Module 1

Introduction

Syllabus

Introduction : 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, and Ethical Issues Related to Authorship

Textbook :

Dipankar Deb , Rajeeb Dey, Valentina E. Balas

"Engineering Research Methodology", ISSN 1868-4394 ISSN 1868-4408 (electronic), Intelligent Systems Reference Library, ISBN 978-981-13-2946-3 ISBN 978-981-13-2947-0 (eBook), https://doi.org/10.1007/978-981-13-2947-0

Reference Book:

David V. Thiel "Research Methods for Engineers" Cambridge University Press, 978-1-107-03488-4

1.1 Meaning of Research:

1.1.1 What is Research? :

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 can be defined as the search for knowledge or as any systematic investigation to establish facts. Research is like a careful and organized journey to find new information or create new knowledge. It involves setting a clear goal, asking questions, forming hypotheses (educated guesses), analyzing data, and making sure your conclusions match your initial ideas.

Example: Imagine you are curious about why plants in your garden grow differently. Your research could involve observing, making guesses (hypotheses), collecting data about sunlight, soil, and water, and then figuring out why plants grow differently.

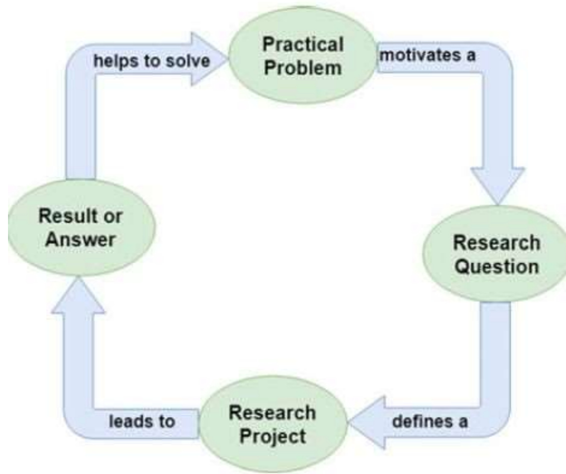
1.1.2 Starting a Research Cycle:

The research process (or research cycle) basically begins with a **practical problem** or an existing gap in knowledge or practice. This could be a practical challenge, an unanswered question, or an area that needs improvement.

Once the problem is identified, researchers formulate a clear and concise problem statement. From the formulated problem statement, researchers then develop specific research questions. Building on the **research questions**, researchers set clear objectives for the study. Objectives outline what the research aims to achieve and contribute to solving the identified problem. They serve as a roadmap for the **research project**.

Based on the research questions and objectives, researchers design a methodology to gather relevant data and conduct the investigation. This may involve selecting research methods, data collection techniques, and analytical tools suitable for addressing the research questions. Researchers collect data according to the defined methodology.

This data is then analyzed to derive meaningful insights and **results or answers** to the research questions. The results of the analysis are interpreted in the context of the research questions and objectives. The final step involves translating research findings into practical implications. This helps to solve the practical problem that one started with in the first place, as shown in the following figure.



Example: If you notice your plants are not growing well, the problem is the poor plant growth. Your research question might be, ”What factors affect plant growth in my garden?”

1.1.3 Building Background:

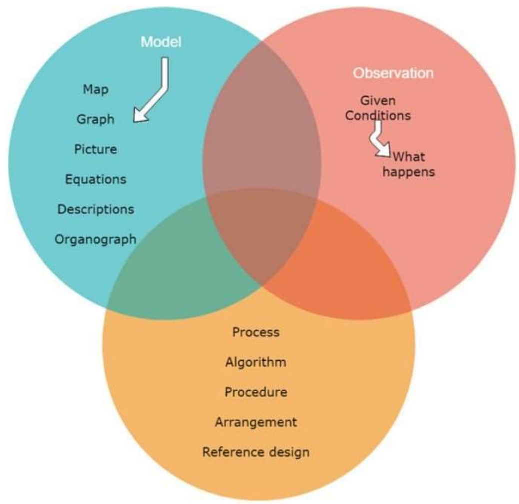
The building up of background for doing good research includes connecting different areas or different pieces of knowledge. The purpose is to prepare the mind for active work. as opposed to becoming a repository or an encyclopedia. Research is not just about reading a lot of books and gathering a lot of existing information. It is about adding our own ideas to what we already know. It involves critical thinking, analysis, and the generation of new insights. Research is about asking questions that matter in the real world and then finding answers through a careful and organized approach. It involves systematically exploring, investigating, and understanding topics that are relevant to our lives.

The purpose is to prepare the mind for active work as opposed to becoming a repository or an encyclopedia. Research is not just about reading or gathering a lot of existing information. It is instead adding, maybe small and specific, yet original, contribution to that existing body of knowledge.

Example: Before fixing your garden, you might learn about soil types, sunlight needs, and plant nutrition. Instead of just gathering facts(existing information), you aim to contribute something new and specific.

1.1.4 Ways of Developing Knowledge:

The ways of developing and accessing knowledge come in three, somewhat overlapping, broad categories. They are observation (seeing things), models (simplified descriptions or equations), and processes (methods or designs).



(i) **Observation:**Observation is described as the most fundamental way to gather information. It becomes particularly important when the subject being observed is unusual, exciting, or challenging to study. Observation can take various forms, ranging from traditional measurements in a laboratory setting to conducting surveys among a group of subjects.

(ii)**Models :** After making observations, the collected data often needs to undergo some form of processing, which leads to the second category of knowledge, which is the "model". **Models** are described as approximated and simplified representations in the form of a statistical relationship, a figure, or a set of mathematical equations. Models help us understand and interpret observed phenomena more abstractly, providing a way to analyze and make sense of the data.

(iii)**Processes and Algorithms:** The final category involves methods for organizing and doing things to achieve a specific result. This category includes processes, algorithms, procedures, arrangements, or reference designs.

Example 1: In gardening research, observation involves directly watching and recording how plants respond to sunlight. This may include noting changes in leaf color, growth patterns, or flowering times. For instance, you might observe that certain plants thrive in direct sunlight, while others prefer shaded areas.These direct observations form the foundation of your understanding of the plants' behavior in different light conditions. You might create a simple model to predict growth based on sunlight hours. This could involve developing a simple equation or chart that correlates the number of sunlight hours with plant growth. For example, your model might suggest that plants receiving more sunlight tend to grow taller or produce more flowers. The model serves as a tool to generalize and make predictions about how plants are likely to respond to varying sunlight conditions. Finally, you develop a process (a watering schedule) to achieve the desired plant growth. Your process could involve adjusting the frequency and amount of water based on the observed sunlight levels. This systematic approach ensures that your gardening efforts are aligned with the knowledge gained from observation and modeling, ultimately aiming for the desired plant growth.

Example 2 : Let us consider an example related to the development of a smartphone:

Engineers observe user interactions with existing smartphones, studying how people use different features, how they hold the device, and identifying common issues such as battery life and durability concerns. This observation helps engineers understand user behavior and preferences, as well as identify potential problems or areas for improvement.

Based on the observed data, engineers create models to simulate the behavior of various smartphone components. These models help predict factors like power consumption, signal strength, and heat dissipation, influencing design choices.

Engineers follow a detailed development process for manufacturing the smartphone. This involves procedures for designing the circuit board, arranging hardware components such as the battery, processor, camera, and sensors within the device, implementing algorithms for software functionalities, and adhering to reference designs to ensure compatibility with industry standards.

1.1.5 Good Research :

Good research involves a systematic approach to collecting and analyzing information. Good research includes systematically collecting and analyzing information. It goes beyond existing knowledge, attempting to add valuable discoveries. The research journey in engineering typically starts with a broad research area (e.g., computer science and engineering) and narrows down to a specific topic (e.g., machine learning algorithms for image recognition), ultimately focusing on a well-defined problem (e.g., enhancing accuracy in image recognition systems). This progression from area to topic to problem showcases the gradual refinement of research focus.

Example: In gardening research, after applying your watering schedule, you analyze plant growth data. If you discover a new and effective way to make plants thrive, you have made an important discovery.

1.1.6 Engineering Research:

In engineering, research involves recognizing, planning, designing, and executing investigations to improve knowledge and skills.

Engineering research is the process of developing 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. In other words, engineering research is a systematic and disciplined process aimed at discovering new knowledge or improving existing knowledge in the field of engineering.

Example: If you are an engineer wondering why a machine works a certain way, your research might involve studying its parts, creating models to understand interactions, and eventually suggesting ways to make it work better.

1.2 Objectives of Engineering Research

The primary goal of engineering research is to address new and significant problems. While the ultimate conclusion is unknown at the start, the process begins with educated guesses based on circumstantial evidence, intuition, and imagination. A guess gives a target to work toward. and after initial attempts, it may turn out that the guess is incorrect.

Engineering research serves various important objectives, contributing to the advancement of knowledge, technology, and societal well-being. Some key objectives of engineering research include the following:

(i) **Innovation and Advancement:** Engineering research aims to push the boundaries of current knowledge and technology. By exploring new ideas, concepts, and methodologies, researchers seek to innovate and advance the field, leading to the development of new technologies and solutions.

(ii) **Problem Solving:** Engineering research often focuses on solving real-world problems. Researchers aim to address challenges and issues faced by industries, communities, or individuals, seeking practical and effective solutions through the application of engineering principles.

(iii) **Optimization:** Research in engineering aims to optimize existing processes, systems, and products. This involves improving efficiency, reducing costs, enhancing performance, and minimizing environmental impacts.

(iv) **Knowledge Expansion:** One of the primary objectives of research is to expand the body of knowledge in engineering. Through experimentation, analysis, and documentation, researchers contribute to the understanding of fundamental principles and phenomena in various engineering disciplines.

(v) **Interdisciplinary Collaboration:** Many engineering challenges require a multidisciplinary approach. Research objectives may involve collaboration between engineers, scientists, and professionals from other fields to address complex problems that span multiple domains.

(vi) **Education and Training:** Engineering research contributes to the education and training of future engineers and scientists. The dissemination of research findings through publications, conferences, and other channels helps educate the next generation of professionals.

(vii) **Technological Transfer:** Research often leads to the development of new technologies and methodologies. The objective is not only to create knowledge but also to transfer this knowledge to industry, enabling the practical application of research findings for the benefit of society.

(viii) **Societal Impact:** Many engineering research projects are driven by a desire to have a positive impact on society. This could involve improving infrastructure, addressing environmental issues, enhancing healthcare technologies, or promoting sustainable practices.

(ix) **Quality and Safety Improvement:** Engineering research aims to enhance the quality and safety of products, processes, and systems. This is particularly important in fields such as aerospace, healthcare, and transportation, where safety standards are crucial.

(x) **Global Challenges:** Engineering research often addresses global challenges such as climate change, resource scarcity, and public health issues. The objective is to contribute to solutions that can have a positive impact on a global scale.

1.3 Motivation in Engineering Research

Motivation in engineering research plays an important role in driving researchers to explore new frontiers, address challenges, and contribute to the advancement of knowledge and technology. Motivations can broadly be categorized into intrinsic, extrinsic, and sometimes a blend of both. The combination of both intrinsic and extrinsic motivators can shape the overall motivation of individuals engaging in engineering research. The possible motives may be the result of one or more of the following desires:

1.3.1 Intrinsic Motivations

Intrinsic motivations refer to the internal factors that drive a person to engage in an activity,

(i) **Curiosity and Intellectual Interest:** Many researchers are motivated by a natural curiosity and a genuine interest in understanding how things work. Studies have shown that intrinsic motivations like interest, challenge, learning, Meaning and purpose are linked to strong creative performance.

Example: An engineer may be naturally curious about the functioning of renewable energy systems. This curiosity drives him to explore innovative approaches to harnessing solar energy, leading to research in the development of more efficient solar panels.

(ii) **Personal Fulfillment:** For some researchers, the pursuit of knowledge and the satisfaction of contributing to the greater body of human understanding are personally fulfilling. The intrinsic rewards of research, such as personal growth and a sense of accomplishment, can be powerful motivators. Personal motivation for solving unsolved problems, intellectual joy, service to the community, and respectability are all driving factors.

Example: An environmental engineer driven by a sense of purpose to address pollution may engage in research on innovative waste management solutions. The meaningful impact on the environment serves as a driving force.

(iii) **Passion for Technology:** Individuals with a genuine passion for engineering and technology may find motivation in the joy of working with and contributing to the development of advanced technologies.

Example: An engineer with a deep passion for robotics may initiate research to enhance the capabilities of autonomous robots. The joy and satisfaction derived from contributing to the field of robotics serve as intrinsic motivators.

1.3.2 Extrinsic Motivations

(i) **Career Development:** Engaging in research can contribute to career advancement in academia, industry, or both. Researchers may be motivated by the desire to establish themselves as experts in their field, gain recognition, and open up new opportunities for professional growth. Extrinsic motivating factors like rewards for good work, such as money, fame, awards, praise, and status, are very strong motivators but may block creativity.

Example: Research outcomes may enable a researcher to obtain a patent, which is a good way to become rich and famous, opening up opportunities for career growth and recognition.

(ii) **Competitive Drive:**The desire to be at the forefront of a field or to compete with other researchers and institutions can drive motivation. The pursuit of excellence and the aspiration to be recognized for outstanding contributions can be strong motivating factors.

(iii) **Influences from others:** Influences from others, like 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, be doing well and I want to do better.

1.3.3 Mix of Extrinsic and Intrinsic Motivations

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

(i) **Wanting to do better than what has been achieved in the world:** This is an intrinsic motivation, driven by personal motivation and a desire for self-improvement & excellence, and a sense of internal fulfillment.

(ii) **Improve the state of the art in technology:** The pursuit of advancing technology is typically motivated by an intrinsic interest in innovation, curiosity, and the internal satisfaction derived from pushing the boundaries of knowledge and capability.

(iii) **Contribute to the improvement of society:**This comes under both intrinsic and extrinsic types of motivation. It arises from an internal sense of purpose and the desire to make a positive impact on society and address societal challenges. It may also be influenced by external factors such as recognition, social approval, or a sense of duty.

(iv) **Fulfillment of the historical legacy in the immediate socio-cultural context:** This is a mixed type of motivation. The fulfillment of a historical legacy may be driven by intrinsic factors, such as personal meaning and connection to the historical and cultural context, emphasizing a sense of identity and continuity. Simultaneously, external factors like societal expectations or recognition may also play a role.

(v) **Government directives and funding opportunities:** This represents a mixed type of motivation, influenced by external factors such as government policies and financial incentives. The motivation to align research with targeted areas for funding is primarily driven by external rewards like financial support. Simultaneously, it supports researchers in pursuing projects that align with their personal interests, curiosity, and passion for contributing to knowledge and innovation.

(vi) **Terms of employment:**This represents an extrinsic type of motivation. Terms of employment, including benefits, salary, promotions, or job security, are external factors that can motivate individuals to engage in specific activities, including engineering research.

1.4 Types of Engineering Research

The different types of research are :

1.4.1 Descriptive versus Analytical:

A **descriptive type** of research aims to describe the characteristics of a phenomenon through fact-finding inquiries to effectively describe the present state of art. It involves observing, recording, and reporting without manipulating variables. Descriptive research can be further classified into comparative (comparing different groups or conditions) and correlational (examining relationships between variables) methods. The researcher holds no control over the variables but rather only reports them as they are. Descriptive research also includes attempts to determine causes, even though the variables cannot be controlled.

On the contrary, **analytical** research involves critically evaluating existing information and analysing it to gain a deeper understanding.

Example: Research Topic: Traffic Congestion in Urban Areas.

The following comparison gives us a clear understanding of how descriptive research aims to provide a comprehensive overview, while analytical research explores the underlying causes and potential solutions.

Descriptive Research:	**Analytical Research:**
Objective: Describe the current state of traffic congestion in a specific urban area.	*Objective:* Analyze the factors contributing to traffic congestion and propose potential solutions.
Methodology: Conduct surveys and collect data on traffic patterns, peak hours, and congestion levels. Use traffic cameras and sensors to gather real-time information. Analyze historical data to identify trends.	*Methodology:* Use statistical methods to identify correlations between variables such as population growth, urban development, and traffic congestion. Analyze the impact of specific interventions or traffic management strategies. Compare the effectiveness of different approaches through modeling and simulation.
Findings: Present a detailed description of the current traffic congestion situation, including statistics on peak congestion times, affected areas, and common causes.	*Findings:* Provide insights into the root causes of traffic congestion and propose analytical solutions. For example, the research may suggest optimizing traffic signal timings, implementing public transportation improvements, or introducing congestion pricing.

1.4.2 Applied versus Fundamental:

Research can either be applied research or fundamental (basic or pure) research.

Applied research is practical and problem-oriented. It is conducted to address specific issues or problems faced by organizations or industries. In Applied research, the goal is to find solutions that can be implemented in real-world situations. 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.

Fundamental Research is also known as basic or pure research. Fundamental research is driven by a desire to expand knowledge and understanding rather than to solve a practical problem. It focuses on concerned with generalizations and formulation of a theory, contributing to the development of a broader knowledge base. Research concerning natural phenomena or relating to pure mathematics are examples of fundamental research.

Example :

Research Topic: Treatment for a Specific Disease (e.g., Diabetes)

The following comparison demonstrates how engineering research can contribute to the development of practical solutions (Applied Research) and, at the same time, deepen the scientific understanding of the disease at a fundamental level (Fundamental Research).

Applied Research:	**Fundamental Research :**
Objective: Develop a new drug or treatment protocol for managing diabetes in patients.	*Objective:* Investigate the molecular mechanisms underlying insulin resistance in diabetes to deepen our understanding of the disease.
Methodology: Conduct clinical trials with diabetic patients to test the effectiveness and safety of a new drug or treatment approach. Collect data on blood sugar levels, side effects, and overall health outcomes. Analyze the results to determine the practical benefits and risks of the proposed treatment.	*Methodology:* Use molecular biology techniques to study the interactions of insulin with cells and identify the factors contributing to insulin resistance. Explore the genetic and biochemical aspects of diabetes at the cellular level.
Findings: Provide a treatment option that can be immediately applied in clinical settings to improve the management of diabetes.	*Findings:* Contribute to the broader scientific knowledge of the cellular and molecular basis of diabetes. While the immediate application might not be evident, the research lays the foundation for future therapeutic approaches and a deeper understanding of the disease.

1.4.3 Quantitative versus Qualitative:

Quantitative research involves the collection and analysis of numerical data, using statistical observations of a sufficiently large number of representative cases to draw any conclusions. It aims to quantify relationships and patterns, making use of measurable variables. Surveys, experiments, and statistical analyses are common in quantitative research.

Qualitative Research focuses on a few non-representative cases or verbal narrative in behavioral studies such as clustering effect in intersections in Transportation engineering to make a proposition. Qualitative methods include interviews, focus groups, observations, and content analysis. It provides in-depth insights into the complexity of human behavior and social phenomena.

Example:

Research Topic: Evaluation of an Online Learning Platform for Engineering Education

The following table effectively illustrates how student satisfaction with a learning platform for engineering education can be approached using both quantitative and qualitative research methods.

Quantitative Research:	**Qualitative Research :**
Objective : Measure overall satisfaction levels of engineering students using a numerical rating scale.	*Objective :* Explore detailed feedback and experiences of engineering students using open-ended questions.
Methodology : Administer a satisfaction survey with quantifiable rating questions tailored to engineering coursework. Collect numerical data on satisfaction scores. Use statistical analysis to identify trends and overall satisfaction levels specific to engineering education.	*Methodology :* Conduct interviews or open-ended surveys with engineering students to gather qualitative responses. Analyze qualitative data thematically, focusing on aspects relevant to engineering education.
Findings : Provide numerical insights into the average satisfaction level and key trends specific to the engineering learning context.	*Findings* Offer rich, detailed descriptions of engineering student's experiences and capture refined feedback that quantitative measures might miss, shedding light on unique challenges and opportunities in online engineering education.

1.5 Finding and Solving a Worthwhile Problem :

1.5.1 Finding a Research Problem :

A researcher may start with problems stated by the Supervisor or posed by others that are yet to be solved. Alternately, it may involve rethinking basic theories or formulating ideas from provided information or need to be formulated or put together from the information provided in a group of papers suggested by the Supervisor. Research scholars face the task of finding an appropriate problem to begin their research.

1.5.2 Skills Needed:

Skills required for finding a research problem are crucial but often not explicitly taught. Critical thinking about possible implications is important.

1.5.3 Identifying a Problem:

Once the problem is identified, the process of literature survey and technical reading takes place to further ascertain the significance and validity of the intended problem.However, An initial spark is ideally required before the process of literature survey may duly begin. The process may involve an initial spark from an oral presentation by somebody which is followed by asking questions or introspection provides this perspective oral presentation, asking questions, or introspection. Developments in other subjects may produce a tool or a result which has direct implications to the researcher's subject and may lead to problem identification.

1.5.4 Attributes or characteristics of a Worthwhile Research Problem:

Once a potential research problem is identified, the researcher faces the critical task of evaluating its worthiness. A worthwhile research problem possesses one or more attributes, such as being nonintuitive(something that goes against common intuition) or counterintuitive(does not align with what one might naturally expect based on prior knowledge or experience), even to someone familiar with the area. These attributes include:

(i) Addresses a topic that the research community has been anticipating.

(ii) Simplifies a central part of theory.

(iii) Introduces a new result, initiating a new subject or area.

(iv) Offers a novel method or enhancements to existing methods with practical applications.

(v) sometimes, provides a result that stops further work in a particular area.

1.5.5 Decision to Tackle a Problem:

The researcher must be thoroughly convinced that the problem is worthwhile before initiating the investigation. Optimal 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.

It is essential to recognize that not every solved problem needs to be of great importance or impact. 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.

Majority of researchers may not engage with such problems during their careers. However, hard problems get solved only because people take them seriously as challenging problems and **tackle** them with willingness and with determination. Such people have a mindset that embraces complexity and uncertainty in the pursuit of solutions. They approach problems with a mindset that welcomes complexity and uncertainty in the quest for solutions.

Even if the attempt to solve a challenging problem is unsuccessful, there might be partial or side results that can still fulfill the immediate requirement of generating content for the dissertation.

1.5.6 Problem-Solving Methodology: Polya's Approach :

George Polya (1887–1985) proposed a **4-step procedure** for mathematical problem-solving, which has been found to be applicable to engineering researchers. Recent studies have affirmed the relevance of these recommendations. The suggested steps to solve a research problem are:

1. **Understand :** Understand the problem, Restate the problem in your own words , and visualize the problem by drawing figures, and determine if additional information is needed.
2. **Explore Strategies :** Explore various strategies to solve the problem, systematically. Look for patterns that might lead to a solution.
3. **Implement :** Implement the chosen strategy(plan) to solve the problem, to see if it works. If the plan doesn't work, start over(iterate) with another approach. Having engaged with the problem extensively and revisiting it multiple times, one may develop a new idea to solve the problem.
4. **Reflect :** After completing the problem-solving process, take the time to look back and reflect on the journey. This practice aids in understanding and assimilating the strategy. Such reflective practice serves as an investment in the future for continuous improvements in problem-solving and personal growth.

1.6 Ethics in Engineering Research

Ethics in engineering research is focused on the ethical considerations within the research process. Ethics refers to a set of rules distinguishing acceptable and unacceptable conduct, distinguishing right from wrong. Most people learn such norms in their formative years but moral development continues through different stages of growth. Although everyone recognizes common ethical norms, there can be differences in interpretation and application.

1.6.1 Historical Evolution of Research Ethics:

Nuremberg Code :

International norms for the ethical conduct of research have a deep-rooted history, dating back to the adoption of the **Nuremberg Code** in 1947. The Nuremberg Code, is a set of ethical principles for human experimentation. It originated in response to the Nuremberg Trials, where Nazi doctors were prosecuted for conducting inhumane experiments during World War II. Researchers must obtain informed consent from participants, especially in studies involving human subjects.

Influence of the British Royal Society on Research Credit:

The issues associated with research credit find their roots in the seventeenth-century establishment of the British Royal Society (BRS), which aimed at refining the methods and practices of modern science. BRS played a crucial role in shaping the timing and credit issues related to research results. According to this, priority for publication was given to whoever first submitted findings, rather than focusing on determining who had first made the discovery.

1.6.2 Ethical Considerations in Authorship :

Two simple but significant questions to address the tricky issue of authorship in research are :
(i)who should be included as an author and
(ii)the appropriate order of listing authors.
In today’s interconnected world, the issue of coauthorship is very relevant to all researchers, challenging the contributions during different phases of research.There are issues around individuals may be actively involved in the research process but may not contribute to the drafting phase. Moreover, certain universities have imposed restrictions on coauthorship to prevent malpractices.

1.6.3 Distinguishing Research Ethics and Responsible Conduct of Research in Engineering :

Government bodies, and universities worldwide have adopted certain codes for research ethics. However, there is a common misconception regarding the interchangeable use of two terms: research ethics and responsible conduct of research. Research ethics and the responsible conduct of research are related but not interchangeable. Research ethics looks at the ethical application of research outcomes, while Responsible Conduct of Research addresses the ethical considerations in how the research work is undertaken.

Research Ethics:

Research ethics primarily focuses on the moral principles and guidelines governing the conduct of research. It focuses on ensuring integrity, honesty, and fairness in the research process. Key areas include the treatment of research subjects, confidentiality, data handling, and ethical communication of research outcomes. In essence, research ethics addresses the ethical implications of the research itself.

Responsible Conduct of Research(RCR) :

Responsible Conduct of Research is a broader concept that extends beyond the ethical dimensions of the research itself. It encompasses the entire research process, emphasizing ethical behavior in interactions, collaborations, and the dissemination of results. RCR aims to maintain high standards of integrity and professionalism throughout the research process.

Research Ethics	**Responsible Conduct of Research (RCR)**
Research ethics involves moral principles governing the conduct of research. For example, in engineering, it ensures the fair treatment of participants in a human subjects study, protection of intellectual property, and honest reporting of results.	Responsible Conduct of Research is a broader concept that extends beyond the ethical dimensions of the research itself. In engineering, this includes maintaining integrity in project management, acknowledging collaborators' contributions, and avoiding the fabrication or falsification of data.
Key areas include the treatment of research subjects, confidentiality, data handling, and ethical communication of research outcomes.	RCR aims to maintain high standards of integrity and professionalism throughout the research endeavor. It involves ethical considerations in how the research work is undertaken, including interactions and collaborations.

Example: Consider a project focused on developing driverless(autonomous) cars. During testing, researchers uncover vulnerabilities that could be exploited for malicious purposes. **Research ethics considerations** in this scenario might involve:
(i) What ethical considerations should guide the development of such technology?
(ii)How can the team prevent the misuse of autonomous vehicles for harmful activities?
(iii) Are there ethical guidelines for the responsible development of autonomous systems?
Responsible Conduct of Research Now, consider how the research is carried out. It involves challenges such as:
(i) Are researchers actively engaged in developing safety measures for autonomous cars?
(ii) Do they collaborate with cybersecurity experts to secure the technology?
(iii) How do they communicate potential risks to the public and regulatory bodies?
In this way, research ethics addresses the broader implications and applications of the research outcomes, while the responsible conduct of research focuses on the integrity and methodology of the research process itself.

1.7 Ethics in Engineering Research Practice

Ethics in engineering research practice extends beyond the laboratory or research setting to encompass the ethical challenges faced by engineers in the practical application of their knowledge and skills.

1.7.1 Ethical Concerns in Technological Developments:

Technological progress in engineering introduces ethical considerations, especially regarding privacy and data in surveillance systems. Engineering researchers bear the responsibility of making ethical decisions, and they are answerable for the consequences arising from their research outcomes.

Data Collection and Privacy

Ethics is crucial in engineering research, especially when working with data, as it directly influences human well-being. For example, Research involving data collection, especially personal or sensitive information, requires respect for individuals' privacy and obtaining informed consent.

Example: A mobile weather app that requests location data for accurate forecasts. Ethical concerns arise if the app shares this data without explicit user consent or uses it for purposes beyond weather predictions.

Acceptability and Validity

Certain practices may be acceptable in specific situations, but the reasons for their unacceptability can be valid. Engineering ethics serves as our rulebook, offering guidance on determining what is ethically acceptable and and what is not, providing a framework for responsible data use.

Example: The use of facial recognition in smartphones for unlocking devices might be acceptable for convenience, but concerns arise if the technology lacks accuracy and wrongly denies access to users based on facial features.

1.7.2 Ethical Decision-Making in Technological Choices

Engineering research is closely interconnected with ongoing technological developments, and researchers make numerous choices that hold ethical significance, influencing the impact of technology in various ways.

Setting Ethical Requirements

At the outset of a project, engineering researchers can shape the effects of the developed technology by establishing ethically sound requirements. This initial step sets the stage for the responsible technological advancements.

Example: Engineers working on smart home devices may set ethical requirements for user privacy, ensuring that devices like voice-activated assistants only record and transmit data when explicitly activated by users.

Influencing Through Design

Influence may also be applied by researchers through design, which is 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.

Example: In the design of automobiles, engineers may prioritize safety features such as collision avoidance systems and advanced driver assistance. Ethical considerations involve protecting occupants and other road users from potential accidents.

Choosing Alternatives

Throughout the research journey, engineering researchers have to choose between different alternatives fulfilling similar functions, considering their ethical implications.

Example: When developing packaging materials, engineers might choose between traditional plastics and biodegradable alternatives. Ethical considerations include the environmental impact and long-term sustainability of each option.

1.7.3 Minimizing Unintended Consequences

Research outcomes can have unintended and adverse side effects. It is important for researchers to ethically address these issues by minimizing the hazards and risks associated with their technologies. This involves considering safer alternatives, incorporating inherent safety features in designs, implementing safety factors, utilizing multiple independent safety barriers, and establishing supervisory mechanisms to take control if the primary process fails. This commitment to safety demonstrates a careful approach to mitigating potential negative consequences from research outcomes.

Example: Agricultural engineers developing autonomous farming machinery consider unintended consequences, such as potential impacts on employment in rural communities. Ethical considerations involve implementing strategies to support affected workers and communities.

1.8 Types of Research Misconduct

Engineering research should be undertaken with the primary goal of advancing the current state-of-the-art technologies. **Research integrity** plays a crucial role in achieving this objective and involves fair dealings with others, honesty in presenting methods and results, and replication of findings whenever possible to minimize errors. Additionally, upholding the welfare of research subjects, ensuring laboratory safety, and addressing other ethical considerations are integral aspects of research integrity. In order to prevent mistakes and enhance the quality of research, peer reviews should take place before the research output is published.

To prevent errors and enhance the quality of research, it is imperative to subject research outputs to peer reviews before publication. This practice guarantees that the research undergoes thorough examination by subject-matter experts, contributing to the overall reliability and credibility of the research findings.

Serious deviations from accepted conduct is construed as **research misconduct**. Different types of research misconduct are :

1.8.1 Fabrication (Illegitimate Creation of Data)

This involves the act of creating data or experiments with preconceived notions about the expected conclusions. This unethical practice may arise when there are time constraints imposed by supervisors or customers, leading researchers to generate data rather than waiting for genuine results.

Example: Imagine a student conducting a science experiment on the growth of plants under different light conditions. Due to a lack of time, the student decides to fabricate the data by recording measurements that were never actually taken. The fabricated data might show consistent and impressive growth differences between plants subjected to various light conditions.In this case, the fabrication involves making up experimental results instead of honestly recording the actual outcomes of the plant growth experiment. This kind of behavior is unethical and goes against the principles of honesty and integrity in research.

1.8.2 Falsification (Inappropriate Alteration of Data)

:Falsification involves the inappropriate alteration of data or experiments, including mis-representation, misinterpretation, or illegitimate changes to support a desired hypothesis. This unethical practice occurs even when the actual data obtained from experiments indicate a different outcome. Falsification undermines the credibility and reliability of scientific research by presenting distorted information to align with a preconceived notion or agenda.

1.8.3 Consequences of Fabrication and Falsification

Negative impacts of fabrication and falsification include:

Percolation of False Data

When researchers engage in falsification or fabrication, it hampers engineering research, and inaccurate results (conclusions) may find their way (percolate) into published literature. This compromises the reliability of existing knowledge and can mislead other researchers who rely on this information for their work.

Wrecking Trustworthiness

Unethical practices wreck the trustworthiness of individuals (researchers) involved, damaging their reputation.

Additional Costs

Discovering falsification or fabrication often requires extensive investigations and corrective actions, leading to additional financial burdens.

Impeded Progress and Delays in Technical Advancement

Unethical practices, like falsification and fabrication, slow down research progress by injecting false information into the body of knowledge. This misguides other researchers, leading to actual delays in technical advancement.

Hurt to Honest Researchers

Fabrication and falsification create a challenging environment for honest researchers. When dishonest or misleading data is already published due to misconduct, it can set a false standard. Honest researchers may face challenges in getting their legitimate work recognized and published if it falls short of the falsely elevated standards created by misconduct.

Publication Barriers

The presence of fraudulent or manipulated data in the published literature can create barriers for honest researchers. This can make it harder for legitimate research to be accepted and published.

Establishment of Misconduct

Until misconduct is established and proven, the fraudulent data may remain in the published literature. This process can take time and may involve investigations and retractions. During this period, the misleading information continues to influence the research community. The retraction may not fully erase the impact of the false data on the scientific community.

Engineering researchers are often perceived as objective truth seekers. They can prevent misconduct by independently reproducing results whenever they are interested in doing further work on published material, which is likely to be part of their literature survey.

1.8.4 Plagiarism

Plagiarism is defined as the act of using or reusing someone else's work, including text, data, tables, figures, illustrations, or concepts, without proper attribution. It involves presenting the work as if it were one's own without explicit acknowledgment.
The concept of **self-plagiarism** occurs when researchers verbatim copy or reuse their own previously published work without appropriate citation. This practice is considered unacceptable in scientific literature.

Challenges of Internet Availability

The increasing availability of scientific content on the internet may encourage plagiarism in some cases, but also enables detection of such practices through automated software packages designed to identify similarities between texts.

Detection of Plagiarism

How are supervisors, reviewers or editors alerted to plagiarism?

Original author comes to know and informs everyone concerned.

Reviewers might discover plagiarism during the review process.

Readers conducting research may come across plagiarized content in articles or books.

Plagiarism Detection Tools

Plagiarism Detection Tools: The availability of both free and paid plagiarism detection tools, often accessible through institutional licenses, offers a way to assess the originality of written content. it is important to note that these tools provide a similarity score,indicating the level of similarity between published and unpublished content, rather than a conclusive identification of plagiarism. A similarity score is not conclusive evidence of plagiarism, it only serves as a metric for assessing similarity.

However, a low similarity score doesn't guarantee that the document is plagiarism free. It requires human evaluation to determine whether the content has been plagiarized or not. Additionally, it is essential to consider individual scores of sources rather than just the overall similarity index. Setting a maximum allowable similarity index may be insufficient in utilizing the tool effectively. This is because certain types of plagiarism, such as patchwork plagiarism, where sections of text are strategically rearranged, can be more challenging to detect through automated tools.

Ethical Writing Practices:

To avoid a high similarity count, researchers can use relevant published content by rephrasing or summarizing the content in their own words. This maintains the original meaning without replicating the original text. Whenever using ideas, concepts, or findings from other sources, cite them appropriately. This gives credit to the original authors and demonstrates transparency in acknowledging the use of external information. It is important to note that citing a source does not justify verbatim copying. A researcher should practice writing in such a way that the reader can recognize the difference between the ideas or results of the authors and those that are from other sources.

1.8.5 Other Aspects of Research Misconduct

Deception and Damage: Fraudulent Practices

Serious deviations from accepted conduct could be construed as research misconduct. When there is both intentional deception (misleading actions) and damage (negative consequences), the actions are officially recognized as fraudulent, and the term "research misconduct" is often used to describe such behavior. Such ethical violations are likely to be discovered or exposed over time sooner or later.

Simultaneous Submission

Engaging in practices that violate publication policies can be considered research misconduct. Simultaneous submission of the same article to two different journals violates publication policies.

Handling Mistakes in Published Content

If a researcher discovers mistakes in their published work and fails to report or correct them, it may be viewed as a form of research misconduct, unless a researcher takes responsibility for the accuracy of their work, acknowledges the mistake, and is motivated to contribute a corrected version.

1.9 Ethical Issues Related to Authorship

Academic authorship involves communicating scholarly work and establishing priority for their discoveries and building peer reputation. It also comes with an intrinsic burden of accepting responsibility for the contents of the work, serving as the primary basis for evaluation in areas such as employment, promotion, and other honors.

Here are some common ethical issues related to authorship:

1.9.1 Gift or Guest Authorship

Including ”guest” or ”gift” authors, where coauthorship is granted to someone with little or no contribution to the work, is misleading and unethical. This practice dilutes the contributions of those who did the actual work, artificially enhances the credentials of the listed authors, and raises concerns about possible research misconduct.

1.9.2 Career-Boost Authorship

Sometimes, the primary author may grant coauthorship in a suspicious way to a junior faculty member or a student with the intention of enhancing their chances of employment or promotion. This practice is referred to as career-boost authorship. This may misrepresent contributions, weaken or diminish the integrity of authorship, and be considered unethical manipulation for personal gain.

1.9.3 Career-Preservation Authorship

This malpractice, termed ”career-preservation authorship,” involves adding department heads, deans, or other administrators as coauthors in exchange for benefits or maintaining a ”good relationship.” In such cases, the principal author benefits from a favorable relationship with superiors, while the administrator gains authorship credits without fulfilling the necessary work for it, resulting in a mutually beneficial arrangement. This raises concerns about fairness, transparency, and the actual contributions of individuals listed as authors.

1.9.4 Ghost Coauthorship

Sometimes, an actual contributor may choose not to be included in the list of authors due to an undisclosed conflict of interest (personal or financial) within the organization or other reasons. Such instances of coauthorship are referred to as ghost coauthorship. This lack of transparency can compromise the integrity and credibility of the research process and findings. Full disclosure of all individuals engaged in the research is essential to enable a comprehensive evaluation based on both the research findings and an assessment of potential influences arising from conflicts of interest.

1.9.5 Reciprocal Authorship

In this form of questionable authorship, researchers may include each other as coauthors in a reciprocal gesture, often without genuine collaboration. The inclusion is based on mutual agreements with an expectation of shared benefits or outcomes. In some cases, there might be minimal collaboration, limited to basic tasks such as reading and editing. This practice lacks genuine engagement in thoroughly reviewing the work, potentially diminishing the credibility of authorship and the research itself.

1.9.6 Misrepresentation of Sole Authorship

Some authors try to present their work as solely authored, even when they depend on significant contributions from others. They choose to acknowledge those contributions only in the form of a general acknowledgment. This approach misrepresents the true extent of the contributions made by those not listed as authors. In this case, the unrecognized contributors are then unavailable to readers for additional clarification or explanation about their role in the research.

1.9.7 Authorial Accountability

All listed authors have full responsibility for all contents within a research article, and so naturally, they should also be made aware of a journal submission by the corresponding author. Obtaining consent from all authors regarding the content and submission of the paper is essential. All listed authors are responsible for the content, but determining individual accountability can be challenging. If one author commits misconduct, it is unclear to what extent other coauthors are responsible. Establishing a method to quantify individual contributions would be beneficial in appropriately recognizing and assessing the degree of associated accountability for each coauthor.

1.9.8 Double Submission

Double submission is an important ethical issue related to authorship, which involves the submission of a paper to two forums simultaneously. This practice is motivated by the desire to enhance the possibility of publication and potentially reduce the time to publication. This practice violates the principle of publishing original work, as reputable journals discourage double submissions to maintain the integrity of the publication process. Reputable journals aim to publish original papers — ones that have not been previously published elsewhere—and strongly discourage double submission.

Question Bank-Module 1 :

Meaning of Research:

1. Describe the key steps involved in starting a research cycle.
2. Discuss the significance of building background in the research process.
3. Identify and explain the three broad categories of developing knowledge.
4. Define engineering research. What are the different stages of engineering research?
5. Define research and explain the essential components of starting a research cycle. How does building background knowledge contribute to the research process?

Objectives of Engineering Research

1. Explain, in detail, the diverse objectives of engineering research.
2. Discuss in brief on objectives of engineering research.
3. Outline the primary objectives of conducting research in the field of engineering.

Motivation in Engineering Research

1. Discuss the primary objectives of engineering research. Explore the concepts of intrinsic and extrinsic motivations in the context of engineering research. Provide examples of how motivation influences the research process.
2. Analyze the intrinsic and extrinsic types of motivations. Provide examples of how both types of motivations can influence an engineer's involvement in research.
3. What are the different motivations for engineering research.?
4. Discuss the factors that motivate researchers in the field of engineering.
5. Explain the importance of motivation in sustaining long-term research endeavors.

Types of Engineering Research:

1. Provide an overview of different types of engineering research.
2. Compare and contrast descriptive research and analytical research in engineering.
3. Compare and contrast fundamental research and applied research in engineering.
4. Compare and contrast qualitative research and quantitative research in engineering.

Finding and Solving a Worthwhile Problem:

1. What skills are essential for identifying and solving a research problem in engineering? Explain the attributes of a worthwhile research problem. Discuss the decision-making process when choosing to tackle a specific problem. Explore Polya's problem-solving approach.
2. Explain the process of finding and defining a worthwhile problem in engineering research.
3. Elaborate on the steps involved in finding a worthwhile problem for engineering research. How does the identification of a meaningful problem contribute to the research process?

Ethics in Engineering Research:

1. Trace the historical evolution of research ethics. Differentiate between ethical considerations in authorship and the responsible conduct of research in engineering. Why is maintaining ethical standards crucial in the field of engineering research?
2. Define ethics in the context of engineering research.
3. Discuss why ethical considerations are crucial in engineering research practices.

Ethics in Engineering Research Practice:

1. Identify and discuss ethical concerns associated with technological developments. How does ethical decision-making play a role in technological choices? Explain strategies for minimizing unintended consequences in engineering research.
2. Explain how ethical principles are applied in the practice of engineering research.
3. Discuss potential ethical challenges faced by researchers in engineering.

Types of Research Misconduct:

1. Define and elaborate on the types of research misconduct, including fabrication, falsification, and plagiarism. Discuss the consequences of fabrication and falsification. Explore other aspects of research misconduct and their implications.
2. Define research misconduct and provide examples of different types.
3. Discuss the consequences of research misconduct on the scientific community.

Ethical Issues Related to Authorship:

1. Discuss ethical considerations in determining authorship of research papers.
2. Explain how issues related to authorship can impact the credibility of research.
3. Discuss the ethical issues surrounding academic authorship.