Engineering Research Methodology

Chapter 1: Introduction

What's Research?

- A scientific and systematic search for pertinent information on a specific topic.
- Derived from the French compound word "re-" + "cerchier", or "sercher".
- An active, diligent, and systematic process of inquiry in order to discover, interpret or revise facts, events, behaviours, or theories, or to make practical applications with the help of such facts, laws, or theories.
- A careful investigation or inquiry specially through search for new facts in any branch of knowledge.
- Systematized effort to gain new knowledge.
- A collection of information about a particular subject.
- Creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications.
- Original investigation undertaken in order to gain knowledge and understanding.
- An art of investigation of new and innovative aspect of any branch of knowledge.
- It comprises of `defining and redefining problems`, `formulating hypothesis`, `suggesting solutions or solution approaches`, `collecting and analyzing data`, `deriving, experimenting`, and `eventually validating the hypothesis or deducing new conclusions`.

Purposes of Research

- The purpose of research is to discover answers to questions through the application of scientific procedures.

Objectives of Research

- To gain familiarity with a phenomenon or to achieve new insights into it. (`exploratory` or `formulative` research studies)
- To portray accurately the characteristics of a particular individual, situation or a group. (`descriptive` research studies)
- To determine the frequency with which something occurs or with which it is associated with something else. (`diagnostic` research studies)
- To test a hypothesis of a causal relationship between variables. (`hypothesis-testing` research studies)

Benefits of Research

- It inculcate the ability of a researcher to evaluate and use research results with reasonable confidence.
- Enables use to make intelligent decisions concerning problems.
- Helps the consumer of research results to evaluate them and enables him to take rational decisions.
- It helps us to develop disciplined thinking or a ‘bent of mind’ to observe the research field objectively.

Motivations in Research

- Intellectual satisfaction of doing something innovative and creative.
- Meaningful and long-lasting contributions towards the advancement of mankind and society.
- Enjoy the challenges of solving unsolved problems.
- Attain higher level of understanding of fundamental concepts as well as practical significances.
- Degrees, financial benefits, and respect comes along the way.

Types of Research

- Descriptive vs. Analytical:
  - `Descriptive research` includes surveys and fact-finding enquiries of different kinds to describe the state of affairs as it exists at present.
  - `Analytical research` uses facts or information already available, and analyse these to make a critical evaluation of the material.
- Applied vs. Fundamental:
  - `Applied research (or action)` aims at finding a solution for an immediate problem facing a society or an industrial/business organisation.
  - `Fundamental research (to basic or pure)` is mainly concerned with generalisations and with the formulation of a theory.
- Quantitative vs. Qualitative:
  - `Quantitative research` is based on the measurement of quantity or amount.
  - `Qualitative research` is concerned with qualitative phenomenon.
- Conceptual vs. Empirical:
  - `Conceptual research` :
    - Related to some abstract idea(s) or theory.
    - It is generally used by philosophers and thinkers to develop new concepts or to reinterpret existing ones.
  - `Empirical research` :
    - Relies on experience or observation alone, often without due regard for system and theory.
    - It is `data-based` research, coming up with conclusions which are capable of being verified by observation or experiment.
    - It is type of `experimental` type of research.
    - It is necessary to get at facts first-hand, at their source, and actively to go about doing certain things to stimulate the production of desired information.

        - Appropriate when proof is sought that certain variables affect other variables in some way.

Research Approaches

- The collection of procedures and plans that decide the overall process of research.
- Decides the methods for `data collection` , `analysis` , and `interpretation` .

Types of Research Approaches

- Quantitative approach:
    - `Inferential approach` is creating database to infer characteristics or relationships of population.
    - `Experimental approach` has much greater control over research environment and some variables are manipulated to observe their effect on other variables.
    - `Simulation approach` involves the construction of an artificial env't within which relevant info and data can be generated to build models and understand future conditions.
- Qualitative approach:
    - concerned with subjective assessment of attitudes, opinions and behaviour.
    - a process to understand the uniqueness of situations in a particular context.
    - researchers focus towards data collection and analysis process during the qualitative research.
    - Involves a lot fieldwork and observation.
    - Inductive by nature.
    - Relies on abstractions, concepts, testing of hypothesis rather than relying on a body of existing theory.

Significance of Research

- Research provides the basis for nearly all government policies in our economic system.
- Research has its special significance in solving various operational and planning problems of business and industry.
- Research is equally important for social scientists in studying social relationships and in seeking answers to various social problems.

Research Methods vs Methodology

- Research methods:
    - The methods the researchers use in performing research operations.
    - All those methods which are used by the researcher during the course of studying his research problem are termed as research methods.
    - `Data collection` , `Data preparation` and `analysis` and `system evaluation` .
- Research methodology:
    - A way to systematically solve the research problem.
    - A science of studying how research is done scientifically.
    - It explains:
        - The logic behind the methods we use in the context of our research study,

- Why we are using a particular method (technique) and
- why we are not using others so that research results are capable of being evaluated either by the researcher himself or by others.

	Research method	Research methodology
1	defined as the procedure or technique applied by the researcher to undertake research	a system of methods, used scientifically for solving the research problem
2	nothing but the behavior or tool, employed in selecting and building research technique	implies the science of analysing, the manner in which research is conducted appropriately.
3	is concerned with carrying out experiment, test, surveys, interviews, etc.	concerned with learning various techniques which can be employed in the performance of experiment, test or survey.
4	covers various investigation techniques	which consists of complete approach aligned towards the attainment of purpose.
5	intends to discover the solution to the problem at hand.	aspires to apply appropriate procedures, with a view to ascertaining solutions.

Research and Scientific Methods

- `Research` can be termed as “an inquiry into the nature of, the reasons for, and the consequences of any particular set of circumstances, whether these circumstances are experimentally controlled or recorded just as they occur”.
- `Scientific method` is the pursuit of truth as determined by logical considerations.
- Observation + Reasoning = Hypothesis -> Experiment = Theory

Elements of a Scientific Method

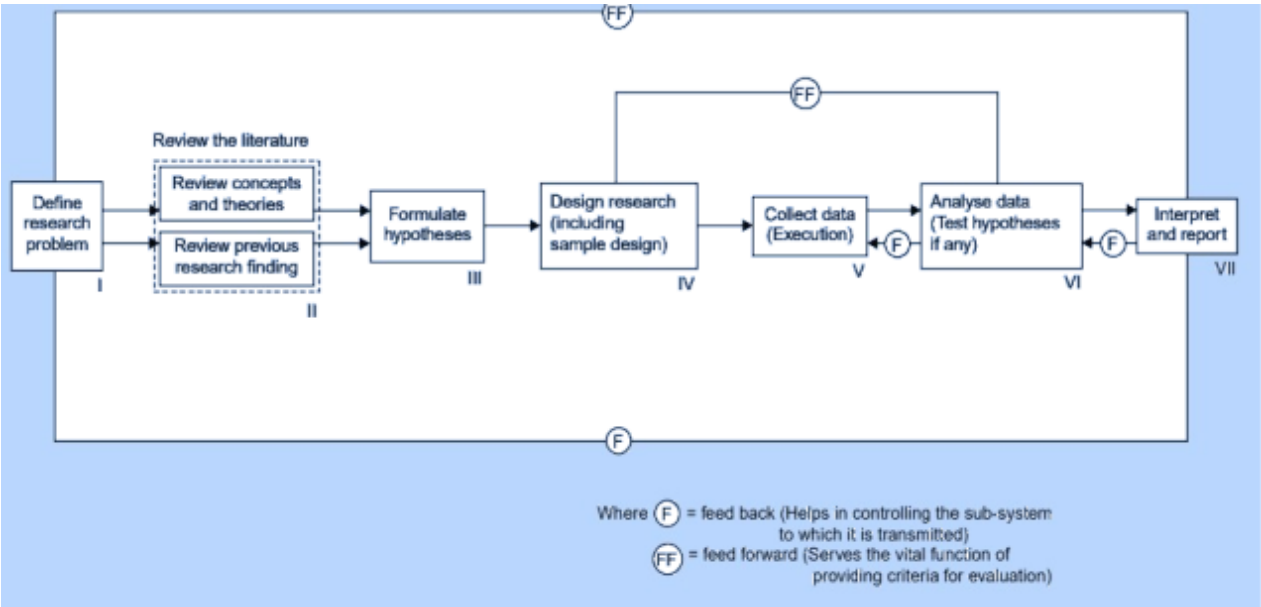
- `Iterations` , `recursions` , `interleavings` and `orderings` of:
  - `Characterization's` -> (Quantifications, observations and measurements)
  - `Hypotheses` -> (Theoretical, hypothetical explanations of observations and measurements)
  - `Predictions` -> (Reasoning including logical deduction from hypotheses and theories)
  - `Experiments` -> (Testing all of the above)

Basic postulates of Scientific Method

- It relies on empirical evidence.
- It utilizes relevant concepts.
- It is committed to only objective considerations.
- It presupposes ethical neutrality, i.e., it aims at nothing but making only adequate and correct statements about population objects.
- It results into probabilistic predictions.
- Its methodology is made known to all concerned for critical scrutiny are for use in testing the conclusions through replication.
- It aims at formulating most general axioms or what can be termed as scientific theories.

Research process

1	• Research question / Problem	What are you interested in? What do you have to know about it?
2	• Background / Observation	Make observations & gather background information about the problem.
3	• Formulate hypothesis	An *educated guess* ... It shall be possible to measure / test it. It should help answer the original question.
4	• Design experiment	How will you test your hypothesis? What tests will answer your question?
5	• Test hypothesis / Collect data	Test your hypothesis by executing your experiments. Collect data from them.
6	• Interpret / Analyze results	What do your results tell you? Do they prove or disprove the hypothesis? ... It is OK to be wrong.
7	• Publish findings	Write papers for conferences & journals. Write dissertation.



Criteria of Scientific Research

- The purpose of the research should be clearly defined and common concepts be used.
- The research procedure used should be described in sufficient detail (keeps continuity and advancement of the research).
- The procedural design of the research should be carefully planned to yield results that are as objective as possible.
- The researcher should report with complete frankness, flaws in procedural design and estimate their effects upon the findings.
- The analysis of data should be sufficiently adequate to reveal its significance and the methods of analysis used should be appropriate.
- The validity and reliability of the data should be checked carefully.
- Conclusions should be confined to those justified by the data of the research and limited to those for which the data provide an adequate basis
- Greater confidence in research is warranted if the researcher is experienced, has a good reputation in research and is a person of integrity.

Criteria of Good research

- Systematic
- Logical

- Empirical
- Replicable

Structure of Research Proposal

- Title
- Introduction
- Literature and review
- Research objective and hypothesis
- Methodology
- Ethical consideration
- Significance of the study
- Limitations
- Timeline
- Budget
- Expected results
- References

Research ethics

- Principle and guideline that ensure the responsible and ethical conduct of research.
- It inclues:
  - Obtaining informed consent from participants
  - Maintaining privacy and confidentiality
  - Avoiding plagiarism
  - Adhering to ethical standards in data collection
  - Analysing and publication

Research Ethics principles and guidelines

- Informed consent
- Confidentiality and privacy
- Honesty and integrity
- Avoidance of harm
- Fairness and equality
- Respect for participant
- Transparency
- Data management
- Compliance with regulations
- Publication ethics

Chapter 2: Defining Research Problem

What's Research Problem?

- Refers to some difficulty which a researcher experiences in the context of either a theoretical and practical situation and wants to obtain a solution for it.
- Sources of research problem:
  - Observation
  - Literature reviews
  - Professional conferences
  - Experts
  - Previous experience
- Components:
  - There must be an individual or a group which has some difficulty or the problem.
  - There must be some objective(s) to be attained.
  - There must be alternative means (or the courses of action) for obtaining the objective(s) one wishes to attain.
  - There must remain some doubt in the mind of a researcher with regard to the selection of alternatives.
  - There must be some environment(s) to which the difficulty pertains.
- Selecting research problem:
  - Subject which is overdone should not be normally chosen.
  - Contriversial subject should not become the choice of an average researcher.
  - Too narrow or too vague problems should be avoided.
  - The subject selected for research should be familiar and feasible so that the related research material or sources of research are within one's reach.
  - The importance of the subject, the qualifications and the training of a researcher should be considered.
  - The costs involved, the time factor are few other criteria that must also be considered.
  - The selection of a problem must be preceded by a preliminary study.

Necessity of defining the problem

- Properly defined research problem will enable the researcher to be on the track.
- **Questions used**:
  - What data are to be collected?
  - What characteristics of data are relevant and need to be studied?
  - What relations are to be explored?
  - What techniques are to be used for the purpose?

- **Techniques**:
    - Statement of the problem in a general way
    - Understanding the nature of the problem
    - Surveying the available literature
    - Developing the ideas through discussions
    - Rephrasing the research problem into a working proposition
- **Hypothesis and Working Hypothesis**:
    - `Hypothesis` is a tentative answer to research question that has not yet been tested.
    - `Working Hypothesis` are a set of suggested tentative solutions of explanations of a research problem which may or may not be the real solutions.
    - Properties:
        - Should be clearly and precisely stated in simple terms.
        - Should be testable
        - Limited in scope
        - Should state relationship between variables
        - They should be amenable to testing within a reasonable time
        - Should be consistent with most of the known facts
- **Considerations**:
    - Technical terms and words or phrases, with special meanings used in the statement of the problem, should be clearly defined.
    - Basic assumptions or postulates (if any) relating to the research problem should be clearly stated.
    - A straight forward statement of the value of the investigation (i.e., the criteria for the selection of the problem) should be provided.
    - The suitability of the time-period and the sources of data available must also be considered by the researcher in defining the problem.
    - The scope of the investigation or the limits within which the problem is to be studied must be mentioned explicitly in defining a research problem.

Factors to consider when selecting a research area

- Some of them have to do with your particular `interests` , `capabilities` , and `motivations` . Other centers on area that will be of greatest interest to both the academic and private sectors.

11 Points to consider in finding and developing a research topic

- Can it be excitedly pursued?
- Can interest be sustained by it?
- Is the problem solvable in a reasonable period of time?
- Is it worth doing?

- Will it lead to other research problems?
- Is it manageable in size?
- What is the potential for making an original contribution to the literature in the field?
- If the problem is solved, will the results be reviewed well by scholars in your field?
- Are you, or will you become, competent to solve it?
- By solving it, will you have demonstrated independent skills in your discipline?
- Will the necessary research prepare you in an area of demand or promise for the future? To market yourself