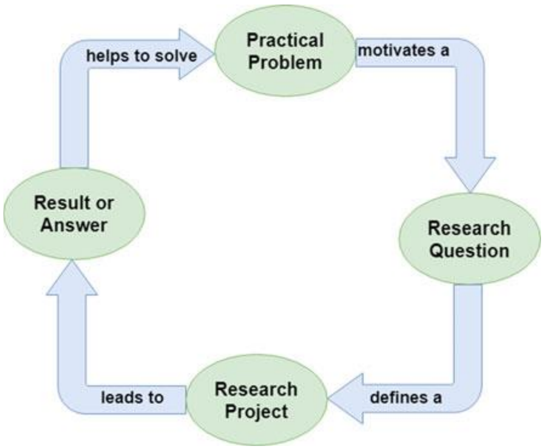
MODULE 1
Introduction

SYLLABUS: Meaning of Research, Objectives of Engineering Research, and Motivation in Engineering Research, Types of Engineering Research, Finding and Solving a Worthwhile Problem.
Ethics in Engineering Research, Ethics in Engineering Research Practice, Types of Research Misconduct, Ethical Issues Related to Authorship.

Research refers to a careful, well-defined (or redefined), objective, and systematic method of search for knowledge, or formulation of a theory that is driven by inquisitiveness for that which is unknown and useful on a particular aspect so as to make an original contribution to expand the existing knowledge base.
Research involves formulation of hypothesis or proposition of solutions, data analysis, and deductions; and ascertaining whether the conclusions fit the hypothesis.
Research is a process of creating, or formulating knowledge that does not yet exist.

Booth et al. [1] explains that the research cycle starts with basically a practical problem: one must be clear what the problem being attempted to solve is and why it is important. This problem motivates a research question without which one can tend to get lost in a giant swamp of information.
The question helps one zero in onto manageable volume of information, and in turn defines a research project which is an activity or set of activities that ultimately leads to result or answer, which in turn helps to solve the practical problem that one started with in the first place as in figure.



Research is not just about reading a lot of books and finding a lot of, gathering a lot of existing information. It is instead adding, maybe small and specific, yet original, contribution to that existing body of knowledge. So, research is about how one poses a question which has relevance to the world that we are living in, while looking for that answer one has to be as systematic as one can be. There must be a balance between what is achievable in a research program with a finite endpoint and also, the contribution it is going to make. The objective of a good research program is to try and gain insight into something. Or indeed, to try and solve a problem.

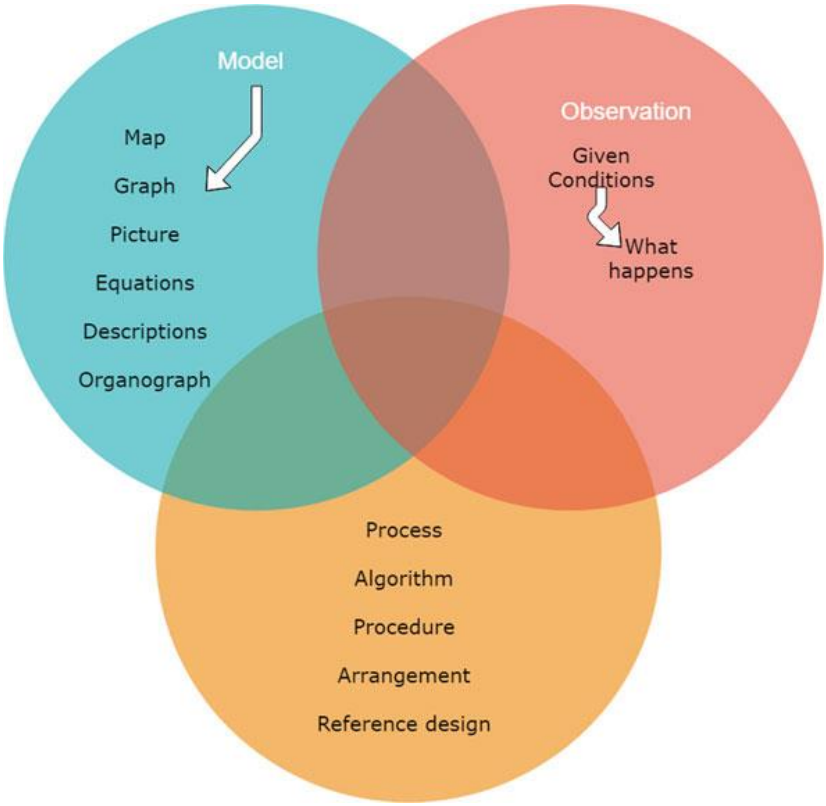
The ways of developing and accessing knowledge come in three, somewhat overlapping, broad categories:
(i) **Observation** is the most fundamental way of obtaining information from a source, and it could be significant in itself if the thing that we are trying to observe is really strange or exciting or is difficult to observe. Observation takes different forms from something like measurements in a laboratory to a

survey among a group of subjects to the time it takes for a firmware routine to run. Observational data often needs to be processed in some form and this leads to the second category of knowledge, the model.

(ii) **Models** are approximated, often simplified ways of describing sometimes very complex interactions in the form of a statistical relationship, a figure, or a set of mathematical equations. For instance, the modeling equation captures the relationship between different attributes or the behavior of the device in an abstract form and enables us to understand the observed phenomena [2].

(iii) The final category is a way of arranging or doing things through processes, algorithms, procedures, arrangements, or reference designs, to get a certain desired result.

The categories of knowledge



Good research involves systematic collection and analysis of information and is followed by an attempt to infer a little bit beyond the already known information in a way that is a significant value addition. Engineering research is a journey that traverses from a research area (Example: Control Systems), to the topic (example: Control of Microbial Fuel Cells) and finally onto the problem (example: Adaptive Control of Single Chamber Microbial Fuel Cells) (Area → Topic → Problem). Getting a good problem to solve is more than half the work done.

Engineering research is the process of developing the perspectives and seeking improvements in knowledge and skills to enable the recognition, planning, design, and execution of research in a wide range of forms relevant for engineering and technology investigations and developments.

Objectives of Engineering Research

The objective of engineering research is to solve new and important problems, and since the conclusion at the end of one's research outcome must be new, when one starts, the conclusion is unknown. So, the start itself is tricky, one may say. The answer is, based on "circumstantial evidence", intuition, and imagination, one guesses what may be a possible conclusion.

A guess gives a target to work toward, and after initial attempts, it may turn out that the guess is incorrect. But the work may suggest new worthy avenues or targets which may be based on some modifications of the initial target, or may need new techniques, or one may obtain negative results which may render the initial target or some other targets as not realizable or may lead to fortunate discoveries while looking for something else (serendipity). can sometimes be convoluted and difficult to follow. Following are the few listed objectives:

- To solve new and important problems - the conclusion is unknown.
- To arrive at possible conclusion based on circumstantial evidence, intuition or imagination.
- To know where and how to find different types of information.
- To apply scientific approaches to seek answers to open questions.
- To apply different types of research studies: exploratory or formulative, descriptive, diagnostic, and hypothesis-testing.
- To develop new theoretical or applied knowledge and not necessarily limited to obtaining the desired result.

Motivation in Engineering Research

The possible motives may be the result of one or more of the following desires:

(i) Studies have shown that intrinsic motivations like interest, challenge, learning, meaning, purpose, are linked to strong creative performance.

(ii) Extrinsic motivating factors like rewards for good work include money, fame, awards, praise, and status are very strong motivators, but may block creativity. For example: Research outcome may enable obtaining a patent which is a good way to become rich and famous.

(iii) Influences from others like competition, collaboration, commitment, and encouragement are also motivating factors in research. For example: my friends are all doing research and so should I, or, a person that I dislike is doing well and I want to do better.

(iv) Personal motivation in solving unsolved problems, intellectual joy, service to community, and respectability are all driving factors.

The following factors would be a mix of extrinsic and intrinsic aspects:

(i) Wanting to do better than what has been achieved in the world,
(ii) Improve the state of the art in technology,
(iii) Contribute to the improvement of society,
(iv) Fulfillment of the historical legacy in the immediate sociocultural context.

Several other factors like government directives, funding opportunities in certain areas, and terms of employment, can motivate people to get involved in engineering research.

Types of Engineering Research

The different types of research are:

i. **Descriptive versus Analytical:** Descriptive research includes comparative and correlational methods, and fact-finding inquiries, to effectively describe the present state of art. The researcher holds no control over the variables; rather only reports as it is. Descriptive research also includes attempts to determine causes even though evaluation are utilized. Some research studies can be both descriptive and analytical.

ii. **Applied versus Fundamental:** Research can either be applied research or fundamental (basic or pure) research. Applied research seeks to solve an immediate problem facing the organization, whereas fundamental research is concerned with generalizations and formulation of a theory. Research concerning natural phenomena or relating to pure mathematics are examples of fundamental research. Research to identify social or economic trends, or those that find out whether certain communications will be read and understood are examples of applied research. The primary objective of applied research is to determine a solution for compelling problems in actual practice, while basic research is aimed at seeking information which could have a broad base of applications in the medium to long term.

iii. **Quantitative versus Qualitative:** Quantitative research uses statistical observations of a sufficiently large number of representative cases to draw any conclusions, while qualitative researchers rely on a few nonrepresentative cases overall narrative in behavioral studies such as clustering effect in intersections in Transportation engineering to make a proposition.

Finding and solving a Worthwhile Problem

A researcher may start out with the research problems stated by the Supervisor or posed by others that are yet to be solved. Alternatively, it may involve rethinking a basic theory, or need to be formulated or put together from the information provided in a group of papers suggested by the Supervisor. Research scholars are faced with the task of finding an appropriate problem on which to begin their research. Skills needed to accomplish such a task at the outset, while taking care of possible implications are critically important but often not taught.

Once the problem is vaguely identified, the process of literature survey and technical reading, as described in the next chapter, would take place for more certainty of the worthiness of the intended problem. However, an initial spark is ideally required before the process of literature survey may duly begin. Sometimes, an oral presentation by somebody which is followed by asking questions or introspection provides this perspective which reading papers do not. At other times, a development in another subject may have produced a tool or a result which has direct implications to the researcher's subject and may lead to problem identification. A worthwhile research problem would have one or more attributes. It could be nonintuitive/counterintuitive even to someone who knows the area, something that the research community had been expecting for some time, a major simplification of a central part of the theory, a new result which would start off a new subject or an area, provides a new method or improves upon known methods of doing something which has practical applications, or a result which stops further work in an area. The researcher has to be convinced that the problem is worthwhile before beginning to tackle it because best efforts come when the work is worth doing, and the problem and/or solution has a better chance of being accepted by the research community. Not all problems that one solves will be great, and sometimes major advancements are made through solutions to small problems dealt with effectively. Some problems are universally considered hard and open, and have deep implications and connections to different concepts. The reality is that most researchers in their lifetime do not get into such problems. However, hard problems get solved only because people tackle them.

The question a researcher must grapple with whether the time investment is worth it given that the likely outcome is negative, and so it is a difficult personal decision to make. At the same time, even in the case of failure to solve the intended hard problem, there may be partial/side results that serve the immediate need of producing some results for the dissertation.

George Pólya (1887–1985) suggested a 4-step procedure for mathematical problem-solving, which is relevant to engineering researchers as well. Recent work suggests the relevance of these recommendations.

The recommended steps to solve a research problem are:

i. Understand the problem, restate it as if its your own, visualize the problem by drawing figures, and determine if something more is needed.

ii. One must start somewhere and systematically explore possible strategies to solve the problem or a simpler version of it while looking for patterns.

iii. Execute the plan to see if it works, and if it does not then start over with another approach. Having delved into the problem and returned to it multiple times, one might have a flash of insight or a new idea to solve the problem.

iv. Looking back and reflecting helps in understanding and assimilating the strategy and is a sort of investment into the future.

Ethics in Engineering Research

Ethics generally refers to a set of rules distinguishing acceptable and unacceptable conduct, distinguishing right from wrong, although everyone recognizes some common ethical norms, but there is difference in interpretation and application. Ethical principles can be used for evaluation, proposition or interpretation of laws.

International norms for the ethical conduct of research have been there since the adoption of the Nuremberg Code in 1947. British Royal Society (BRS) in the seventeenth century to refine the methods and practices of modern science. This event altered the timing and credit issues on the release of research results since BRS gave priority to whoever first submitted findings for publication, rather than trying to find out who had first discovered.

Whitbeck raised two simple but significant questions to address the tricky issue of authorship in research:

(1) who should be included as an author and (2) the appropriate order of listing of authors?

There are issues around individuals who may be deeply involved during the conduct of the research work but may not contribute to the drafting phase. Additionally, certain universities now put restrictions on coauthor ship to prevent malpractices.

Ethics in Engineering Research Practice:

Technological developments raise a whole range of ethical concerns such as privacy issues and data related to surveillance systems, and so engineering researchers need to make ethical decisions and are answerable for the repercussions borne out of their research as outcomes. Engineering ethics gives us the rule book; tells us, how to

decide what is okay to do and what is not.

Researchers make many choices that matter from an ethical perspective and influence the effects of technology in many ways:

i) By setting the ethically right requirements at the very outset, engineering researchers can ultimately influence the effects of the developed technology.
ii) Influence may also be applied by researchers through design (a process that translates the requirements into a blueprint to fulfill those requirements). During the design process, decision is to be made about the priority in importance of the requirements taking ethical aspects into consideration.
iii) Thirdly, engineering researchers have to choose between different alternatives fulfilling similar functions.

Research outcomes often have unintended and undesirable side effects. It is a vital ethical responsibility of researchers to ensure that hazards/risks associated with the technologies that they develop, are minimized and alternative safer mechanisms are considered.

Types of Research Misconduct

Engineering research should be conducted to improve the state-of-the-art of technologies. Research integrity encompasses dealing fairly with others, honesty about the methods and results, replicating the results wherever possible to avoid errors, protecting the welfare of research subjects, ensuring laboratory safety, and so forth. To prevent mistakes, peer reviews should take place before the research output is published.

Different types of research misconduct as described in research articles are:

(i) **Fabrication** (Illegitimate creation of data): It is the ***construction*** and/or addition of data, observations, or characterizations that never occurred in the gathering of data or running of experiments.
(ii) **Falsification** (Inappropriate alteration of data): It is ***manipulating*** research materials, equipment, or processes, or changing or omitting data or results such that the research is not accurately represented in the research record.

Fabrication and falsification of data in published content can hurt honest researchers getting their work published because what they can churn out may short fall of what is already published through misconduct till the misconduct is established and subsequently retracted.

(iii)**Plagiarism (Taking other's work sans attribution):** Plagiarism takes place when someone uses or reuses the work (including portions) of others (text, data, tables, figures, illustrations or concepts) as if it were his/her own without explicit acknowledgement. Verbatim copying or reusing one's own published work is termed as self-plagiarism and is also an unacceptable practice in scientific literature. The increasing availability of scientific content on the internet seems to encourage plagiarism in certain cases, but also enables detection of such practices through automated software packages.

Supervisors, reviewers or editors alerted to plagiarism by:

(i) Original author comes to know and informs everyone concerned.

(ii) Sometimes a reviewer finds out about it during the review process.

(iii) readers who come across the article or book, while doing research.

Many free tools and also paid tools available that one can procure institutional license of, one cannot conclusively identify plagiarism, but can only get a similarity score which is a metric that provides a score of the amount of similarity between already published content and the unpublished content under scrutiny.

(iv) Other Aspects of Research Misconduct:

1) Serious deviations from accepted conduct could be construed as research misconduct.
2) Simultaneous submission of the same article to two different journals also violates publication policy
3) When mistakes are found in an article or any published content, they are generally not reported for public access unless a researcher is driven enough to build on that mistake and provide a correct version of the same.

Ethical Issues Related to Authorship

Academic authorship involves communicating scholarly work, establishing priority for their discoveries, and building peer-reputation, and comes with intrinsic burden of acceptance of the responsibility for the contents of the work. There are several important research conduct and ethics related issues connected to authorship of research papers as described by Newman and Jones as follows:

1) Credit for research contributions is attributed in three major ways in research publications: by authorship (of the intended publication), citation (of previously published or formally presented work), and through a written acknowledgment (of some inputs to the present research). Authorship establishes both accountability and gives due credit. A person is expected to be listed as an author only when associated as a significant contributor in research design, data interpretation, or writing of the paper.
2) The primary author dubiously bestows coauthor ship on a junior faculty or a student to boost their chances of employment or promotion, which can be termed as Career-boost authorship
3) Unfortunate malpractice of co authorship that can be described as "Career-preservation authorship" wherein a head of the department, a dean, a provost, or other administrators are added as Coauthors because of quid pro quo arrangement wherein the principal author benefits from a "good relation" with the superiors and the administrator benefit from authorship without doing the required work for it
4) Sometimes, an actual contributor abstains from the list of authors due to an undisclosed conflict of interest within the organization. Such coauthor ships can be termed ghost coauthor ship.