UNDERSTANDING ENGINEERING RESEARCH

MODULE-1

MEANING OF RESEARCH

•**Research:** A careful, well-defined (or redefined), objective, and systematic method of search for knowledge.
•**Driven by:** Inquisitiveness for the unknown and useful, aiming for an **original contribution** to expand existing knowledge.
•**Process involves:**
- Formulation of hypothesis or proposition of solutions.
- Data analysis and deductions.
- Ascertaining if conclusions fit the hypothesis.

•**Essentially:** Research is the process of creating or formulating knowledge that does not yet exist; it's the **art of scientific investigation**.

OBJECTIVES OF ENGINEERING RESEARCH

- **Core Purpose:** To discover answers to questions through scientific procedures; to find hidden truths.
- **Broad Groupings of Research Objectives:**
  - **Exploratory or Formulative:** Gain familiarity or new insights into a phenomenon.
  - **Descriptive:** Accurately portray characteristics of an individual, situation, or group.
  - **Diagnostic:** Determine frequency of occurrence or association.
  - **Hypothesis-testing:** Test causal relationships between variables.

SPECIFIC OBJECTIVES OF ENGINEERING RESEARCH

- **Solve New & Important Problems:** Conclusions must be new, even if unknown at the start.
- **Navigate Information:** Understand where and how to find information to solve engineering problems in academic and professional careers.
- **Prevent Failures:** Lack of investigation into engineering guidelines, standards, and best practices can lead to severe repercussions.
- **Effective Communication:** Ability to conduct thorough, accurate research and clearly communicate results is crucial for decision-making.
- **Develop New Knowledge:** Aim to develop new theoretical or applied knowledge, not just desired results.
- **Contribute Even in Failure:** If a desired result isn't achieved, understanding *why* is also a valuable contribution to ongoing research.

MOTIVATION IN ENGINEERING RESEARCH

- **Intrinsic Motivations:** (Linked to strong creative performance)
  - Interest, challenge, learning, meaning, purpose.
- **Extrinsic Motivating Factors:** (Can be strong, but may block creativity)
  - Rewards for good work: money, fame, awards, praise, status.
  - *Example:* Obtaining a patent for research outcome.
- **Influences from Others:**
  - Competition, collaboration, commitment, encouragement.
  - *Example:* Peer influence or desire to outperform others.
- **Personal Motivation:**
- Solving unsolved problems, intellectual joy.
- Service to community, respectability.
- **Mix of Extrinsic & Intrinsic Aspects:**
- Desire to excel beyond current achievements globally.
- Improve the state of the art in technology.
- Contribute to societal improvement.
- Fulfillment of historical legacy in socio-cultural context.
- **External Factors:**
- Government directives, funding opportunities in specific areas, terms of employment.

Types of Engineering Research

1. Descriptive vs. Analytical:

- **Descriptive:** Fact-finding inquiries, comparative, co-relational; researcher has no control over variables, just reports the present state. Can attempt to determine causes.
- **Analytical:** Utilizes already available facts for analysis and critical evaluation.
- *Note:* Some studies can be both.

2. Applied vs. Fundamental (Basic/Pure):

Applied Research: Seeks to solve an **immediate problem** (e.g., in an organization). Primary objective is a solution for compelling practical problems.

Fundamental Research: Concerned with generalizations and theory formulation (e.g., natural phenomena, pure mathematics). Aims for broad applications in medium to long term.

3. Quantitative vs. Qualitative:

Quantitative: Uses statistical observations of a large number of representative cases for conclusions.

Qualitative: Relies on a few non-representative cases or verbal narratives (e.g., behavioral studies) to make propositions.

4. Conceptual vs. Empirical:

•**Conceptual Research:** Related to abstract idea(s) or theory; used by philosophers/thinkers to develop/reinterpret concepts.

•**Empirical Research:** Relies on experience or observation alone, often without regard for system/theory.

•**Empirical is:** Data-based; conclusions verifiable by observation/experiment (experimental type).

- Requires firsthand facts, active stimulation of information.
- Researcher starts with a working hypothesis, then gathers data to prove/disprove it.
- Characterized by experimenter's control over variables and deliberate manipulation.
- Most powerful support for a hypothesis.

ENGINEERING RESEARCH PROCESS OVERVIEW

- **Process:** A series of closely related activities, often overlapping rather than strictly sequential.
- **(Visual Aid: You can insert a flowchart similar to the one described in the original text, showing interconnected steps from Problem Formulation to Report Preparation)**

Engineering Research Process: Key Steps

1. Formulating the Research Problem:

1. Identify the specific problem to study (states of nature or relationships between variables).
2. Decide the general area of interest.

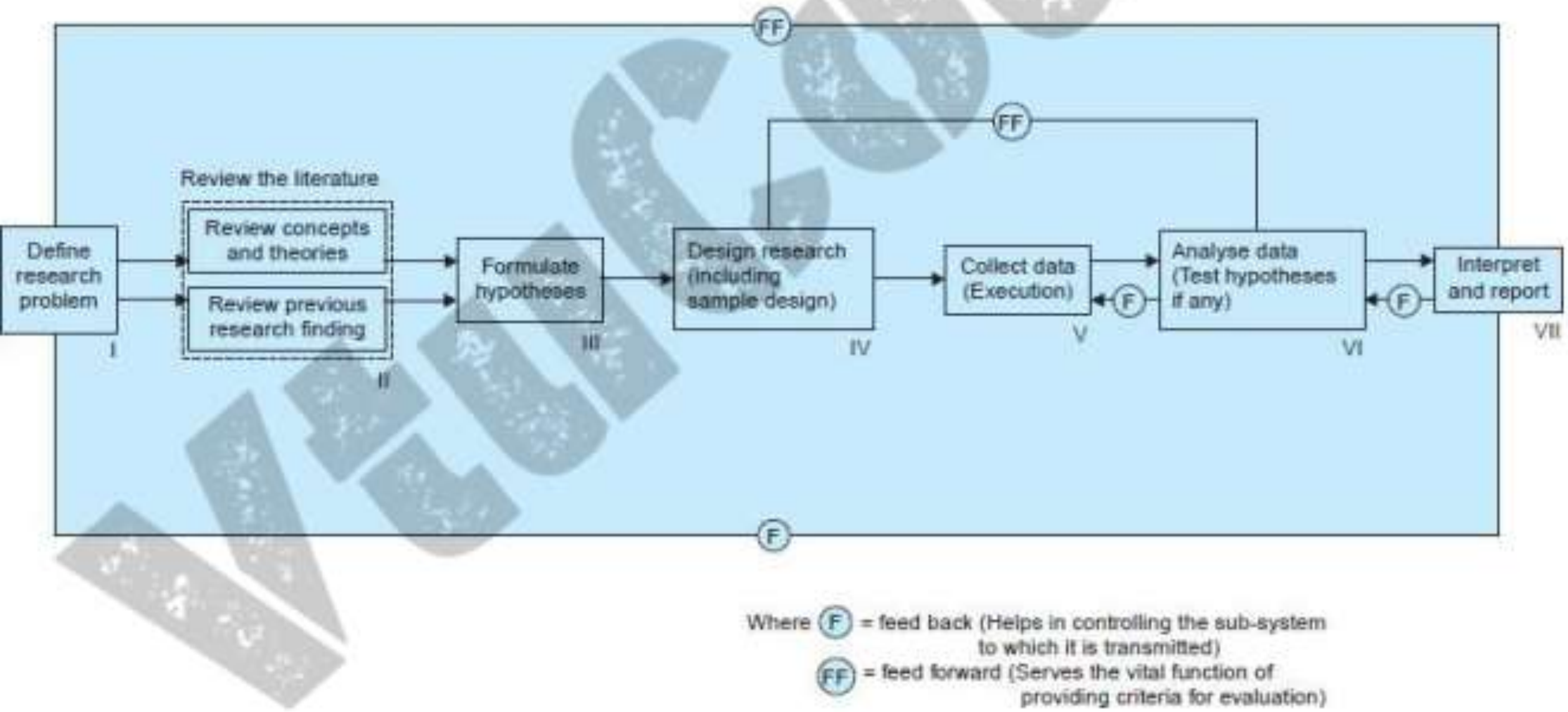
2. Extensive Literature Survey:

1. Write a brief summary of the formulated problem.
2. Undertake extensive survey of existing literature related to the problem.
3. (Often required for PhD synopses submission).

3. Development of Working Hypotheses:

1. State clear, specific, and limited tentative assumptions.
2. Hypotheses guide research by delimiting the area, sharpening thinking, and focusing attention.

RESEARCH PROCESS IN FLOW CHART



Where (F) = feed back (Helps in controlling the sub-system to which it is transmitted)

(FF) = feed forward (Serves the vital function of providing criteria for evaluation)

4. Preparing the Research Design:

4. State the conceptual structure for research conduct.
5. Aims for efficiency, maximal information with minimal effort, time, and money.

5.Determining Sample Design:

4. Decide the method of selecting a sample from a given population (e.g., random, stratified, cluster, multi-stage).

6.Collecting the Data:

4. Gather appropriate data, as existing data may be inadequate.
5. Methods: Experiment (quantitative measurements) or Survey (observation, interviews, questionnaires).

7.Execution of the Project:

7. Crucial for adequate and dependable data.
8. Systematic execution, on time, with careful watch for unanticipated factors.

8.Analysis of Data:

7. Establish categories, apply coding, tabulation, and draw statistical inferences.
8. Condense unwieldy data into manageable groups and tables.

9.Hypothesis-testing:

7. Test formulated hypotheses using statistical tests (e.g., Chi-square, t-test, F-test).
8. Results in either acceptance or rejection of the hypothesis.

10.Generalizations and Interpretation:

7. If a hypothesis is repeatedly upheld, generalize findings to build a theory.
8. The true value of research lies in its ability to arrive at generalizations.

11.Preparation of the Report or Thesis:

7. Careful report writing with a specific layout.

Report Layout and Main Text

- **Report Layout:**
  - **(i) Preliminary Pages:** Title, date, acknowledgements, foreword, table of contents, lists of tables/graphs.
  - **(ii) Main Text:**
    - **Introduction:** Objective, methodology, scope, limitations.
    - **Summary of Findings:** Non-technical statement of findings and recommendations.
    - **Main Report:** Logical, broken into identifiable sections.
    - **Conclusion:** Clear, precise summing up of results.
  - **(iii) End Matter:** Appendices (technical data), bibliography (consulted sources), index (especially for published reports).

Finding a Worthwhile Problem

- **Starting Points:** Supervisor-stated problems, rethinking basic theory, combining information from existing papers.
- **Key Skills:** Finding an appropriate problem and understanding its implications are critical but often not explicitly taught.
- **Process:**
  - Initial vague identification.
  - Literature survey and technical reading for certainty.
  - Initial spark (oral presentations, introspection, new tools/results from other subjects).
- **Why it's Worthwhile:**
  - Non-intuitive/counterintuitive, long-awaited by community.
  - Major simplification of theory, starts new subject/area.
  - New/improved methods with practical applications, or a result that stops further work.

Finding a Worthwhile Problem (Cont.)

- **Researcher's Conviction:** Essential for best efforts and acceptance by the community.
- **Problem Hardness:** Not all problems are "great"; major advancements can come from small, effectively solved problems.
- **Hard & Open Problems:** Have deep implications and connections; most researchers don't tackle them, but they get solved because people try.
- **Time Investment:** A difficult personal decision, considering potential negative outcomes.
- **Even in Failure:** Partial/side results can still contribute to a dissertation.

Solving a Worthwhile Problem (George Pólya's 4-Step Procedure)

1. **Understand the Problem:** Restate it, visualize with figures, determine what else is needed.
2. **Explore Strategies:** Systematically explore possibilities, or a simpler version, looking for patterns.
3. **Execute the Plan:** Test if it works; if not, restart with another approach. (May lead to sudden insights).
4. **Look Back & Reflect:** Understand and assimilate the strategy; an investment in future problem-solving.

ETHICS IN ENGINEERING RESEARCH

- **Definition:** Set of moral principles guiding conduct, distinguishing right from wrong, acceptable from unacceptable.
- **Learning Ethics:** Mostly in formative years, but moral development continues.
- **Ethical Principles:** Used for evaluation, proposition, or interpretation of laws. Laws often follow shared ethical values.
- **Historical Context:** International norms since Nuremberg Code (1947). British Royal Society (17th century) influenced research credit with priority given to first submission for publication.
- **Whitbeck's Questions on Authorship:**
  - Who should be included as an author?
  - What is the appropriate order of listing?
- **Modern Relevance:** Co-authorship in an interconnected world is highly relevant.
- **Distinction:** Research ethics (application of outcomes) vs. Responsible Conduct of Research (how work is undertaken).

ETHICS IN ENGINEERING RESEARCH PRACTICE

- **Ethical Concerns:** Technological developments raise issues like privacy, data from surveillance systems.
- **Engineer's Responsibility:** Make ethical decisions and be accountable for repercussions of research outcomes.
- **Impact on Humans:** Ethics in data use often stems from its impact on people.
- **Data Access & Analysis:** Unprecedented access and analysis options necessitate ethical boundaries: *Are there things we can do with data that we should not?*
- **"Rule Book":** Engineering ethics provides guidelines for acceptable practices.
- **Influence of Researchers' Choices:**
  - **Requirements:** Setting ethically right requirements from the outset.
  - **Design:** Prioritizing ethical aspects during the design process (translating requirements into blueprints).
  - **Alternatives:** Choosing ethically sound alternatives for similar functions.
- **Unintended Side Effects:** Research outcomes can have undesirable side effects.
- **Ethical Responsibility:** Minimize hazards/risks associated with developed technologies; consider safer alternatives.
- **Design for Safety:**
  - Inherently safe designs (avoid dangers).
  - Safety factors and multiple independent safety barriers.
  - Supervisory mechanisms to take control if primary process fails.

TYPES OF RESEARCH MISCONDUCT

- **Research Integrity:** Fair dealings, honesty, result replication, welfare of subjects, lab safety, peer reviews.
- **1. Fabrication (Illegitimate creation of data):**
  - Conjuring data or experiments, often due to timeline pressures, without actual results.
- **2. Falsification (Inappropriate alteration of data):**
  - Misrepresenting, misinterpreting, or illegitimately altering data (even partly) to support a desired hypothesis.
  - **Consequences:** Hampers research, causes false data percolation, wrecks trustworthiness, incurs costs, impedes progress.
  - *Note:* Can also result from poor experimental design or incorrect measurement.
- **3. Plagiarism (Taking others' work without attribution):**
  - Using or reusing others' work (text, data, figures, concepts) as one's own without explicit acknowledgement.
  - **Self-plagiarism:** Verbatim copying or reusing one's own published work (unacceptable).
  - **Detection:** Increased availability of content aids detection via software, but human judgment is crucial.
    - Similarity scores are metrics, not conclusive proof.
    - Low similarity doesn't guarantee plagiarism-free.
    - Patchwork plagiarism is harder to evaluate.
- **Avoiding Plagiarism:**
  - Paraphrase in your own words, summarize relevant content.
  - **Always cite the original source.**
  - Do not copy sentences/paragraphs verbatim even with citation.
  - Clearly distinguish your ideas/results from others' in writing.

OTHER ASPECTS OF RESEARCH MISCONDUCT

- **Serious Deviations:** Can be construed as research misconduct.
- **Fraud:** Occurs when there is both deception and damage.
- **Simultaneous Submission:** Submitting the same article to two different journals simultaneously (violates publication policies; journals want original papers).
- **Reporting Mistakes:** Mistakes in published content are often not publicly reported unless a researcher aims to correct them.

ETHICAL ISSUES RELATED TO AUTHORSHIP

- **Academic Authorship:**
  - Communicates scholarly work, establishes priority, builds peer reputation.
  - Carries the burden of accepting responsibility for content.
  - Primary basis for employment, promotion, and honors.
- **Credit Attribution Methods:**
  - **Authorship:** Significant contributor in research design, data interpretation, or writing.
  - **Citation:** For previously published/presented work.
  - **Acknowledgment:** For minor inputs.
- **Accountability & Credit:** Authorship establishes both.
- **"Guest" or "Gift" Authorship:**
  - Co-authorship bestowed on someone with little or no contribution.
  - Dilutes real contributors' work, inflates credentials, **ethically a red flag.**
- **"Career-Boost Authorship":** Primary author dubiously adds junior faculty/student for their career advancement.
- **"Career-Preservation Authorship":** Administrators added as co-authors due to quid pro quo arrangements, benefiting from authorship without work.
- **"Ghost Co-authorship":** Actual contributor abstains from author list due to undisclosed conflict of interest. **Full disclosure is vital.**

Ethical Issues Related to Authorship (Cont.)

- **Reciprocal Authorship:** Researchers list each other with minimal actual collaboration.
- **Misrepresentation of Contributions:** Sole-authored works where significant contributions from others are only acknowledged, not recognized with authorship.
- **Author Responsibility:** All listed authors have full obligation for all contents; consent for submission must be sought.
- **Accountability in Misconduct:** Quantifying contributions helps ascertain accountability.
- **Double Submission:** Submitting the same paper to two forums simultaneously to increase publication chances. **Strongly discouraged by reputed journals.**

CONCLUSION

- Engineering research is a systematic and objective pursuit of knowledge and solutions to real-world problems.
- It encompasses various types, from fundamental exploration to applied innovation, guided by a structured process.
- **Ethical conduct is paramount** in all stages, from problem formulation to report writing.
- Adherence to principles of **integrity, honesty, and accountability** prevents misconduct like fabrication, falsification, and plagiarism.
- Responsible authorship practices are crucial for fair recognition, maintaining academic integrity, and fostering trust in the research community.