA has decided by Congress. These factors played the main cause for unavoidable delay in the decision to be taken for the shuttle performance, the pressures placed for urgency in launching in 1986 itself, before the launch of RUSSIAN probe to prove to the congress that the program was on processing. The launching date had already been postponed for the availability of vice president GEORGE BUSH, the space NASA supporter. Later further delayed due to a problem in micro switch in the hatch-locking mechanism. The cold weather problem and long discussions went on among the engineers. The number of tele-conferences further delayed the previous testing in 1985 itself. The lowest temperature was 53-degree Fahrenheit but O-ring temperature during the proposed launch period happened to be only 29-degree Fahrenheit, which was far below the environment temperature at which NASA had the previous trail. Somehow, the major factor that made the revised final decision was that previous trial. Somehow, the major factor that made the revised final decision was that with the available data at that time there seemed to be no correlation between the temperature and the degree at which O-rings had eroded by the blow-by gas in the previous launch. Assuming a safety concern due to cold weather, though the data were not concluded satisfactorily, a decision was taken not to delay further for so many reasons, and the launch was finally recommended.

But unexpectedly the overnight temperature at the time of launch was 8-degree Fahrenheit colder than ever experienced. It was estimated that the temperature of the right-hand booster would be only at 28-degree Fahrenheit. The camera noticed a puff of smoke coming out from the field joints as soon as the boosters were ignited. But the O-rings were not positioned properly on their seats due to extreme cold temperature. The putty used as heat resistant material was also too cold that it failed to protect the O-rings. All these effects made the hot gases to burn past both the O rings, leading to a blow-by over an arc around the O-rings. Though immediately further sealing was made by the by-products of combustion in the rocket propulsion, a glassy oxide formed on the joints. The oxides which were temporarily sealing the field joints at high temperature, later were shattered by the stresses caused by the wind. Again, the joints were opened and the hot gases escaped from the solid boosters. But the boosters were attached to the large liquid fuel boosters as per the design. This made the flames due to blow-by from the solid fuel boosters quickly to burn through the external tank. This led to the ignition of the liquid propellant making the shuttle exploded.

Later the accident was reviewed and investigations were carried out by the number of committees involved and by various government bodies. President Regan appointed a commission called Rogers Commission which constituted many distinguished scientists and engineers. The eminent scientists in the commission after thorough examination and investigations gave a report on the flexibility of the material and proved that the resiliency of the material was not sufficient and drastically reduced during the cold launch.

As the result of commission hearings, a lot of controversial arguments went on among the Thiokol engineers. Thiokol and NASA investigated possible causes of the explosion. Mr.Boisjoly, the main member in the investigation team, accused Thiokol and NASA of intentionally downplaying the problems with the O-rings while looking for the other causes of the accidents. The hot discussions hurt the feelings and status of the headed engineers like Mr.Boisjoly, Mr.Curtis and Mr.Mellicam. Finally, the management's atmosphere also became intolerable. This event shows the responsibility, functions, morality, duties of the engineers leading to ethical problems.

INDUSTRIAL STANDARDS

A set of criteria within an industry relating to the standard functioning and carrying out of operations in their respective fields of production. In other words, it is the generally accepted requirements followed by the members of an industry. It provides an orderly and systematic formulation, adoption, or application of standards used in a particular industry or sector of the economy. Industry standards vary from one industry to another. Industry standards facilitate global as well as domestic competitiveness. It is a crucial tool for developing and meeting industry goals. For example, in the automotive industry, tire sizes and durability must fall within a standardized range. Standardization serves as a quality check for any industry.

Purpose of various types of standards:

- Accuracy in measurement, inter changeability, ease of handling.
- Prevention of injury, death and loss of income or property.
- Fair value of price.
- Competence in carrying out tasks.
- Sound design, ease of communications.
- Freedom from interference.