Unit 1 Research – An Introduction

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1.0 Objectives

After studying this unit, the learner will be able to:

- Understand the meaning and nature of scientific research
- Explain the characteristics of scientific research
- Describe the steps in the scientific method
- Understand the importance and relations of objectivity, reliability, and validity in research
- Recognize how these principles ensure quality and credibility of research findings

1.1 Introduction

Research is an important intellectual activity that contributes to the developments of ideas and knowledge of any field of study. In simple words, research means a systematic search for new knowledge or information. We, human beings have always been curious about the world and how does they work and this curiosity leads to asking questions and exploration about with their investigations. Research provides a structured way to find the answers of our curiosity by allowing individuals to examining the problems carefully and reaches to a reliable conclusions over the evidence. In academic environments, the research causes for the

foundation of learning and discoveries, while in professional settings the researchers helps the organizations to improve practices, develop new theories, innovations, and make the informed decisions.

Research is an academic activity and as such term should be used in technical terms. The research is also near about to problem solving, but in systematic and objective way. Many research activities starts with the problem or question identification, requires systematic investigations about certain things. In the next step it designs methods for collecting relevant information, by analyze research's findings, and thus it proposes the solutions of problems which are based on evidences. This structured approach helps individuals and organizations for addressing complex issues in a single logical and systematic way. By applying and implementing research methods, the problems can be read in-depth, with possible solutions that can be evaluated with the most appropriate course of actions that can be identified. Another important characteristic of research is of the systematic and organized investigation, process in research work**.** Unlike casual inquiries or simple information searching systems, the research follows a structured sequence of steps. These steps generally includes identifying of the research problem, then reviewing existing literature, and then their formulating hypotheses or research questions, the next processes incudes data collection and analyses the data for interpreting the final result. These stage should be planned carefully and executed accordingly while ensuing the conclusions that reaches to be supported by valid and reliable evidence, with these structured approaches, the research is often described as a disciplined and scientific method of inquiries**.**

To understand the research work in more depth, let us take some real-world examples, such as in the fields of medical sciences, the researchers conducts scientific studies for developing new treatments, medicines, and technologies which can improve treatment quality and human health for saving lives. The clinical trials and lab experiments helps scientists for evaluating effectiveness and safety of new drugs over simulations before introducing to public. Another example is of environmental research that focuses on studying issues likewise climate changes, pollutions, and natural resource management, the scientists analyzes environmental data and helps it for developing predictive models, and strategies for reducing environmental damages and thus promote sustainable developments. Such research work plays an important role while addressing global environmental challenges. The business and operations management field studies includes the work for improving organizational efficiency and productivity. For

instance the companies may conduct research for optimizing their supply chain systems with aiming to reduce operational costs, and improving customer's satisfactions. Techniques like of data analysis, forecasting, and operational research helps for the businesses in identifying effectiveness of strategies and survives competitive in the market.

With these examples, we can say that the research is not a limited tasks of academic institutions but also a widely applied in sciences, industries, governments, and everyday decisions. It provides a structured and reliable way for exploring new ideas, solving problems, and contributing to advancements of society. Therefore, there is a need for understanding research is essential for everyone involved in the academic studies, professional practices, or knowledge developments to think critically for their own study areas.

1.2 Meaning and Definition of Scientific Research

The word research is made up of two words: Re + Search, where "Re" means "again", and the word "Search," meaning "to examine or explore". Thus, the term research literally means "to search again" or "to investigate thoroughly" for any new things or enhancing existing literatures. This means research is not a goal for one-time attempt for finding information but rather, it is a process of rapidly and systematic procedures of investigation**.** The researchers often revisits questions by examining of evidences multiple times, and refining their understanding as a new valuable information becomes available to the literature. Thus the research represents a continuous effort and processes of deepening knowledge and gains a clearer understanding of various phenomena or processes. Figure 1, shows meaning of research as Re and Search.

In academics the research often considers as one of the most important methods for expanding knowledge and thus promoting intellectual growths. Universities and research institutions often encourages the scholars and students for engaging towards research activities the research processes helps developing analytical and critical thinking with logical reasoning, and systematic problem-solving abilities**.** Through research, the individuals learns about how to formulate any questions while gathering relevant information with analyzing data, and interpreting their findings logically. Thus, these skills are essential not only for academics, but also for professional development of scholars in several fields such as in science, engineering, medicine, management, and social sciences.



Figure 1: Research means to search again.

Beyond the academic world, the research also plays a crucial role in professional and organizational environments, such as in businesses, industries, and government institutions which rely on research for making informed decisions while aiming for improving efficiency, and developing innovative products and services. For example, the companies often conducts market research for understanding consumer's preferences and identifies new business opportunities for enhanced profitability and efficiency. Similarly, the governments also uses research findings for designing effective and public policies while addressing social and economic challenges. In this way, the research contributes significantly for economic development, technological progresses, and social welfare**.**

One of the key roles of research is for contribution to the generation of new knowledge. The research helps expanding existing understanding by exploring new ideas, testing theories, and discovering unknown relationships with variables. The knowledge produced through research is usually based on the systematic observations and careful data collection for logical analysis**,** ensures that the conclusions drawn are reliable and meaningful at the context. As a result, the research is not only strengthens existing knowledge but also creates or enhances the opportunities for further exploration and innovation.

The research can also be considered as a process of knowledge creation and enhancing through careful observations, experimentations, and analysis the researchers generate new insights that contribute to the overall development of knowledge in a particular discipline area. Over the time, the accumulation of research findings leads for the development of new theories, models, and practical applications. This way, the research serves as the driving force behind scientific discoveries, through enhancements with the help of technological advancements for the

improvements of social and economic systems. The importance of research can be observed and considered across a wide range of disciplines. In this the researching scientific fields helps the scientists for understanding natural phenomena's and developing their theories with technologies. In social sciences, the research helps scholars for analyzing human behaviors, social relationships, and societal issues such as education, health, and economic development for overall growth of systems. In the area of technology, the research also supports by the developments of innovative systems, software, and engineering solutions. In business and managements, the research helps organizations for improving decision-makings, optimizing operations, and responding effectively for the market trends.

1. Scientific Research

The scientific research, represents a more structured and disciplined form of investigations towards acquiring knowledge through observations, experiments, and logical analysis. Systematically and organized research is widely used in academics, scientific, and professional fields to studies the problems including testing theories, and discovering new facts about the world. The primary aim of scientific research is for producing reliable knowledge that can be tested, verified, and applied to understand natural and social phenomena. Scientific research differs something from ordinary forms of inquiry because it follows a planned and systematic approaches for the investigation and acquiring knowledge. In our everyday life, the peoples often form their opinions and conclusions based on their personal intuitions and experiences and by informal observations. However, the scientific research requires the use of structured methods, careful data collections, and objective analysis. The process generally begins by identifying a research problem or question with followed by reviewing existing knowledge, developing hypotheses via collecting relevant data, analyzing results, and thus drawing conclusions based on those evidences. This step-by-step procedure ensures, the findings of certain scientific research would be accurate and dependable to data or investigations.

Another important characteristic of scientific research is that it totally based on the observation and empirical evidences**.** The researchers collects information through various methods such as through experiments, surveys, field studies, and laboratory analysis. The reached conclusions reached should not be based on personal opinions and beliefs but on due measurable and observable data. This reliance on evidences helps ensuring the knowledge produced through scientific research is objective and credible. Scientific research also relies heavily on our logical reasoning and critical thinking abilities. Researchers analyzes the data

they often collects through logical methods while identifying patterns, relationships, and recent trends. The two types of reasoning commonly used in scientific research includes the inductive reasoning and deductive reasoning. The Inductive reasoning involves drawing general conclusions from their specific observations and the deductive reasoning involves testing specific hypotheses based on existing theories. Through these logical approaches, the scientific research contributes to the developments and refinement of existing knowledge.

2. Definitions of Scientific Research

There have several scholars, the provided the definitions of scientific research highlighting the systematic and objective nature.

According to **Redman and Mory**, research may be defined as **"**a systematized effort to gain new knowledge." The definition emphasizes the core ideas of the research that involves an organized and purposeful efforts for expanding existing knowledge.

Clifford Woody have described research as a process that involves **"**defining and redefining of problems, by formulating the hypotheses and suggests solutions through data collection, organization, and evaluating data, makes deductions, and reaches to conclusions**."** This highlights the various stages involved in a research processes and this shows that the scientific research is a continuous and have systematic processes, involving stpes for defining problems to conclusions.

Kerlinger have defined the scientific research as "it is a systematic, controlled, empirical, and critical investigation of hypothetical propositions about the presumed relations among natural phenomena**."** The definition have stressed several important characteristics of the scientific research including steps such as systematic investigation, empirical evidences, and critical evaluation of relationships between variables in the research processes.

These definitions shows collectively that the scientific research is a well-organized, evidence-based research and it is basically focused on discovering relationships and generating new knowledge and ideas for improving existing theories.

3. Scientific Approach to Knowledge discoveries

The scientific approach to knowledge discovery is based on the principle that the knowledge should be obtained through the systematic observations, careful experimentations, and logical

reasoning. Instead of relying on beliefs, traditions, and assumptions, the scientific research requires that the conclusions should be supported by evidences and the objective should be clearly analyzed. This approach helps the researchers for developing their explanations that should be reliable and capable of being tested. The scientific approach encourages the critical evaluations and examination of existing theories, knowledge and ideas**.** The researchers continuously enhances it by evaluating previous findings and attempts for improving or refining them through new investigations. As a result, the scientific knowledge is not static but continually evolving as a new evidence and this way our new discoveries emerges. This continuous process of questioning, testing, and verification helps in ensuring reliability and progresses of scientific understandings with clear and transparent goals. Another aspect of the scientific approach is the transparency and replicability of research processes. For this the researchers documents their methods, procedures, and their results so that the other scholars can examine them and replicate the study with same procedure acquires the same results. This openness helps maintaining the credibility of scientific research and allowing the academicians for building upon existing knowledge more scientific and clearer.

4. **Difference in Scientific Research and Ordinary Inquiry**

The scientific research differs significantly from the everyday methods of collections or acquiring knowledge through their intuitions, guesswork, and casual observations. Although these methods often leads to generation of new useful ideas, they might lack with the systematic procedures required for the reliable conclusions.

a. **Intuition** refers to the words from one's inner soul and it also be considered as through the knowledge gained by any instance or immediate understanding of anything without conscious reasoning just only from one's idea. People sometimes rely on these intuitions while making quick decisions or sudden judgments about any situations. However, the intuition is more subjective and may not be always leading to accurate conclusions because it is not supported by systematic evidences or observations.
b. **Guesswork** involves making certain assumptions or predictions about an entity without adequate information or careful analysis. While guesses may occasionally be correct but they may not be reliable every time because they are not based on the structured investigations or empirical data.
c. **Casual observation** means an individual's when notices certain events or patterns in the everyday life without carefully recording or analyzing them, these includes of causal

discoveries and such observations may provide useful insights for solving certain takss and they might lack with controlled conditions and systematic analysis for required scientific research.

Thus, the scientific research represents a structured and evidence-based approach as for acquiring knowledge from systematic investigations and careful observation towards logical reasoning. The use of empirical data in scientific researchers is to test ideas and develop conclusions. By distinguishing itself from intuition, guesswork, and casual observation, the scientific research can provide a reliable method for understanding complex phenomena with expanding knowledge in various academic and professional fields.

Activity A

1. Give two examples from real-life conditions where the research can help in improving the decision-making in several areas such as for education, business, and healthcare.

1.3 Characteristics of Scientific Research

Scientific research possesses includes the characteristics that differentiate it from ordinary investigation or informal inquiries. These characteristics ensure that the research has been conducted in a systematic, reliable, and objective manner with allowing the results for contributing meaningfully to the development of knowledge and ideas. When a study follows these characteristics, it becomes more structured, credible, and capable of producing valid conclusions. Understanding these essential features helps researchers for designing studies scientifically correct and capable of addressing complex problems effectively.

1. Systematic Nature

Scientific research follows an organized and well-planned procedure for systematic nature with consisting of clearly defined steps. These steps usually includes identification of the research problem, reviewing existing literature work formulating hypotheses, collecting relevant data, analyzes the data, and drawing conclusions. Each step should be systematically and carefully planned for ensuring that the investigation progresses logically and efficiently correct. The systematic approach helps in avoiding confusions and this ensures that the research process remains focused on the objectives of the study.

***Example**:* A study examining student's academic performance may begin with defining the research problem, by collecting data through surveys and examination records, with analyzing the results statistically, and then finally interpreting the findings for determining factors affecting student's performance.

2. **logical reasoning**

Scientific research relies on logical thinking for interpreting information and establishing relationships between the variables. The researcher uses reasoning for developing hypotheses, analyzing patterns in the collected data, and drawing meaningful conclusions. Logical reasoning ensures that research findings are not based on random assumptions but on rational analysis and evidences. Both inductive reasoning, develops general conclusions from specific observations, and includes deductive reasoning, that tests hypotheses based on established theories and thus commonly used in research.

Example: If a researcher observes that the students that spend more time in studying tends for achieving higher grades, so they might logically infers the study time related to the academic performance.

3. **Reliance**

The scientific research is also characterized by the reliance in research with empirical evidence. The empirical evidence refers to the information obtained through the observation, experiments, or measurements rather than speculation and with their personal belief. The researchers' collects data using tools such as surveys, experiments, field of observations, and laboratory analysis. These evidences forms the basis for analyzing the research problems and drawing the conclusions accordingly. Because of empirical evidences thus it is observable and measurable, and it strengthens the reliability of research findings. Figure 2: shows the characteristics of scientific research.

Example: A researcher studying for the impacts of exercises on health may collect the measurable data like of heart rate, body weights, or blood pressures for supporting their conclusions.

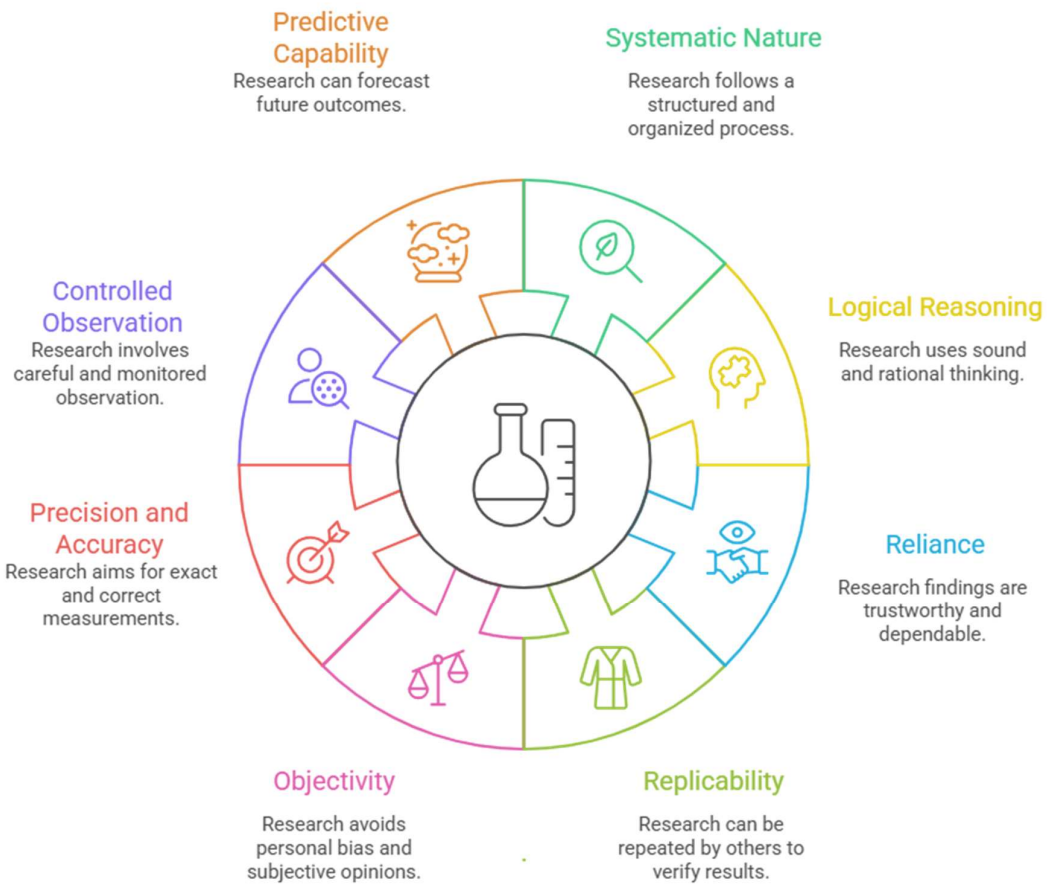


Figure 2: Characteristics of Scientific Research

4. Replicability

Replicability means that the results of a research study can be replicable, with the same methods and steps any one can simulates the same results. When the study would be replicable, it demonstrates that the findings are consistent and error free. The process replication strengthens the credibility of research work and allows other scholars to build upon previous findings.

Example: If the scientific experiment on the plant growth under specific light conditions it produces certain results, the other researchers should able to repeat the experiment and obtain similar outcomes.

5. **Objectivity**

Objectivity means that research should be free from individual's personal biasness, emotions, or subjective opinions. The researchers must depend on facts, evidence, and logical analysis rather than just from Individuals personal beliefs. Maintaining objectivity helps ensuring that the conclusions are based solely on data and does not influenced by the researcher's preferences or expectations.

Example: While analyzing survey responses for the consumer preferences, a researcher should analyses and interpret the results based on the actual data collected rather than just their own opinions and assumptions about the market.

6. **Precision and Accuracy**

The scientific research also emphasizes the precisions and accuracies in the data collection and analysis processes. The precision refers to the consistency and exactness or correctness of measurements, while accuracy refers to know about how close a measurement is towards the true value. Accurate and precise data are very essential for producing reliable conclusions and further avoiding misleading interpretations. Researchers therefore use their appropriate tools, instruments, and methods for ensuring that data is correctly collected and recorded efficeintly.

Example: In the laboratory experiments measuring of chemical reactions with precise instruments such as digital scales and calibrated measuring devices for using and ensuring towards accurate results.

7. **Controlled Observation**

Another characteristic of systematic research is focusing controlled observations. Scientific research often involves controlling of certain variables in order to isolate and perfuming the study of the effect with specific factors. By controlling external influences, the researchers can better understand the relationship between variables and then they can ensure that the results should not be affected by unrelated factors. The controlled observation is particularly important in experimental research where the specific conditions must be maintained efficiently

Example: In the controlled observations the experiment studying for the effect of fertilizer on plants growth, researchers may keep the factors such as sunlight, water, and soil conditions the constant may be controlled like changing only the type or amounts of fertilizers should be used.

8. Predictive Capability

The scientific research also possesses predictive capabilities. In scientific research the research findings can sometimes be predicted for the future events or outcomes based on the established patterns or relationships. Predictive capability allows the researchers for developing models or theories that explains about how certain factors influence the specific result outcomes. These predictions can then be tested through the further research work and with applied in our practical situations.

Example: Economic research analyzes the market trends that may help for predicting future demands and provides materials with certain products while allowing businesses for planning the production and marketing strategies more effectively and consistently.

Thus, the characteristics of scientific research—includes systematic procedures, logical reasoning, empirical evidences, replicability, objectivity, precision and controlled observation with predictive capabilities, these ensures that the research can be conducted in a rigorous and reliable manner. These features distinguishes the scientific research from the informal inquiries and thus helps in making it a powerful tool for generating trustworthy knowledge and solves the complex problems in various fields.

Activity B

1. How the scientific research differs from the casual observations or guesswork, explain with an example.
2. Consider a study on student' study habits and explain the types of data or evidence that should be used for collecting and ensures the study is scientific?

1.4 The Scientific Method

The scientific method can be considered as the fundamental foundation of scientific researches. It provides a structured and organized approach for investigating problems, ideas testing, and then in generating reliable knowledge. The researchers from different fields such as science, social science, technology, and management also heavily rely on the scientific methods while ensuring their research that the investigations should be done in systematic and logical manner ensures highly effectively. By following these method, the researchers will be able to study the

phenomena carefully, while collecting relevant evidences, and data leading for conclusions that should be supported by data rather than just their personal opinions.

In simple terms, the scientific methods can be defined as a systematic procedure used for exploring the questions, and analyzing problems, for discovering new knowledge through observation and experimentation by the researchers. It is a disciplined method of thinking and investigating that allows the researchers for moving from uncertainty to understanding level. The method involves a sequence of carefully planned steps that can be used for guiding the entire research processes, while ensuring that the investigation would remain focused and organized in well manner.

1. **Structure to the Research Process**

The key purposes of scientific method is to makes and bring order and structure to the research processes. The researchers can attempt for understanding a problem without a clear procedure, the investigation may become disorganized by the conclusions that may be unreliable in the current work. The scientific methods helps in avoiding problems such as by providing a logical sequence of steps that the researchers can follow for accomplishing overall tasks. These steps usually includes identifying a research problem, then reviewing existing knowledge, and developing their hypotheses, while collecting data, analyzing them for the results, and thus draws the conclusions accordingly. By this structured procedures, the researchers will be able for investigating solutions of problems in a consistent and effective manner.

2. **Reliable and Credible Knowledge**

The scientific method also plays an important role in scientific research while producing reliable and credible knowledge or works**.** Knowledge is generated by the method that are often based on observations, evidences, and logical reasoning. Researchers collects data through certain experiments, surveys, or field observations and then they analyze these information for determining the patterns or relationships through scientific methods. Because the conclusions are supported by empirical evidences, the results can be more trustworthy and should be verified or simulated by other researchers. These emphasis on evidences which ensures that the scientific knowledge should be objective and dependable accordingly.

3. Logical Reasoning

The logical reasoning is another important aspect of the scientific method, because it promotes the logical reasoning in the field of research**.** The researchers uses logical thinking for interpreting data and evaluates whether their hypotheses should be supported or rejected thereby. The logical reasoning helps the researchers for avoiding biased conclusions and these ensures that their findings would be consistent while collecting evidence of the research. In this way, the scientific method encourages the researchers for critically thinking and evaluating carefully for every stages of the investigation or research works.

4. Systematic Manner

The scientific method ensures that the research should be conducted or followed through a systematic manner. A systematic approach means the investigation would follows a clear sequence of steps rather than the random exploration for every steps. Each stages of the scientific methods were built upon the previous one, they allows the researcher for gradually developing and upgrading with a deeper understanding of the research problems. This structured approach helps maintaining clarity and consistency throughout the research processes. Figure 3 shows the component of scientific research.



Figure 3: Components of the Scientific Method

5. **Evidence-based**

The evidence based scientific methods includes evidences for certain works while requiring that the conclusions should be supported by observable and measurable data. The researchers must collect factual information through reliable methods and then analyzes them objectively before drawing certain conclusions. This reliance on evidences distinguishes the scientific research from methods based on certain intuition or speculations. This results, in the knowledge generated through this scientific method includes more reliable content delivering and it contribute it academically and in professional fields efficiently.

The scientific methods are widely used in several work areas while investing the different types of works and problems. In the natural sciences, it can be used for conducting experiments and understanding natural phenomena. In social sciences, the researchers uses it for studying human behavior and social relationships accordingly. In business and management fields, the scientific method helps in analyzing organizational problems, market trends, and decision-making processes accordingly. Despite these differences in research topics, the suggesting principles includes scientific method while remaining the same across several disciplines. Another significant advantages of the scientific method is t allowing researchers for findings to be tested and verified by other scholars and researchers. When the researchers documents their methods or certain works clearly, the other researchers can replicates the study for confirming the results and may use them for conducting works. The process of verification strengthens the credibility of research and this helps building a solid work area of scientific knowledge.

Thus, the scientific method serves as the foundation of the scientific research, by providing a structured and systematic approach for investigates of problems, by collecting evidences, and generating reliable knowledge. This, by ensuring whether research is logical, systematic, and evidence-based, the scientific method enables the researchers for producing their findings to be objective, verifiable, and valuable for advancing knowledge in various fields or research areas.

1.5 Steps in the Scientific Method

The scientific method follows a systematic sets or sequence of steps that guides the researchers for conducting certain investigations in an organized and logical manner. These steps helps in ensuring that the research process should be structured and the findings obtained from that

methods should be reliable and meaningful. Although the exact number of steps may slightly vary depending on the nature and field of the study and most research activities follows a common sequence at beginning with the identification of a problem and ends with the presentation of conclusions and results. For each step, it plays an important role in ensuring that the research has been conducted effectively and the generated knowledge contributes for the understanding of the subjects for further studies.

1. **Identification of Research Problem**

The first step in the scientific method includes by the identification of the research problem with clear objectives. This step involves recognizing and clearly defining a problem or question that needs for certain investigations. A research problem usually arises from observations, practical difficulties, gaps in existing knowledge, and curiosity about a particular phenomenon, by clearly defining the research problem, one can determine the directions and scopes of works through the scientific methods for the entire research study

For this step, the researcher have to examine the area of interests carefully and identifying a specific issues and thus formulating a clear research question that can be studied systematically. A well-defined research problem helps in focuses for the investigation of problems and this ensures that the study remains relevant and manageable.

Example*:* A researcher have interested in the field of education he/she may identify the following problem as: Why do some students performs better in online learning environments as compared to the traditional classroom settings or environments?

2. **Review of Literature**

Once the research problem has been identified, the next step is for reviewing the existing literature. In this step the literature review involves examining previously published studies, such as books, articles, and reports related to this research topic. The purpose of reviewing literature is for understanding about what has already been studied for identifying existing theories, and thus determine gaps in existing knowledge, that require further investigation for avoid repetitive works. During this process, the researchers collects and analyzes information from reliable academic sources by reviewing literatures it helps researchers for refining their research questions for avoiding duplication of previous studies, and developing a strong theoretical foundation for their investigations.

***Example**:* In the above case of student' performance in online learning, the researcher may review a previous studies available on digital and online learning environments, by considering student motivation, teaching methods, and the effectiveness of online education over the classroom settings.

3. Formulation of Research Objectives or Hypotheses

After reviewing the literature, the researcher can proceeds to the formulation of research objectives or hypotheses**.** Research objectives describes the specific goals of work that the study aims to achieve at the end, while hypotheses are tentative statements that predicts the relationship between variables and these can be tested through research. The purpose of this step is for clearly defining what the researcher wants to investigate and what will be the outcomes. Thus, the well-defined objectives or hypotheses helps researchers guiding the research process and determining the type of data that needs to be collected.

***Example**:* A researcher studying over the internet or online learning may formulate an objective such that for examining the relationships between students engagement and academic performance for online classes**.** A possible hypothesis could be students who are actively participating in online discussions achieves higher academic performance than the passive students.

4. Research Design Selection

The next step in the scientific method is the selection of an appropriate research design. A research design refers to the overall plan or strategies used for conducting the study through several processes. It specifies how the data would be collected, what will be the methods, and how these variables will be measured and analyzed. The purpose of selecting a research design is ensuring the research problem that can be studied in a systematic and effective way. The different types of research designs include experimental research, survey research, case studies, and observational studies. The choice of design depends on the nature and work of the research problem and the type of information required. Figure 4, shows the steps involved in scientific methods.

Example: In the study of online learning performances, the researcher may choose a survey research design and collect the effective responses from the students about their study habits, participation levels, and towards academic results.

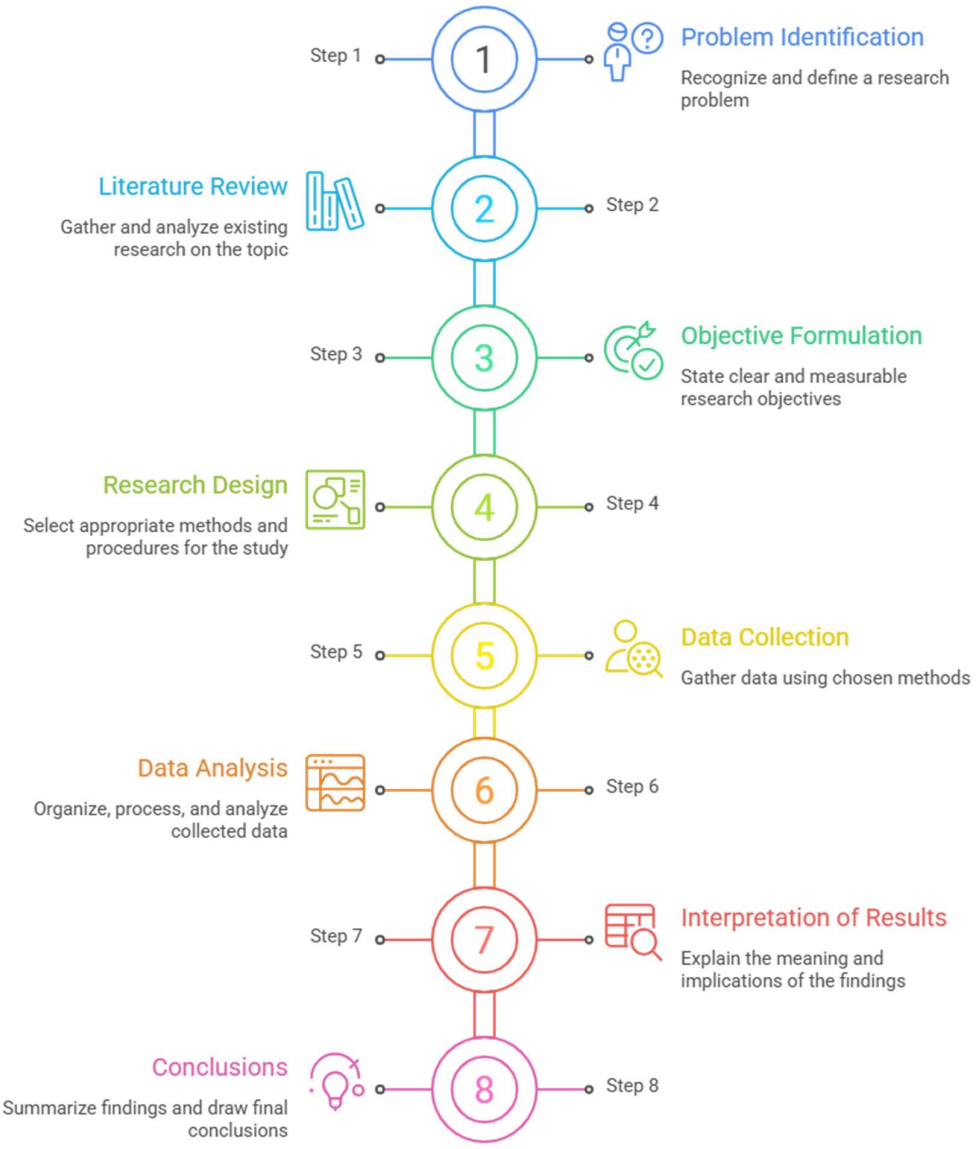


Figure 4: Steps involved in scientific research

5. Data Collection

After determining the research design, the next step is for data collection. This step involves gathering of relevant information needed for answering the research questions and tests the hypotheses accordingly. The data can be collected through various methods such as by surveys, interviews, questionnaires, and observations. The main purpose of data collection is for obtaining reliable and accurate information related for the research problems. Researchers must ensure that the data collection methods should be appropriate and the information gathered should be relevant to the objectives of the study.

***Example**:* In our online learning study, the researcher may divide the questionnaires to students by asking about their participations in online discussions, study times, and examination scores.

6. **Data Analysis**

After the data collection step, the next step is of data analyses, it analysis involves the processes of organizing, processing, and interpreting collected information for identifying patterns, relationships, or trends from the collected data. The researchers may use statistical methods, graphs, charts, or qualitative analysis techniques for examining data quality and accuracy. The purpose of data analysis is for transforming raw data into meaningful information which can helpful in answering the research questions or tests the hypotheses. The proper analysis of the data for certain or significant researches the responses should be analyzed with the context of qualitative and quantitative analysis for determining and making decisions and graphs over it.

Example: The researcher may analyze surveys, questionnaires, and responses for determining the student participation in online discussions may results for higher grades.

7. **Interpretation of Results**

The next step is of interpretation of results, which involves explaining the meaning of the findings and determining what they can reveal about the research problems. This step connects the results of the analysis with the research objectives or hypotheses. The purpose of interpretation is for understanding the implications of the research findings and this explain how they would contribute to existing knowledge. The researchers may also compare their findings with the previous studies for identifying similarities or differences between results and objectives.

Example: If the analysis shows that students engages more actively in online discussions and perform better in both terms of scientifically and academically, the researcher may interpret this as the core evidences of student' engagements that plays an important role in online learning success**.**

8. **Conclusion and Reporting**

The final step of the scientific method is drawing conclusions from the sreseach processes from data collection, analyses and interpretations. In this stage, the researcher summarizes the major results of the study via explaining their significance, and thus presents them in a clear and

organized manner. The research findings are usually documented at the end in the form of research reports, journal articles, dissertations, or presentations forms**.** The purpose of this step is for communicating or transferring the results of the research to other scholars, professionals, and stakeholders, so that they could start from that point. This reporting allows others for reviewing, verifying, and building upon the work, thereby contributes significantly to the overall advancements of knowledge.

Example*:* The researcher may prepare a detailed report by describing the study on online learning, including the research problem, methodologies, data analysis, findings, and recommendations used for improving the online education systems.

Thus, the steps of scientific method from identification of the research problem, literature reviews, hypotheses formulations, research design selection, data collection, data analysis, interpretation of results, and conclusion—forms a structured framework for conducting scientific researches. By following these steps carefully, the researchers can find the solutions of problems systematically and produces reliable knowledge while contributing to the academic and for professional fields.

Activity C

1. If a researcher is conducting surveys on student's satisfactions in online learning what steps he should follow for collecting reliable and valid data.

1.6 Importance of Objectivity in Research

In Scientific researchers, the objectivity is considered as one of the principles, that the research findings should be based on facts, evidence, and on logical analysis rather than just one's personal opinions or beliefs**.** In scientific studies, the researchers are expected to give true results for seeing problems in an impartial and unbiased manner so that the conclusions would be reliable and credible significantly. Without objectivity, the results of certain research might be misleading and can negatively affects the development of knowledge and decision-making processes, due to misleading or distorted results.

In simple terms, the objectivity refers to the ability of a researcher for remaining neutral and unbiased during the whole research process. An objective researcher examines the research problem carefully from collecting relevant data, analyzing information logically, and

presenting findings truthfully without allowing personal beliefs, feelings and preferences that can significantly influence overall results. The commitment is to give true and neutral results ensures that the research outcomes should reflect the actual situation rather than the researcher's expectations or assumptions.

1. **Accurate and Dependable knowledge**

Objectivity in research intends for giving accurate and dependable knowledge without seeing one's personal opinions, beliefs for influencing their work and the results may become unreliable. For example, if a researcher strongly believes in one particular theory he or she might be unintentionally select data that would supports the whole theory while ignoring information that would contradicts to it. Such practices can lead to incorrect conclusions and thus reduce, the credibility of the research. Maintaining objectivity helps preventing errors and thus ensures that research findings would be based solely on evidence.

2. **Avoidance of personal bias**

Another objective in research is that the research should be done by avoiding personal bias. The term bias refers for taking favors on certain ideas, perspectives, or outcomes based on one's personal beliefs, cultural background, or prior experiences. In scientific research, bias can occur during various stages such as while selecting for the research problem, data collections and analyses, while interpreting results, and presenting final conclusions. The researchers must remain vigilant and should adopt methods that would minimize bias in order to maintaining academic integrity.

3. **Systematic research methods**

Systematic research methods ensures the scientific methods include the objectives for the researchers for following clearly defined methods for data collection and analysis and the chances of personal biasness with influencing the results that to be reduced. For instance, the use of structured questionnaires, statistical analysis, and controlled datasets or variables including experiments can help ensuring the results includes on measurable data rather than just one's subjective judgments. Figure 5, shows the importance of objectives in research.

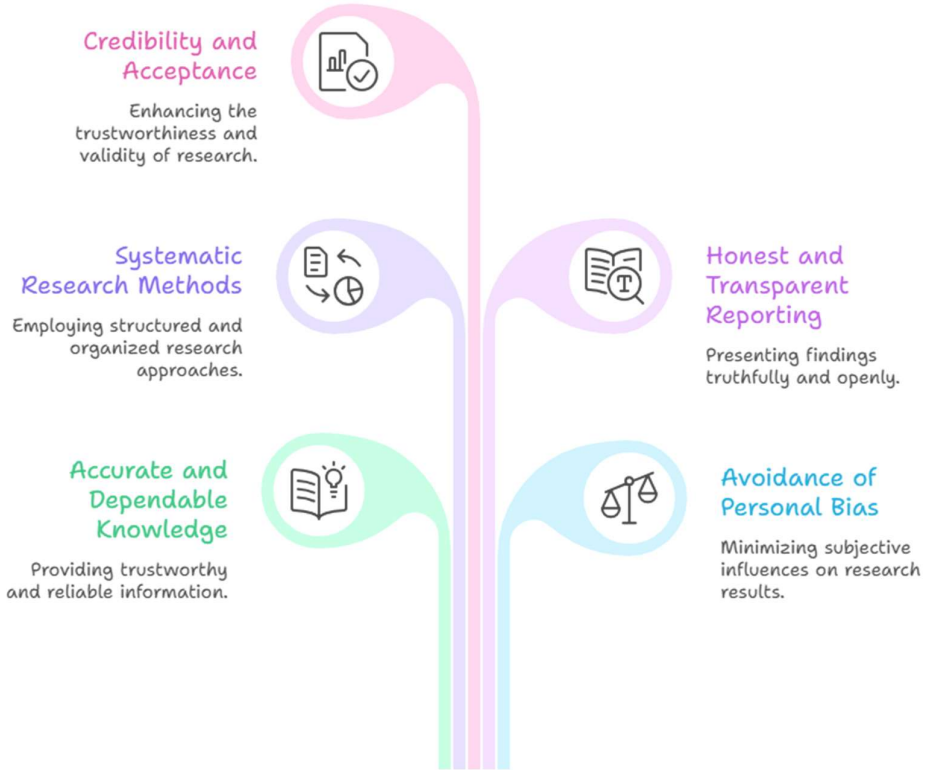


Figure 5: Importance of objectivity in Research

4. Report findings Honestly and Transparently

The researchers should report their findings honestly and transparently, even if the results does not gives as per expectations or hypotheses. The scientific research values the truth and accuracy above the personal preferences and therefore, the researchers must present the data exactly as it is and should provide a clear explanations of how the conclusions was reached from steps. The honest reporting helps other researchers for evaluating the study and replicating the findings, thereby it strengthens the reliability of scientific knowledge and availability.

The results should be on tactful and actual truth for the results in the field of education for example if a researchers conducted a study for comparing the effectiveness of online learning and traditional classroom learning**.** In this the biasness could be due to online learning if the researchers personally prefers it then the results would be biased and would try to give similar results. Thus the objective should be resulted even if it have same disadvantages, it should be reported correctly. Thus, for maintaining this objective ensures for conclusions must be based on evidences rather than personal preferences.

5. Credibility and acceptance of Research Findings

Objectivity also enhances the credibility and acceptance of research findings, like when researcher conducts a research objective, the other scholars and professionals are more likely to trust on the results and use them as a basis for further studies or enhancing studies for furthered practical applications. In contrast, research influenced by some bias may be questioned or rejected by the academic community. Therefore, the maintaining objectivity is essential for ensuring the validity and reliability of scientific research**.**

Thus, the objectivity is an important part of research which requires researchers for remaining neutral, avoid personal bias, and should rely on factual evidence while conducting investigations. By ensuring objectivity, the results should be based on accurate data and logical analysis, thus, objectivity helps producing trustworthy knowledge contributing to the academic progress and informed decision-makings.

1.7 Reliability in Research

Reliability is another important concept in the scientific research, due to it ensures that the results should be consistent and dependable on researchers**.** In simple terms, the reliability refers to the degree for which the research method should produces stable and consistent results over repeated observations or tests**.** If a research is reliable, the findings would remain similar even if the study is repeated with same conditions. This consistency increases the confidence in the accuracy and usefulness for the research results.

In research, the reliability means that the data should be collected reliably and with same accuracy and correctness and then this can be used for producing similar results each time, if it considered reliably. On the other hand, if the results change significantly without any real change such as datasets or variables changed, in the studies , the research method would be not be reliable. Therefore, maintaining reliability ensures that the research findings truly reflects the phenomenon being studied rather than just from random variations or measurement errors.

Reliability Strengthen the Credibility of Research Findings by ensuring that the results are consistent, other researchers and scholars can trust on the study and may use their findings for further investigations. The reliable research allows the studies to be replicated based on their methodologies which helps confirming the accuracies of the results. Without reliability, the research conclusions may become questionable and difficult to verifiable scientifically.

The reliable research Instruments and Tools should be considered with the instruments such as questionnaires, surveys, tests, and measurement devices. It should be carefully designed and tested for ensuring that they produces consistent results every time. If the questions for a survey will be unclear or not structured properly then the respondents may interpret or understand differently every time and this leads to inconsistent results. Therefore, the researchers must design the instruments to be clear, standardized, and appropriate for the study. Pilot testing is to testing of their instruments before conducting the full study, so that this result should be biased free and correct. This process may involve pilot testing, where the research tool is used and applied at a small group of participants for checking whether the results remain consistent or not. If necessary, the instrument is revised to improve accordingly for clarity and reliability before it is used for the main research.

To understand reliability more clearly and simply lets, consider an example education sector. Suppose a researcher wants to conduct a study for measuring students satisfaction with online learning then he should follow standard methods and if the process revised one could get the same results under similar conditions every time then it should provide the same responses consistently**.** If the responses vary for other areas without any real change in students' experiences, it may indicate that the survey instrument is not reliable and due to this it gives wrong answers.

This, the reliability in research refers for the consistency and stability of research results. This ensures that the research methods and instruments used for producing dependable outcomes should repeat the same results repeatedly. By using reliable measurement tools and maintaining consistent and procedures the same results thus, the researchers can increase the trustworthiness and accuracy of their studies.

1.8 Validity in Research

Validity is the process of verifying the research measurements. In simple terms, validity refers to whether a research method or instrument actually measures correctly whatever, it intended to measure**.** If a research study is valid, the data collected should represents the concepts or phenomenon being investigated. This ensures that the validity is essential because inaccurate measurements may lead to incorrect conclusions and this reduces the usefulness of the research.

In research, the term validity is closely related to the design of the research tools such as through questionnaires, surveys, tests, or experiments for the data collections. These

instruments must be carefully developed for the core process and it should capture the correct information about the research topic. If a measuring tool has been poorly designed, it may lead for collecting irrelevant or misleading data, which significantly affects the overall quality of the research findings. Therefore, the researchers must ensure that their methods and instruments would be appropriate for the whole objectives of the study.

Validity is often discussed along with reliability, but these concepts are not exactly the same, then these often differs by their actual meaning where the reliability refers to the consistency of measurements likewise if same methods produces the similar results on each repetition under similar conditions. Validity, on the other hand, refers to the accuracy of those measurements. A research instrument may produces the same consistent results (reliable) but still fail for measuring the intended concept (invalid). For example, a weighing scale can be consistent if it shows the wrong weights every time, it may be reliable because but may not valid because it does not measures the correct weight, so how one can say it a novel work.

1. **Content Validity**

The researchers often evaluates the different types of validity for ensuring selection of accurate and appropriate research instruments. Content validity refers for covering all relevant aspects of the concept being that to be studied. In other words, the questions or items included in a test or surveys should be adequately represents the topic accurately. For example, if a test has been designed for evaluating the knowledge of computer programming, the questions should include the important programming concepts rather than other unrelated topics.

2. **Construct Validity**

Construct validity refers about how well a research instruments measures a theoretical concept or constructs. There are many concepts studied in a research such as intelligence, motivation, or satisfaction that cannot be directly observed. The researchers therefore designs the questions that includes these concepts. Thus, the construct validity ensures that these indicators reflect the theoretical idea accurately that would be intended to measure. Figure 6, shows the research accuracy constraints such as content validity, construct validity and criterion validity.



Figure 6: Shows the research accuracy constraints

3. **Criterion Validity**

The criterion validity refers to the extent for which the results of a research instrument should correspond with another established measure at the same concept. In this case, the obtained results from a new test or method are to be compared with recognized standards and benchmarks. If the results are closely related, the new instrument would is considered valid to the used criterions. For example, in the field of education, for measuring the tests for the student's mathematical ability. The test or questions should focus on the mathematical reasoning, calculations, and their problem-solving skills. If the test questions would include complex language or comprehensive questions then the results would not be as consistent. These cases includes the tests that would lacks on validity because it does not gives answers accurately measures that to be intended.

1.9 Relationship between Objectivity, Reliability, and Validity

In scientific research the objectivity, reliability, and validity are the three closely related concepts helps ensuring accuracy with the quality and credibility to the research findings. Each of these concepts focuses on a different aspect of the research process, but they together contributes for producing trustworthy and meaningful results. Understanding the relationship

between these concepts helps the researchers for designing their studies ensuring both scientifically sound and reliable.

1. Objectivity

Objective refers the ability of a research for remaining constant and neutral without biased for conducting the research. The object helps the researchers for relies on certain factual evidences rather than just someone's personal opinions, preferences or expectations. This means that the researcher collects and analyzes data in an impartial manner and reports the results honestly and correctly. The objective for a research should be clear to avoid personal bias while collecting and analyzing data, which ensure for accurate conclusions. This helps the findings for reflecting the actual evidences rather than just one's own belief. Figure 7, shows the overview of relationships between these concepts with simple route statements.

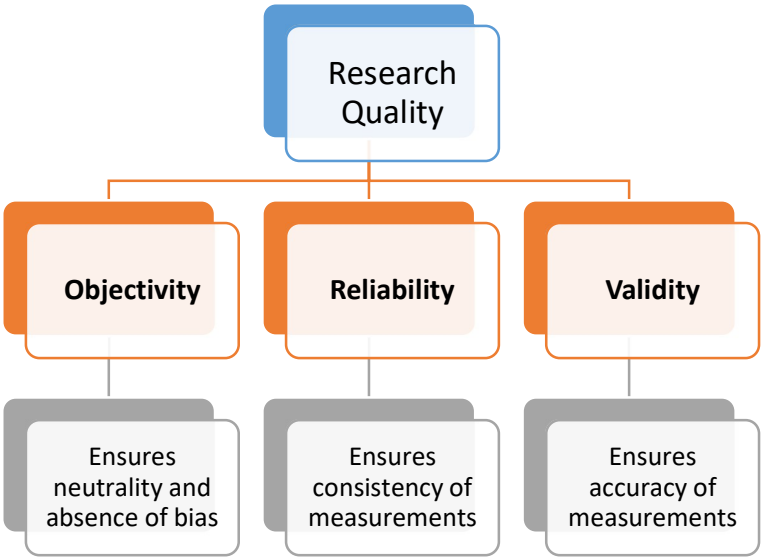


Figure 7: Shows the Research Quality Assurance with objectivity, reliability and validity.

2. Reliability

Reliability, refers to the consistent and stabled research results, it means selection of appropriate research method that would produce similar results if repeated with the same conditions. The reliability in research is important because the results should indicates that the research methods should be dependable. For example, if a questionnaire measures about student satisfactions produces the similar responses every time, with similar student's group at different times, then it can be considered reliable.

3. Validity

Validity refers to the accuracy of the research measures, like it helps in determining whether a research methods or instruments actually provides the intended results. A study may produce the consistent or same results, but if those results do not accurately represents the whole concept then the research lacks with validity. Therefore, the validity ensures that, the data should be collected truly while reflecting the research objectives and providing meaningful conclusions.

These three concepts are closely interconnected together for contributing to overall quality research.

"Objectivity" helps in eliminating "personal bias", "reliability" ensures that results should be consistent, and validity ensures that the measurements or selected methods would be accurate. When all three are maintained, the research findings become more credible and acceptable at the academic and scientific communities. Figure 8 shows the research credibility assurances including objectivity, reliability, and validity.

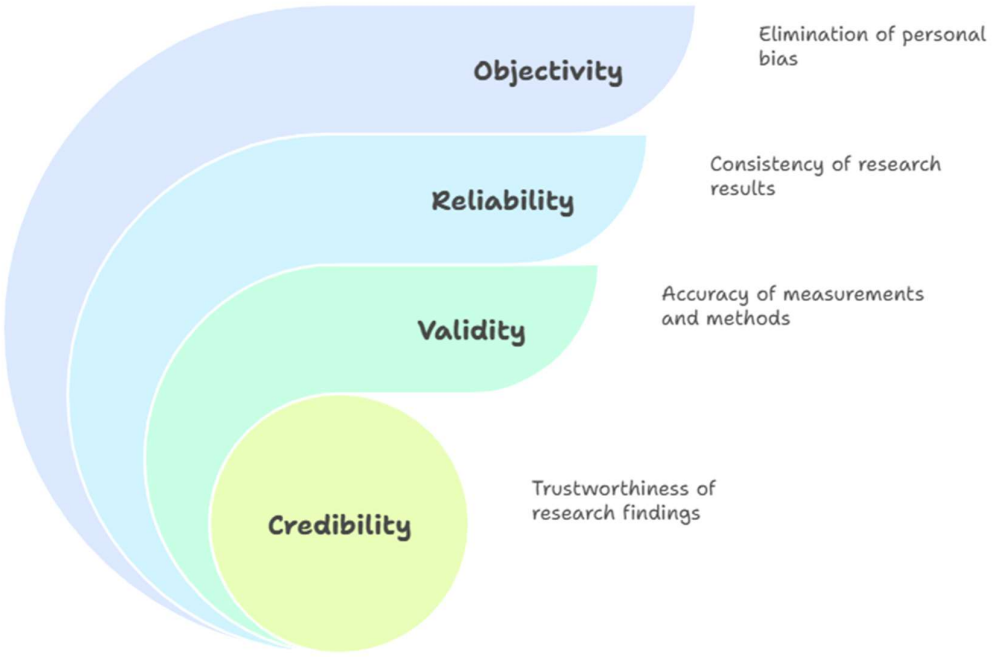


Figure 8: Shows the Research Credibility Assurance.

When the research is conducted while ensuring correct objective, it reduces the chances of biasness while affecting the results. The reliable research methods helps in ensuring that the

results remain consistent whenever it would be repeated. Valid research instruments ensures that the measurements has been accurately represent with their concept to being studied. Together, these principles helps the researcher for creating strong and trustworthy research outcomes that would contribute effectively to knowledge or developments of their theories and practical applications. Figure 9, shows the research credibility including reliability, validity, and neutrality.

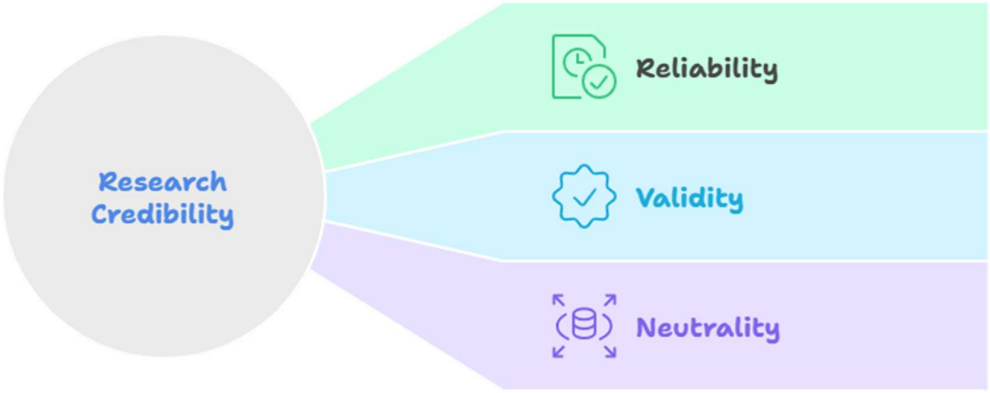


Figure 9: Unveiling the Dimensions of Research Credibility

For example, a study for measuring student satisfaction with online learning systems. If the researcher should remains neutral and does not uses its own personal intuitions, preferences while conducting the study. The research should produces similar results whenever it is repeated with similar group of students, this way demonstrates reliability. The survey questions also influences the accuracy measures with student' satisfaction rather than just through unrelated factors, this way it achieves validity. When these three conditions are met for a study, the research findings become more reliable and credible.

Activity D

1. Give an example of a measurement tool or questionnaire being used in research.
2. Explain why reliability and validity are important for ensuring accurate results.

1.10 Summary

This unit introduces the basic concepts of research, with meaning and introduction of research and defining scientific research and its principles. Research refers to a systematic search for knowledge, with the investigation of problems, exploration of questions, and development of solutions through organized inquiries. The term research implies repeated and carefully examinations for gaining deeper understanding and discovering of new knowledge. In this unit we have discussed the characteristics of scientific research, such as a research should follow systematic procedures, logical reasoning, empirical evidence, objectivity, precision, and replicability, which makes it different from ordinary inquiries. The scientific methods includes steps of identifying research problem, literature review, and formulating their hypotheses, then designs the research, by collecting and analyzing data, and then interprets conclusions. The unit also explains the importance of objectivity, reliability, and validity in research for ensures the research findings should be unbiased, consistent, and accurate. Together, these concepts contributes to the quality, credibility, and usefulness of research in advancing knowledge and supporting informed decision-making.

1.10 Self-Assessment Questions

1. Define research and importance of research.
2. Explain the scientific research and how is different from the ordinary inquiry?
3. Explain the major characteristics of scientific research. Why they are important for reliable research?
4. Explain the steps involved in scientific methods and their importance?
5. What is objectivity in research? Why it is important for scientific investigations?
6. Define reliability in research and their credibility of research findings?
7. Explain validity in scientific research? Differentiate between the reliability and validity with examples.
8. Discuss the relationship between objectivity, reliability, and validity in research.

1.11 Reference Books

1. C. R. Kothari and Gaurav Garg (2014); Research Methodology: Methods and Techniques; New Age International Publishers, 3rd Edition, New Delhi.
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7. Uma Sekaran and Roger Bougie (2016); Research Methods for Business: A Skill Building Approach; Wiley, 7th Edition.
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Unit 2 Types of Research

Structure of Unit

2.0 Objectives
2.1 Introduction
2.2 Meaning and Classification of Research
2.3 Basic and Applied Research
2.4 Quantitative and Qualitative Research
2.5 Exploratory Research
2.6 Descriptive and Explanatory Research
2.7 Longitudinal and Cross-Sectional Research
2.8 Correlational and Experimental Research Designs
2.9 Applications and Examples of Different Types of Research
2.10 Summary
2.11 Self-Assessment Questions
2.12 Reference Books

2.0 Objectives

After studying this unit, the learner will able to:

- Understand the concept and classification of research
- Distinguish between basic and applied research
- Explain quantitative and qualitative research
- Identify different research types based on purpose and design
- Understand correlational and experimental research designs
- Recognize the applications of different types of research

2.1 Introduction

Research is an essential activity in academic study and professional practice. It is a systematic process used for discovering new knowledge, understanding certain phenomena, and solving practical problems. In earlier discussions of research, it was explained that research involves a structured process including identification of problem, data collections, analyzing information, and thus drawing conclusions. As different situations the same research method would not be appropriate and may lead wrong results. The different research problems requires different approaches, methods, and techniques at studies. Because of this diversity the researchers classifies research into different types.

The classification of research helps the scholars and practitioners understanding the various approaches available for conducting a study. Each type of research has their purposes, methods of data collection, and analytical techniques. By categorizing research into types, it helps the researcher for selecting an appropriate research method for their study. For example, a researcher who wants to understand people's opinions may choose qualitative research methods, if wants to measure certain relationships on numerical data may choose quantitative research methodologies.

The research classification is also helps in organizing knowledge and improving clarity in research methodology. It allows the students and researchers for understanding the strengths and limitations of different research approaches. When researchers clearly identifies the type of research it becomes easier for designing the research study with selecting appropriate data collection tools, and interpreting the results accurately. Another reason for classifying research is the research activities that can be considered for different purposes. Some research aims for developing new theories or expand existing knowledge, while other research focuses on solving real-world problems. Similarly, some studies are conducted for exploring new areas with little available information is available, while others may attempt for describing or explaining the phenomena. Because of these different objectives, the research methods may vary significantly.

Therefore, by understanding the different types of research enables the researchers for selecting appropriate strategies for conducting studies and helps them for producing reliable and meaningful results. A clear understanding of research types also assists the students for designing their own research projects and evaluating the work of other researchers.

2.2 Meaning and Classification of Research

Research is a systematic process that is used for discovering new knowledge, examining existing theories, and solving the real-world practical problems. In different fields such as science, education, business, and social sciences, the researchers uses various methods and approaches for investigating problems. Because the research can be conducted in many different ways, it becomes necessary for organizing these approaches into meaningful categories. This process is known as classification of research which refers for grouping of research studies into different types based on certain criteria such as for the purpose of study, nature of the used data, and the objectives of the investigation with time dimension, and at last with the design of the research. Such classification helps the researchers for understanding the

various available approaches for conducting research and selecting the most appropriate methods for addressing any particular research problems. The different research problems requires different research strategies. For example, a researcher wants to develop new theoretical knowledge he/she may select different research method for solving practical problems. Similarly, the study that uses numerical data and statistical analysis would focuse on understanding human experiences or social behavior through observations and interviews. Therefore, this classification of research helps in selecting suitable and appropriate methods for data collection, analysis, and for interpretation. Another important reason for classifying the research is to providing a clear framework for understanding the diverse forms of the research conducted in academic and professional environments. By organizing research into different types the researchers can understand the characteristics, objectives, and applications of each approach, and helps in selecting appropriate research methodology at their research.

Research can be classified in several ways including based on purpose of study, nature of including data, research objectives, with time dimensions and based on research designs, these classification problem have explained below figure 1. Shows the classification of research types.

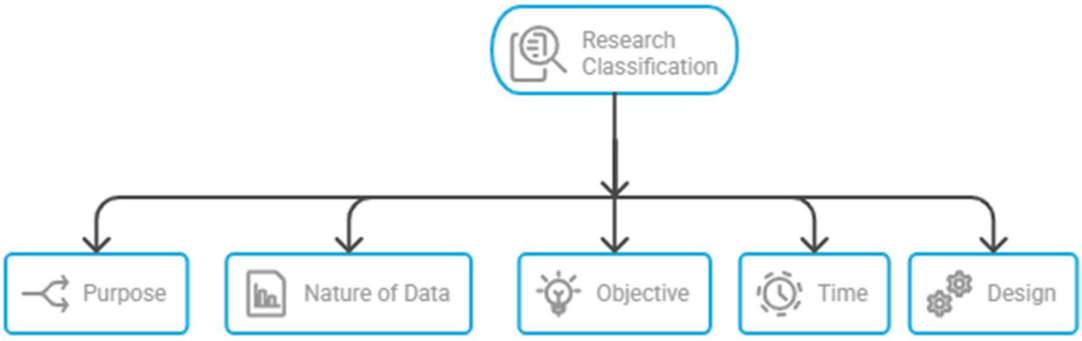


Figure 1. Classification of research

1. Classification Based on the Purpose of Research

The purpose of research indicates for selecting for certain objectives like for knowledge discovering by developing new theories or principles aiming for solving real world problems. In this classification, the research is divided into basic research and applied research.

a. **Basic research** focuses on extending the existing knowledge and develops on new theories and principles. It is primarily concerned with understanding the fundamental

concepts and their relationships without necessarily aiming at the immediate practical application.

b. **Applied research**, aims for solving the real-world practical problems. It applies the knowledge developing through basic research for addressing real-world issues in the fields such as in education, healthcare, engineering, and business.

This classification highlights the research methodology for selecting basis or applied research for studies and intended for increasing theoretical knowledge or solving the practical problems.

2. Classification Based on the Nature of Data

The nature of data categorizes the researchers into quantitative and qualitative research which includes the selection of research problems by focusing on numerical data or observations and experiences, has been categorized into quantitative and qualitative research.

a. **Quantitative research** includes the process of collection and analysis of numerical data. It often uses certain statistical methods for examining the relationships between variables and used for testing hypotheses and the research process involves collecting numerical data through, surveys, experiments, and with statistical studies for research.
b. **Qualitative research**, focuses on the non-numerical data including the questions of asking why certain event occur, like what were their intuitions or beliefs helps for understanding their experiences, opinions and their descriptions. It aims for understanding human behavior, attitudes, and social phenomena for the study of data collections including interviews, surveys and case studies and participates observations frequently for selecting the appropriate methods for numerical or interpretations of descriptive information.

3. Classification Based on Research Objectives

Research objective aims at understating of the objective and goals for the study based on the research objective and the research can be categorized based on research objectives into exploratory, descriptive and explanatory research.

a. **Exploratory research** is conducted when a research problem is not clearly defined or vary due to limited available information about any particular topic. The main goal is to explore ideas, gain insights, and identifying possible research directions.

b. **Descriptive research** aims for describing the characteristics of a population, situation, or certain phenomenon for answering questions such as what, where, when, and how.
c. **Explanatory research** explains the relationships between the variables and determines the cause-and-effect relationships.

The classification based on research objective helps the researchers for determining the depth and purposes of their investigation.

4. Classification Based on Time Dimension

The research classification based on the time dimensions for which the data should be collected from long time or for a certain event. For this perspective, the research is divided into longitudinal research and cross-sectional research studies.

a. **Longitudinal research** involves data collection for the same subjects over a long period of time. It is useful for studying the changes, trends, and developments over time.
b. **Cross-sectional research**, involves data collections at a single point of time. It provides a snapshot of certain situation or population at a particular moment.

This classification is particularly important in fields of sociology, education, and economics where the researchers studies certain patterns and the changes over time.

5. Classification Based on Research Design

The classification based on the research designs includes correlational and experimental research.

a. **Correlational research** examines the relationship between the two or more variables without manipulating or changing. It helps the researchers for determining whether the variables are related and about how strongly they are associated with each other.
b. **Experimental research** involves the deliberate manipulation of one or more variables for observing their effects on other variables. This type of research is often used for establish the cause-and-effect relationships.

This classification is important because it determines how the researchers would control the variables and tests hypotheses as well. Table 1, shows the major classifications of research with their types and key terms.

Table 1. Major Bases for Classification of Research

Basis	Types	Key Focus
Purpose	Basic / Applied	Theory vs Practical solution
Nature of Data	Quantitative / Qualitative	Numbers vs Words
Research Objective	Exploratory / Descriptive / Explanatory	Discovery / Description / Explanation
Time Dimension	Longitudinal / Cross-Sectional	Over time vs One point in time
Research Design	Correlational / Experimental	Association vs Cause-effect

Thus, the classification of research provides helps the researcher for selecting appropriate research methods and designing for effectively addressing the research questions. In the following sections, the major types of research will be discussed in detail while providing a deeper understanding of their characteristics and applications.

2.3 Basic and Applied Research

The research can be classified into basic and applied research based on their objectives and purposes. These research types plays an important role developing knowledge and in solving real-world problems. Although they may differ at their objectives, and may closely related and often complement for each other.

1. Basic Research

Basic research is also known as the fundamental or pure research it is conducted primarily for expanding knowledge and understanding of fundamental principles for the study. The main objective of the basic research is not for solving an immediate problems but also for increasing the scientific knowledge and developing new concepts that can improve our understanding various phenomena. This type of research focuses on discovering general laws, principles, or relationships for explaining the certain processes like how they would work. It involves theoretical investigations and experiments aiming for advancing knowledge at a particular field. Thus the results may not have immediate practical applications, but they helps for the

foundation for future studies and innovations. One of the important characteristic of basic research is that it is used for curiosity-driven approaches. The researchers conducts such studies because they want to understand how certain things work or why certain phenomena occurs. The knowledge generated by basic research contributes for the developments of new theories, models, and frameworks that helps later for the research.

For example, if a scientists studies the structure of atoms or their behavior for human memory, in this he is conducting basic research. These studies aims for understanding basic fundamental or working mechanisms rather than for solving specific problem. However, the knowledge obtained from such research may later contribute to technological, medical, or educational improvements. Basic research is particularly common for the fields such as in physics, chemistry, biology, mathematics, and social sciences, for the researchers to build theoretical foundations for understanding the natural and social phenomena.

Characteristics of Basic Research

The important characterizes of basic research includes:

- It aims for expanding existing knowledge and developing new theories.
- It focuses on fundamental principles and core concepts of literatures.
- It does not necessarily aiming for immediate practical application.
- It provides a foundation for further scientific investigations and research.
- It contributes for further development of new ideas and frameworks in various fields.

2. Applied Research

Applied research is conducted with the objective for solving specific practical problems or addressing the real-world issues. Unlike basic research that focuses on expanding theoretical knowledge, the applied research aims for using existing knowledge for finding solutions of practical challenges. Applied research involves for the practical application of theories, principles, and findings developed through basic research. Researchers in applied research attempts for developing new technologies while improving processes, and designing solutions that can be useful in industry, education, healthcare, and other sectors.

For example, research conducted for the development of new teaching method for improving student performance can be an example of applied research. Similarly, the studies aimed for developing new medicines, improving agricultural productivity, or designing efficient business strategies also falls under the applied research. It is widely used in the fields such as for engineering, medicine, business management, agriculture, and education, where the primary objective is for improving existing practices and solving practical problems.

Characteristics of Applied Research

The major characteristics of applied research includes:

- It focuses for solving practical and real-world problems.
- It applies existing theories and scientific knowledge at studies.
- It aims to producing useful and practical outcomes.
- It is often used for conducting a specific organizational or social contexts.
- The results of applied research are directly applicable for practices.

3. Relationship between Basic and Applied Research

The basic research and applied research although have different objectives, but they are closely related to each other. The basic research provides the theoretical foundation and knowledge base applied at research uses for developing practical solutions. In several case the discoveries made through basic research often leads for important technological and scientific advancements through the applied research.

For example, early scientific studies on electricity were included in basic research for understanding the electrical phenomena. Later, this knowledge was applied for the development of electrical devices, communication systems, and modern technologies. Figure 2 shows the relationships between the basic and applied research.

Thus, both basic and applied research are essential for scientific progress. The basic research contributes for the growth of knowledge, while applied research ensures that the knowledge is used to solving real-world problems and thus improves human life.

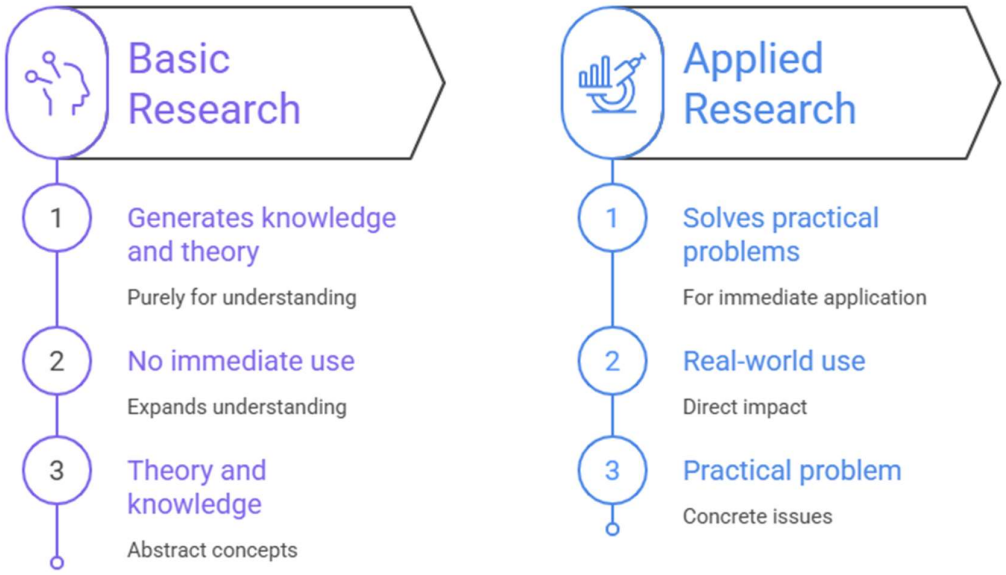


Figure 2. Relationships between basic and applied research

4. Differences between Basic and Applied Research

Although both the basic and applied research are interrelated to each other, but they are differ in several aspects. Some of the main differences are summarized below in Table 2. Shows the key differences of the basic and applied research.

Table 2. Key differences of Basic and Applied Research

Basis	**Basic Research**	**Applied Research**
Purpose	For development of new knowledge and theories	For solve the practical problems
Focus	Understanding fundamental principles	Applying knowledge for real situations
Application	No immediate practical use	Direct practical application
Outcome	Development of theories and concepts	Development of solutions and innovations

Thus, the basic and applied research represents two important approaches for scientific investigations. While basic research aims for expanding theoretical understanding, the applied research focuses on using that knowledge for addressing practical challenges. Both types of research are essential for advancing knowledge and promoting innovation at various fields.

Activity A

1. For the study of student's opinions regarding online learning, which type of research would be chosen from basic or applied research?

2.4 Quantitative and Qualitative Research

The qualitative and quantitative research are characterized based on the nature of data used for study. According to this classification, research is generally divided into quantitative and qualitative research. These two approaches differ in terms of the data collections, analysis methods, and purpose of investigations. These approaches are widely used in research with their aims on quality or accuracy of the results.

1. Quantitative Research

Quantitative research is a type of research that focuses on numerical data collection and using statistical approaches for the analysis. In this approach, the information is measured in terms of numbers and being analyzed using statistical techniques. The quantitative research aims for identifying patterns, relationships, or differences between variables and often involves testing hypotheses. In the quantitative research that data is collected through surveys, questionnaires, experiments, and statistical records then analyzed using mathematical or statistical methods for drawing conclusions. The quantitative research is used in fields of economics, science, psychology, and business studies, where the precise in measurement is important than the quality of the data.

For example, if a researcher wants to determine the student's performance for the students preferring online learning to the traditional classroom learning. The responses can be converted into numerical data collected through fixed questions and analyzed statistically for obtaining the meaningful results.

Characteristics of Quantitative Research

Some important characteristics of quantitative research include:

- It relies on numerical data and measurable variables.
- It uses statistical and mathematical techniques for data analysis.
- Data collection process includes structured and standardized processes.
- It often involves large sample sizes at studies.
- The results are usually presented in the form of tables, graphs, and statistical summaries.

2. Qualitative Research

In qualitative research, it focuses on understanding human experiences, opinions, behaviors, and social phenomena for determining why and how the people have behave like that. Instead of using numbers and statistical analysis, the qualitative research emphasizes detailed descriptions, interpretations, and explanations for understanding certain behaviors of individual benefits. In qualitative research, the data is being collected through interviews, observations, and focuses on group discussions, allows the researchers for gaining deeper insights from their attitudes, beliefs, and motivations.

For example, a researcher may take interviews or group discussions of the students for understanding their experiences and challenges in online learning platform**.** The responses can be analyzed by identifying certain themes, patterns, also with their intentions and beliefs over online learning.

The qualitative research is widely used in social sciences, education, sociology for the goal with understanding the complex human behavior and social interactions. The figure 3 shows the key differences between quantitative and qualitative research.

Characteristics of Qualitative Research

Some key characteristics of qualitative research includes:

- It focuses on descriptive and non-numerical data**.**
- It aims for understanding the meanings, experiences, and social processes**.**
- Data collection methods are usually open-ended and flexible.

- It often involves smaller sample sizes**.**
- The results of qualitative research are presented in the form of descriptions, interpretations, and themes**.**



Figure 3. Visualizes the key terms of quantitative and qualitative research

3. Difference between Quantitative and Qualitative Research

The quantitative and qualitative research are used for different tasks while focusing at understaning nature of data, methods of analysis, data collection and purposes.

Table 3. Key differences of Quantitative and Qualitative Research

Basis	**Quantitative Research**	**Qualitative Research**
Nature of data	Numerical data	Descriptive or textual data
Method of analysis	Statistical and mathematical analysis	Interpretation and thematic analysis
Data collection	Through surveys, questionnaires, experiments	Through interviews, observations, case studies
Purpose	Measuring variables and testing hypotheses	Understanding experiences and social phenomena

Thus the quantitative research focuses on measurements and statistical analysis, and the qualitative research focuses on understanding the meanings and their experiences. Both approaches are valuable in research, and in some studies the researchers combines them for obtaining a more comprehensive understanding of a research problem.

Activity B

1. For conducting a survey for understanding the individuals experience or beliefs on online learning which method would be chosen from qualitative and quantitative research?

2.5 Exploratory Research

Exploratory research is a type of research conducted used for knowledge gaining when there is a limited information available for a particular topic. The main objective is for gaining preliminary insights, develop ideas, and understanding the nature of a problem more clearly. It is often considered as the initial stage of the research process, where the researchers attempt for exploring at the problem and conducting more detailed and structured studies. In many situations, researchers does not have enough knowledge at certain problems. In such cases, it is difficult for designing a detailed research plan. For this the exploratory research helps the researchers for investigating over the topic broadly and identifying the important variables, and formulating their hypotheses. Therefore, this type of research focuses more on exploration and discovers rather than just providing final or conclusive answers.

“According to the objectives of research, the exploratory studies help gaining familiarity for certain phenomenon and achieves new insights (Kothari, 2022).” Exploratory research is particularly useful for the areas with limited studies where the researcher wants to understand the background of a problem before actual investigation. It helps in clarifying the concepts, identifying patterns, and suggesting new directions for future research.

For example, suppose a university has observed sudden dropout rates, so in such cases before conducting detailed research, it may be explored by discussing their problems through interviews, case studies and the results would be due to lack of motivation, ineffective teaching methodologies or may be other factors. By taking an appropriate actions over it, the university can solve this dropout issues.

1. Methods Used in Exploratory Research

The Exploratory research usually uses flexible and unstructured methods for data collection. Figure 4 shows the methods in exploratory research. Some common methods used in exploratory research includes:

- **Literature Review**

  The Researchers examine existing books, research papers, reports, and articles for understanding what already has been studied or investigated about the topic. This helps in identifying gaps in knowledge and helps for possible research directions.
- **Interviews**

  Researchers may conduct informal or semi-structured interviews with individuals who have knowledge or experience about the research problem. Interviews provides a valuable insights and perspectives at data collection.
- **Focus Group Discussions**

  In this method, a small group of participants discusses on a particular topic under the guidance of a moderator. This discussion helps in generating ideas and identifying different viewpoints.
- **Observation**

  Researchers observe behaviors, events, or situations directly in order to understanding certain phenomena like how does these work in real-life situations.

2. Characteristics of Exploratory Research

Some important characteristics of quantitative research includes:

- It focuses on exploring theories for new or unclear problems.
- It helps in generating ideas and hypotheses for further research.
- It uses flexible and open-ended research methods for explorations at research.
- It does not aims of providing final or conclusive results.
- It often serves as the foundation for more detailed research.

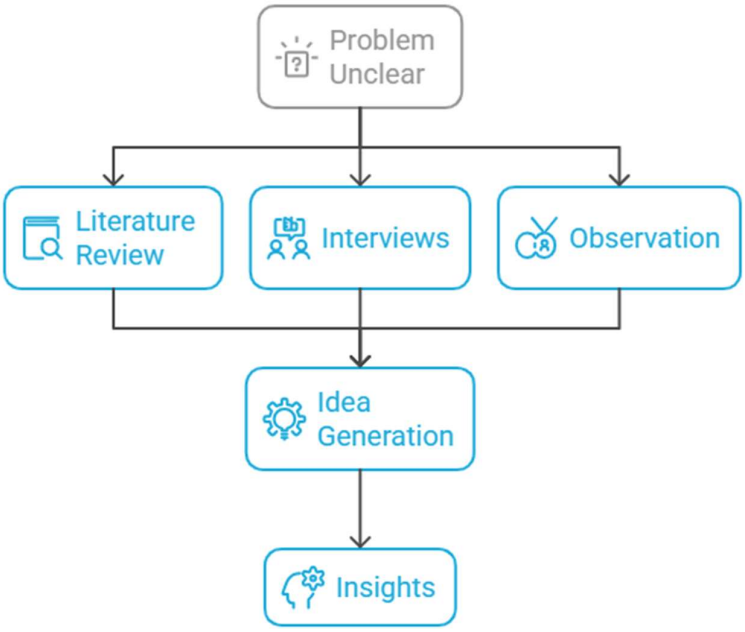


Figure 4. Exploratory research processes

Exploratory research is widely used for studding new trends, consumer behaviors and social issues in social sciences, marketing, education, and management. Thus, it provides initial insights on complex issues and exploratory research helps in guiding further research and supports for the development of more comprehensive studies.

Activity C

1. For a society or education problem, explain how the exploratory research could help the researchers for understating their issues better?

2.6 Descriptive and Explanatory Research

The research based on the objectives or goals, it is of two types including descriptive and explanatory research. These approaches helps the researcher for understanding certain phenomena, but they differ in their purpose and depth or level of analysis. While the descriptive research focuses on describing characteristics or conditions, the explanatory research attempts for explaining the relationships and causes behind those conditions.

1. Descriptive Research

The descriptive research aims for describing the characteristics of a population, situation, or phenomenon that is also called as ex post facto research. The main objective of this type of research is for providing an accurate and systematic description of certain events, people, or conditions as they exist. It answers the questions such as what, where, when, and how, but it does not usually explains why something happens.

In descriptive research, the researcher collects data of present situations and a clear picture for understanding the situation. This type of research does not attempt at manipulating variables or determining the cause-and-effect relationships. Instead, of it focuses on observing and documenting facts in a structured manner. The descriptive research is widely used for many fields such as education, social sciences, marketing, and business, for understanding the characteristics of a population or situation is important. The researchers often uses descriptive studies for analyzing certain patterns, trends, or distributions. Figure 5. Shows the key points of descriptive and explanatory research including the focusing term, observations with descriptions.

For example, a researcher may conduct a survey for determining the percentage of students preferring online learning compared to traditional classroom learning. The purpose of the study is to describe the preferences of students rather than for explaining the reasons behind those preferences.

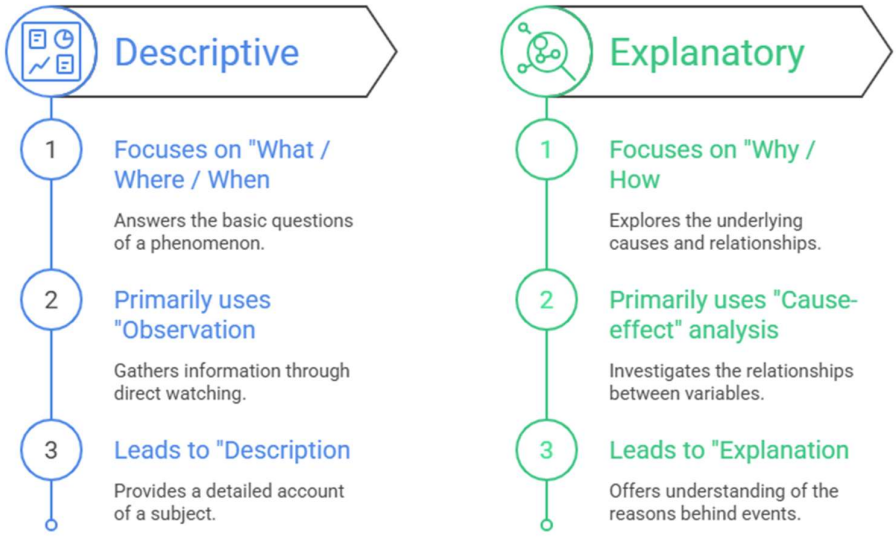


Figure 5. Descriptive and explanatory research: which fits your needs?

The common methods used in descriptive Research includes surveys and questionnaires, observational and case studies with the statistical data helps the researchers for collection and organizing information in a systematic way that represents the situation accurately.

Characteristics of Descriptive Research

Some important characteristics of descriptive research are:

- It provides systematic and accurate descriptions of certain phenomenon.
- It focuses on observing and documenting the facts.
- It answers the questions by asking what, where, and when.
- It does not attempt for determining the cause-and-effect relationships.
- It often uses structured data collection methods such as surveys.

2. **Explanatory Research**

Explanatory research goes beyond the description and focuses on explaining the reasons or causes behind a phenomenon. The main objective of explanatory research is for understanding the relationships between variables and then determining how one variable influences the other.

In this type of research, the researcher investigates why and how certain events occur. The explanatory research is often conducted after exploratory or descriptive studies have identified a problem or pattern. It attempts for providing a deeper insights by analyzing the cause-and-effect relationships.

For example, if a study shows that the students who spend more time on studying tend to achieve higher scores in exams, here the explanatory study may attempt for determining why the increased study time leads for better academic performance.

The explanatory research involves more structured research designs and may include the experiments, statistical analysis, and testing hypothesis. These methods helps the researchers for examining the relationships between variables and testing theoretical explanations.

Characteristics of Explanatory Research

Some key characteristics of explanatory research include:

- It focuses on explaining relationships between variables.
- It attempts for identifying the cause-and-effect relationships.
- It involves hypothesis testing and statistical analysis.
- It provides deeper understanding of certain phenomena.
- It works upon findings of exploratory and descriptive research.

3. Difference between Descriptive and Explanatory Research

The descriptive and exploratory research helps the researchers for understanding certain phenomena but they differs in their objective and approaches shown in table 4.

Table 4. Key differences of Descriptive and Explanatory research

Basis	**Descriptive Research**	**Explanatory Research**
Main purpose	To describe characteristics of a phenomenon	To explain causes and relationships
Research questions	What, where, when	Why and how
Focus	Observation and description	Cause-and-effect relationships
Methods	Surveys, observations, case studies	Experiments, statistical analysis

Thus, the descriptive research helps in understanding and documenting the characteristics of a situation and the explanatory research helps for explaining the underlying reasons and relationships influence those characteristics. Together, these approaches contributes for deeper understanding of research problems and supports the development of effective solutions.

2.7 Longitudinal and Cross-Sectional Research

The research based on time dimensions of data collection has classified into longitudinal and cross-sectional research. In many research problems, it is important for understanding whether the data is collected at a single point in time or over a long period of time. These two approaches

differ mainly in how data is collected over time and how the changes or patterns are studied for certain studies.

These types of research is important because these requires studying the changes over a period of time, while others requires observing a situation for a particular moment.

1. **Longitudinal Research**

The longitudinal research is a type of research that focuses on data collections for the same groups over a long period of time. The main objective of longitudinal research is for observing and analyzing the changes, developments, or trends that occurred over time. Figure 6. Shows the key differences in longitudinal and cross-sectional research types.

In longitudinal studies, the researchers repeatedly collect data from the same individuals, organizations, or groups for different time intervals. This allows the researcher for tracking how certain variables change and how these changes affect the whole subjects being studied. Because of this ability of observing developments over time, the longitudinal research is particularly useful in studies examining growth, behavioral changes for a long-term effects of certain factors.

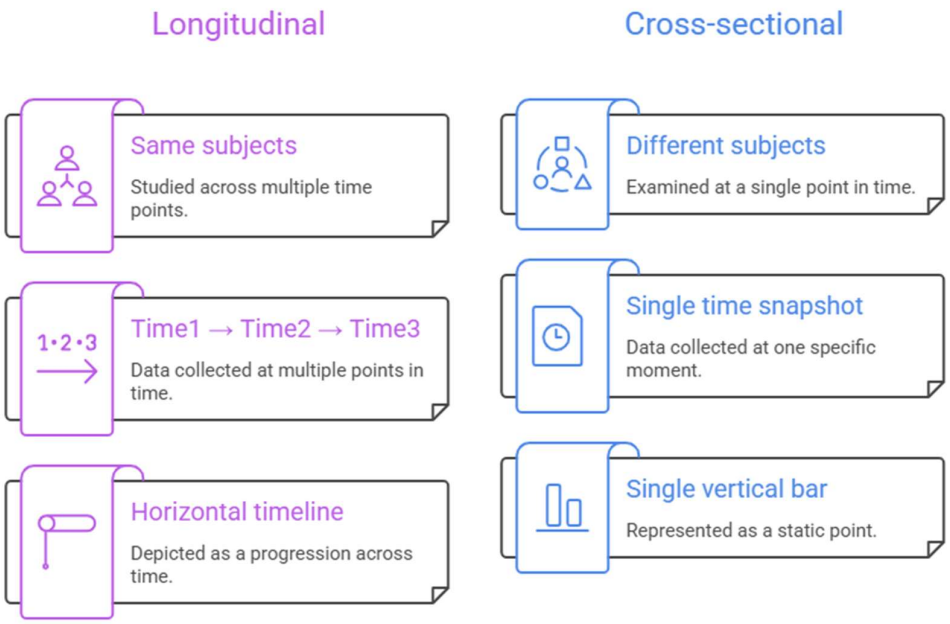


Figure 6. Key differences in longitudinal and cross-sectional research

For example, a researcher studying the academic progress of a group of students from primary school to university. In this study it can be started from data collections at different stages of their education, the researcher analyzes the factors influencing the study habits, teaching methods, or socio-economic conditions that influence their academic performance over time.

Longitudinal research is widely used in fields such for education, psychology, sociology, healthcare, and economics, where the researchers often need for examining the long-term changes and developments. The longitudinal studies may be further classified into trend studies, cohort and panel studies with analyzing changes and enhances experiences for group or panels.

Characteristics of Longitudinal Research

Some important characteristics of longitudinal research includes:

- It collects data over an extended period of time.
- The same subjects or groups are usually studied repeatedly.
- It helps in analyzing the trends, developments, and long-term effects.
- It provides detailed insights on changes in behavior or conditions over time.
- It requires more time, effort, and resources compared to other research methods.

The advantages of longitudinal research includes the study for the patterns, trends over a period of time and helps in understanding the long term relationships between variables, provides more accurate developmental changes, that helps in analyzing the cause-and-effect relationships more effectively.

Despite its advantages, the longitudinal research also has certain limitations like it requires data from a long period of time to complete the study, so may be expensive and resource intensive. The participants may drop out of the study over time that affect the results.

2. **Cross-Sectional Research**

The cross-sectional research is a type of research where the data is collected from a population or sample at a single point of time. Instead of studying the changes over a long period, the cross-sectional research provides a snapshot of a situation or phenomenon at a particular moment. In cross-sectional studies, the researchers gathers information from different individuals or groups simultaneously in order to examining the relationships between variables.

This method is widely used because it is relatively quick and cost-effective compared to the longitudinal research.

For example, if a researcher wants to conduct a survey among university students during one semester for determining satisfaction level with online learning platforms. The collected data would reflects the students' opinions at that particular time.

The cross-sectional research is commonly used for the fields such as in marketing research, social sciences, business studies, and public health, where researchers need for understanding current conditions or attitudes within a population.

Characteristics of Cross-Sectional Research

Some key characteristics of cross-sectional research includes:

- Data is collected at a single point in time.
- It provides a snapshot of a population or situation.
- It often involves large samples from different groups.
- It is faster and less expensive compared to the longitudinal studies.
- It focuses on analyzing the relationships between variables at a specific moment.

The cross-section research includes several advantages such as for studying for a certain point of time requires few resources and lower costs. It allows the researchers for studying multiple variables simultaneously and thus it is suitable for large population studies.

The Cross-Sectional Research includes the limitations such as the lack of changes over time and so this cannot stablish the cause-and-effect relationships. Thus, the results represents for only a specific period of time.

3. Difference between Longitudinal and Cross-Sectional Research

The main differences between longitudinal and cross-sectional research includes the time dimensions and purposes shown in table 5.

Table 5. Key differences of longitudinal and Cross-Sectional research

Basis	**Longitudinal Research**	**Cross-Sectional Research**

Time dimension	Data collected over a long period	Data collected at one point of time
Purpose	To study changes and trends	To study current conditions
Data collection	Repeated observations	Single observation
Time required	Long-term study	Short-term study
Example	Tracking student progress for several years	Survey of student opinions in one semester

Thus, both the longitudinal and cross-sectional research approaches are important for research methodology. Longitudinal research is useful when the researchers wants to study changes and developments over the time and the cross-sectional research is suitable for examining current situations or relationships. The selection is based on their approaches with research objectives, available resources, and the nature of the research problem.

2.8 Correlational and Experimental Research Designs

The research based on designing methodology can be classified into correlational and experimental research designs. The research design provides a structured plan for guiding the data collections, analysis, and interpretations.

These two designs differ mainly in the way of handling the variables, the correlational research focuses on identifying the relationships between the variables without manipulating them, and the experimental research involves continuously manipulating one variable for observing its effect on another variable. These research designs helps the researchers for selecting an appropriate methods for studying the cause-and-effect relationships and patterns in data.

1. Correlational Research

The correlational research is a type of research design used for examining the relationships between two or more variables. The main objective of this approach is for determining the relationship between variables and this measures the strength and direction of that relationship. In correlational research, the researcher does not manipulate or control the variables being studied. Instead, of this measures the variables are observed as they naturally occur.

This research type is commonly used when it is difficult, or impractical for manipulating the variables experimentally. The researchers can identify patterns and associations by analyzing the change in variables and provides useful insights for the phenomenon. Figure shows the key points in correlational and experimental research.

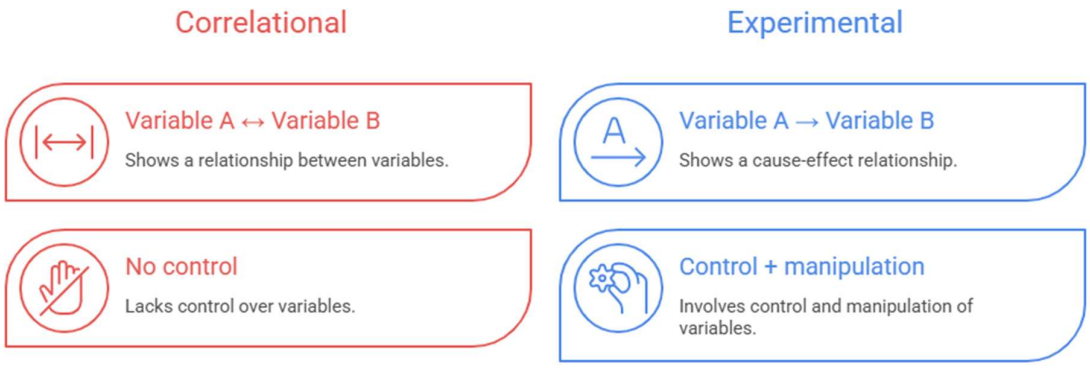


Figure 7. Key differences in Correlation and Experimental research

For example, if a researcher may study the relationship for the amount of time students spends on studying and their academic performance and by collecting data on study hours and exam scores, the researcher can analyze whether the students who studies more on tend achieves higher scores. If a positive relationship is found then it suggests like increased study time is associated with better academic results.

The correlational research does not establishes a cause-and-effect relationship. Instead, it only indicates that how the variables are related one another. For example, if two variables shows a strong relationships, it does not necessarily mean that one variable causes the other. There may be other factors influencing both variables in same manner. The researchers often uses statistical methods such as for correlation coefficients for measure the strengths and direction of relationships between the variables. A positive correlation indicates that both the variables increases and decreases together, with a negative correlation indicating that as one variable increases, the other decreases.

The correlational research is widely used in the fields such as for psychology, education, economics, business, and social sciences, where the researchers often studies the relationships between different factors.

2. Experimental Research

The experimental research is a research design used for examine the cause-and-effect relationships between variables. In this approach, the researcher continuously manipulates one variable, known as the independent variable, for observing its effect on another variable, known as the dependent variable. By controlling other factors that may influences the outcome, the experimental research allows the researchers in determining the changes in one variable directly cause in another. Experimental research typically involves a structured and controlled environment. The participants in an experiment are often divided into two groups: a control group and an experimental group. The experimental group is exposed the treatment, while the control group does not receives any treatments. At the end, by comparing the results, determines the effect of the independent variable.

For example, a researcher may conduct an experiment for testing a medicines effectiveness. The treatments should be given to one group while another group does not receives any treatments so after a certain period of time, if there are significantly changes shown then it would be selected.

The experimental research is widely used for scientific fields such as in medicine, psychology, education, and natural sciences because this allows the researchers for testing their hypotheses and establishing the causal relationships. This type of research requires careful planning, control of variables, and precise measurement techniques for ensuring accurate results. One important feature of experimental research is the control of external variables. The researchers attempt for keeping all conditions constant except for the independent variable that is being tested. This helps ensuring observed changes in the dependent variable caused by the experimental treatment rather than by other factors.

3. Difference between Correlational and Experimental Research

- Although both the correlational and experimental research designs are being used for study the relationships between variables and the factors they differ significantly at their approach and objectives. The correlational research focuses on identifying associations and relationships between the variables without manipulating them, while the experimental research involves deliberating or manipulation of variables in order to determining the cause-and-effect relationships.

- Another important difference lies in the level of control exercised by the researcher. In correlational research, the researcher observes the variables and the research why they occur naturally, whereas in experimental research the researcher actively controls and manipulates the conditions.

In addition, the correlational research is often used when the experiments are not possible or practical, but the experimental research is used when researchers want to test specific hypotheses and determining the causal relationships under the controlled conditions.

Thus, both correlational and experimental research designs plays a significant roles at the field of research methodology. Correlational research helps the researchers for understanding how certain variables are related together and experimental research allows them for determining whether one variable directly influences the other. Together, these research designs contributes at the developments of scientific knowledge by providing insights at patterns, relationships, and causal mechanisms for various fields of study.

Activity D

1. If a researcher wants to study the relationship between two factors study time and exam performance. Explain the type of research being used from correlational research or experimental research.

2.9 Applications and Examples of Different Types of Research

Research plays an important role for generating knowledge and solving the real-world problems in different fields of studies. The various types of research are not only theoretical concepts but are widely applied in the practical situations across different disciplines such as in education, healthcare, business, and social sciences. Each type of research serves as a specific purpose and thus helps the researchers for addressing different kinds of research questions. By understanding these research types helps the researchers to select an appropriate one at their studies. Figure 8 visualizes the applications areas of different types of research.

1. In **education** field there are different types of research used for improving the teaching methods, learning environments, and student outcomes. For instance, applied research is often conducted for developing the effective teaching strategies or evaluating the effectiveness of new educational technologies. A study examining whether the digital

learning platforms improves the student' engagement would be an example of applied research. Similarly, the descriptive research is commonly used in education for analyzing student performance, learning patterns, or classroom behavior. Researchers may conduct surveys for describing students' attitudes toward online learning or identifying the factors affecting academic success. For example at NEP 2020 the evaluation studies includes applied + descriptive research, UPI adoption research uses the correlational + quantitative research, and Ayushman Bharat uses experimental or longitudinal research types.

2. In **healthcare and medicines**, the research is essential for developing new treatments and improving patient care. The experimental research is frequently used for testing new drugs, medical procedures, or treatment methods. For example, the clinical trials are conducted for determining whether a new medicine is effective and safe for patients. At the same time, correlational research may be used for examining the relationships between health-related factors, such as for the relationship between lifestyle habits and the risk of certain diseases. These studies helps the healthcare professionals for understanding patterns and developing preventive strategies.
3. In **business and management**, the research helps the organizations for making informed decisions and improving their operations. Businesses often uses the descriptive research for analyzing consumer behaviors, market trends, and satisfaction levels. For example, if a company may conduct surveys for understanding the customer' preferences for a particular product. In addition, the exploratory research is often used at the early stages of product development for exploring the consumer' needs and identifying the potential market opportunities. This type of research helps the businesses for generating the ideas and plan for future strategies.

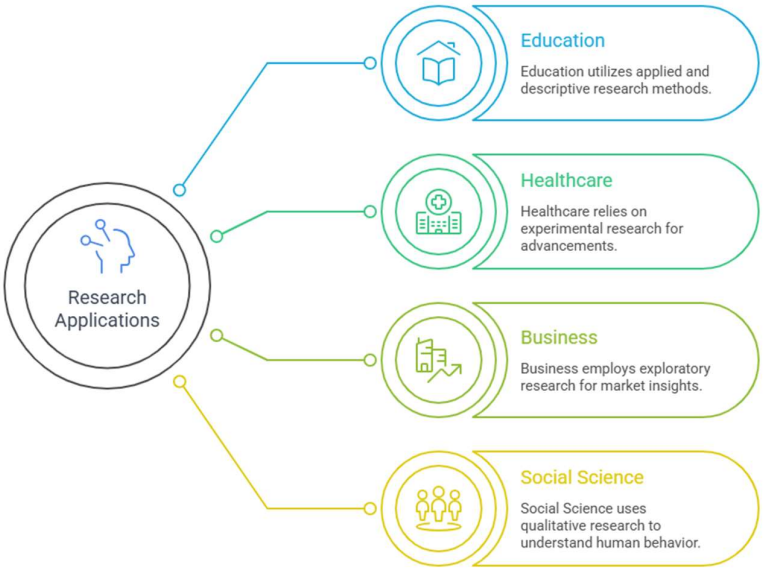


Figure 8. Unveiling Research Applications across multiple disciplines

4. In **social sciences**, the researchers frequently uses qualitative research for understanding the social behaviors, cultural practices, and human experiences. In qualitative research they focuses on interviews group discussions and case studies for understanding complex social issues in depth. For example, the qualitative research may be conducted for understanding the challenges faced by rural communities in accessing education or healthcare services. Such studies provide a valuable insights into social problems and help policymakers for designing appropriate interventions.
5. Similarly, the quantitative research is widely used in the fields such as for **economics**, **sociology**, and **public policy** for analyzing the statistical data and measuring the relationships. The governments and organizations often conduct large-scale surveys for numerical data collect on the issues of employment, income levels, or population growth. The results of such studies helps in planning the development programs and making policy decisions.

The selection of appropriate research types is important for the researchers for moving significantly deeper. For instance, if a researcher may first conduct exploratory research for identifying the key issues and then use descriptive research for gathering detailed information about those issues, and finally apply experimental research for testing possible solutions or hypothesis. The combination of such approaches allows the researchers for developing a more comprehensive understanding of complex problems.

2.10 Summary

In this unit, the different types of research have been discussed based on the purpose, data, objectives, and time dimensions. The unit explains the theories of basic research that focuses on developing new knowledge and theories, and applied research, which aims for solving practical problems. It also described the two major research approaches for data collection such as: quantitative research, that uses numerical data and statistical analysis, and qualitative research, focuses on understanding individual's experiences, opinions, and behaviors through non-numerical data. The unit further introduced exploratory research, used for investigating new or unclear problems, the descriptive research, that describes characteristics of a phenomenon, and explanatory research for explaining the relationships between variables. In addition, the unit explained longitudinal and cross-sectional research based on the time dimension of data collection, and correlational and experimental research designs used for the study with their cause-and-effect situations. Overall, the unit provides a clear understanding of different research types used in various fields for investigating the problems and generating meaningful knowledge.

2.11 Self-Assessment Questions

9. Explain the need of classification of research?
10. Define basic research and applied research with suitable examples.
11. Explain the concepts of quantitative research and qualitative research?
12. What is exploratory research? Discuss its objectives and importance at a study.
13. Explain the concept of descriptive research with its characteristics?
14. What is explanatory research? How does it help the researchers in understanding relationships between variables?
15. Explain the longitudinal and cross-sectional research with characteristics?
16. Explain correlational research for studying the relationships between variables.
17. Explain the experimental research designs and the cause-and-effect relationships.
18. Discuss the applications of different types of research in fields of education, healthcare, business, and social sciences.

2.12 Reference Books

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13. C. R. Kothari and Gaurav Garg (2014); Research Methodology: Methods and Techniques; New Age International Publishers, 3rd Edition, New Delhi.
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15. John W. Creswell (2014); Research Design: Qualitative, Quantitative, and Mixed Methods Approaches; SAGE Publications, 4th Edition.
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Unit-03: Reference Formatives Indexing, Citations, Impact Factor, H-Index

Structure of Unit

3.0 Objective
3.1 Introduction
3.2 Concept of References and Citations
3.3 The Importance of Citations in Mathematical Research
3.4 Referencing Styles in Academic Writing
3.5 Tools for Referencing and Citation Management
3.6 Managing Bibliographies Effectively
3.7 Research Metrics and Their Importance
3.8 Indexing and Abstracting Databases
3.9 Ethical Issues in Citation and Indexing
3.10 Summary
3.11 Self-Learning Exercise
3.12 Exercises
3.13 References

3.0 Objective

This chapter aims to introduce postgraduate students to the fundamental principles of scholarly referencing, citation practices, and research evaluation. It seeks to develop an understanding of major referencing styles, bibliographic management tools, citation ethics, and commonly used research metrics such as impact factor and h-index. Furthermore, it familiarizes students with key indexing databases, helping them identify reliable research sources and make informed decisions in academic publishing.

3.1 Introduction

Research methodology is the backbone of academic inquiry, especially in mathematics, where precision, clarity, and reliability are paramount. Research in science, particularly in mathematics, like all scientific disciplines, is a cumulative and collaborative endeavor. Every new theorem, model, or algorithm builds upon previous ideas, methods, and results. Therefore, proper referencing and citation practices are not merely formal requirements but essential components of academic integrity, scholarly communication, and research evaluation. For postgraduate students, especially at the M.Sc. level, a clear understanding of references, citation styles, bibliographic tools, indexing systems, and research impact metrics is crucial.

This chapter provides a comprehensive discussion of references, citation formats, bibliographic management tools, indexing databases, and commonly used research metrics, such as the impact factor, h-index, and i10-index. This chapter aims to equip students with both the conceptual understanding and practical skills necessary for writing dissertations, research papers, theses, projects, and grant proposals in mathematics and interdisciplinary fields.

3.2 Concept of References and Citations

3.2.1 What is a Reference?

A reference is a detailed description of the source of information used in a work. In academic writing, references typically appear in a reference list or bibliography at the end of a paper, dissertation, thesis, or book chapter. Each reference provides enough information for readers to identify the original source and find more information about it.
In mathematics, references typically include:

- Research journal articles
- Books and monographs
- Theses and dissertations
- Conference proceedings
- Preprints (e.g., arXiv papers, HAL)
- Technical reports

3.2.2 What is a Citation?

A citation is an acknowledgment within the text that indicates that a particular definition, idea, theorem, result, lemma, or data has been taken from an external source. Citations

connect the main text of a research work to the corresponding references provided at the end.

Types:

- In-text citations: Brief references within the main body of the text.
- Footnotes/Endnotes: Detailed notes at the bottom of the page or at the end of the document.

For example, when a researcher uses a well-known result, such as Taylor's theorem, or refers to a numerical scheme developed by another author, it is essential to cite the source appropriately.

3.2.3 Difference Between References and Citations

Aspect	Citation	Reference
Purpose	Acknowledge the source at the point of use	Provide full source details
Location	Within the text	End of the document/page
Format	Short form (author–year or number)	Complete bibliographic entry

3.3 The Importance of Citations in Mathematical Research

3.3.1 Academic Integrity and Avoiding Plagiarism

Plagiarism is the act of using someone else's work, ideas, or expressions without proper attribution. Proper citation is the most crucial way to avoid plagiarism. This is necessary even if the ideas are paraphrased or the mathematical results are presented using different notation or symbols.

3.3.2 Establishing Credibility and Scholarly Context

Citations demonstrate that the researcher is familiar with the existing literature and that their work is situated within a broader research context. In mathematics, this is particularly important when proposing new models, generalizations, or numerical methods.

3.3.3 Acknowledging Intellectual Contributions

Mathematical research often progresses incrementally. Citations ensure that original contributors receive due credit for their work.

3.3.4 Facilitating Verification and Reproducibility

Citations allow readers to consult the sources to verify the evidence, assumptions, and methodology. This is essential for the reproducibility and verification of results.

3.4 Referencing Styles in Academic Writing

Academic writing requires a systematic, standardized method for identifying sources of information. These standardized systems are called referencing styles. A referencing style dictates how citations appear in the text and how the full bibliographic details are presented in the reference list or bibliography.

Different academic disciplines and scholarly journals prescribe different referencing styles based on disciplinary traditions, readability, and technical requirements. In mathematics and interdisciplinary research, both author-date systems and numeric citation systems are commonly used. This section discusses the main referencing styles relevant to mathematical research.

3.4.1 MLA (Modern Language Association) Style

MLA style is not commonly used in core mathematical research. However, it may be found in the history of mathematics, philosophy of mathematics, and mathematics education research, particularly when the work has a strong humanities component.

In-text citation format:

- (Smith 45)

Here, “45” indicates the page number from which the material was taken.

Characteristics of the reference list:

- Emphasis on the author's name and page number.
- The year of publication appears later in the reference entry.
- Journal names are in italics.

3.4.2 APA (American Psychological Association) Style

The APA referencing style is widely used in the social sciences, but it is also frequently adopted in interdisciplinary mathematical research, particularly in applied mathematics, statistics, mathematical education, and computational social science. APA follows an author-year citation system, allowing readers to quickly identify both the contributor and the recency of the cited work.

In-text citation (author–year):

- Single author: (Smith, 2020)
- Two authors: (Smith & Jones, 2021)
- Multiple authors: (Smith et al., 2022)

Characteristics of the reference list:

- Publication year follows the author's name
- Titles are written in sentence case
- Journal names and volume numbers are in italics

The APA style is valued for its clarity and is particularly suitable for research involving surveys, modeling studies, and educational data analysis.

3.4.3 Chicago Style

The Chicago referencing style is very flexible and offers two citation systems:

1. Author-Date System
2. Notes and Bibliography System

The author-date system is sometimes preferred, especially in applied mathematics and interdisciplinary publications.

Key Features

- It allows for both footnote-based and in-text citation systems.
- Suitable for monographs, edited volumes, and extensive studies.
- Many publishers prefer this style for lengthy research books.

3.4.4 Harvard Referencing Style

The Harvard referencing style is widely used in the United Kingdom, Australia, and parts of Europe. Harvard style is commonly used in mathematics, statistics, and interdisciplinary modeling research. It uses the author-date referencing system and is quite similar to APA style, though it allows for greater institutional variation.

Characteristics of the reference list:

- References are arranged alphabetically by the author's surname.
- The year of publication follows the author's name.
- Titles are in sentence case.
- Journal titles are in italics.

3.4.5 Vancouver Referencing Style

The Vancouver referencing style is a numeric citation system initially developed for medical and health sciences. It is increasingly used in interdisciplinary scientific research.

Characteristics of the reference list:

- References are numbered in the order in which they appear in the text.
- Author's initials are given without any punctuation.
- Journal titles are in sentence case.

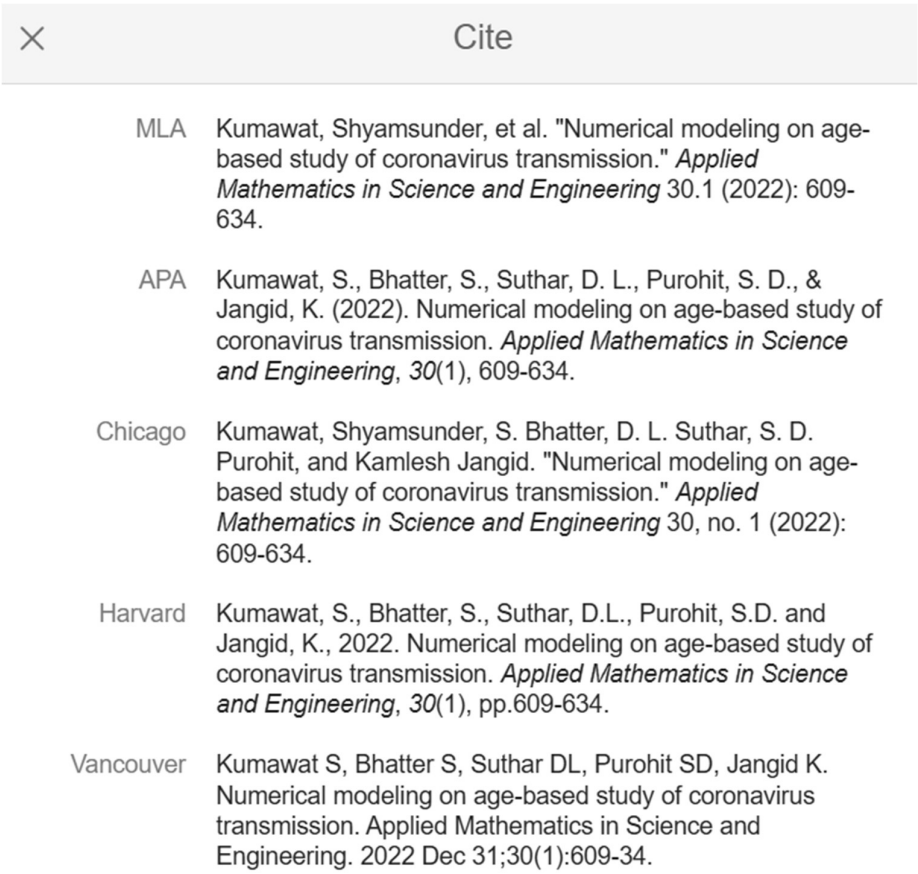


Table: Comparison of Major Referencing Styles

Feature	APA	MLA	Chicago	Vancouver	Harvard
Main consideration	Date	Author	Author	Order of appearance	Author & Date
Footnotes / Endnotes	Not used	Not used	Used (Notes–Bibliography system)	Not used	Not used
Order of sources	Alphabetical by author	Alphabetical by author	Alphabetical by author	Numbered in order of citation	Alphabetical by author
Author name format	Last name, initials	Full first & last name	Full first & last name	Last name, initials	Last name, initials

Use of "and" for multiple authors	Uses "&"	Uses "and"	Uses "and"	Not used in-text	Uses "and"
In-text citation format	(Author, Year, Page)	(Author Page)	Superscript number or (Author Year)	Superscript or [Number]	Author (Year) or (Author, Year)

3.4.5 Choosing the Right Referencing Style

The choice of referencing style depends on several factors:

- Journal or publisher guidelines
- Discipline-specific conventions
- Institutional requirements for theses and dissertations

3.5 Tools for Referencing and Citation Management

In large research projects such as theses, dissertations, and journal articles, managing references manually is complex and error-prone. Reference management tools (also known as citation managers) help researchers systematically collect, organize, annotate, cite, and format references in accordance with various academic styles (APA, MLA, Chicago, Harvard, Vancouver, etc.).

These tools significantly reduce the workload, improve accuracy, and ensure compliance with journal and institutional guidelines.

3.5.1 EndNote

EndNote is a commercial, full-featured reference management software widely used in universities and research institutions, particularly in science, engineering, and medical research.

Key Features

- Creation and management of large personal reference libraries
- Advanced citation and bibliography formatting
- Direct integration with Microsoft Word and Google Docs
- Support for thousands of journal-specific citation styles
- Built-in PDF annotation and full-text searching

Advantages

- Highly customizable and powerful
- Suitable for large-scale and long-term research projects

Disadvantages

- Paid software
- Takes more time to learn compared to other tools

3.5.2 Zotero

Zotero is a free, open-source reference manager that is very popular among students and early-career researchers.

Key Features

- One-click reference capture using a browser extension
- PDF storage and annotation
- Robust support for LaTeX, Microsoft Word, and Google Docs
- Group libraries for collaboration

Advantages

- Free and open-source
- Easy to learn and use
- Excellent for diverse and interdisciplinary sources

Disadvantages

- Limited free cloud storage
- Performance may be slow for extensive libraries

3.5.3 Mendeley

Mendeley is a reference manager and academic social networking platform, originally popular for sharing and discovering research papers.

Key Features

- PDF management, highlighting, and annotation
- Microsoft Word citation plugin
- Cloud storage (larger free storage than Zotero)
- Reference organization via folders and tags

Advantages

- Robust PDF organization
- Simple interface for beginners
- Useful for collaborative projects

Disadvantages

- No Google Docs integration
- Development activity has decreased in recent years

3.5.4 Paperpile

Paperpile is a web-based reference manager specifically designed to work within the Google ecosystem.

Key Features

- Stores references and PDFs directly in Google Drive
- Easy citation insertion in Google Docs
- Folder-based and label-based organization
- Browser-based interface with offline functionality

Advantages

- Excellent Google Docs integration
- Simple, fast, and intuitive interface

Disadvantages

- No free version
- Limited PDF annotation compared to desktop tools

3.5.5 RefWorks

RefWorks is a cloud-based reference management service widely used by academic institutions and libraries.

Key Features

- Fully web-based (no installation required)
- Integration with Microsoft Word and Google Docs
- Support for over 6,000 citation styles
- Robust collaboration and sharing features

Advantages

- Consistent experience across all devices
- Ideal for group projects and teaching environments

Disadvantages

- Typically available through institutional subscriptions

- Less flexible for advanced personal workflows

3.5.4 Comparison of Referencing Tools

Feature	EndNote	Zotero	Mendeley	Paperpile	RefWorks
Cost	Paid	Free	Free/Paid	Paid	Institutional
Cloud-based	Partial	Yes	Yes	Yes	Yes
Google Docs support	Yes	Yes	No	Excellent	Yes
MS Word support	Yes	Yes	Yes	Yes	Yes
PDF annotation	Strong	Strong	Strong	Moderate	Moderate
Best for	Large projects	Free & flexible use	PDF-heavy work	Google Docs	Institutional use

3.6 Managing Bibliographies Effectively

3.6.1 Organizing References

Effective bibliography management involves:

- Using folders or collections
- Applying tags and keywords
- Maintaining consistent naming conventions

3.6.2 Notes and Annotations

Researchers should annotate references with:

- Key results
- Assumptions
- Limitations
- Relevance to their own work

3.6.3 Version Control and Backup

Bibliographic databases should be backed up regularly to prevent data loss, especially during long-term research projects such as dissertations and theses.

3.6.4 Bibliographies in LaTeX

In mathematics, LaTeX is the standard tool for document preparation. Bibliographies are typically managed with BibTeX or BibLaTeX, which provide automatic formatting and consistent citation styles.

3.7 Research Metrics and Their Importance

Research metrics are quantitative indicators used to assess the visibility, impact, and influence of scholarly research. These metrics help universities, funding agencies, and academic bodies evaluate research performance at the journal, article, and individual researcher levels.

3.7.1 Impact Factor (IF)

The Impact Factor is a journal-level metric that measures the average number of citations received by articles published in a journal over a specific period. Clarivate Analytics formally introduced it through Journal Citation Reports (JCR).

Definition: The annual Impact Factor of a journal is calculated as follows:

Impact Factor (Year X) = (Citations in Year X to articles published in Years X–1 and X–2) ÷ (Number of citable items published in Years X–1 and X–2)

Interpretation

- A higher Impact Factor generally indicates greater journal visibility.
- Useful for comparing journals within the same discipline.
- Particularly helpful for journal ranking.

Importance

- Helps researchers identify prestigious journals.
- Assists institutions in assessing journal reputation.
- Useful in academic evaluation when used cautiously.

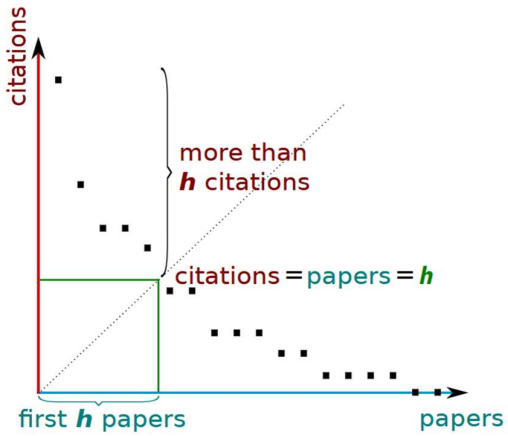
Limitations

- It is a journal-level metric, not an article-level one.
- Heavily influenced by review articles.
- Varies considerably across different disciplines.
- Not ideal for assessing the quality of individual research.

Important Note: The Impact Factor should never be used alone to evaluate a researcher or a single paper.

3.7.2 h-index (Hirsch Index)

The h-index, proposed by Jorge E. Hirsch (2005), is one of the most widely used metrics for evaluating individual researchers.



Definition: A researcher's h-index is h if h of their papers have received at least h citations.

Example

- An h-index of 18 means:
- Each of the 18 papers has received at least 18 citations

Importance

- Measures both: individual and journal impact
- Productivity (number of publications)
- Impact (citations received)
- Easy to understand and intuitive

Advantages

- Balances quantity and quality
- Less affected by a single highly cited paper
- Widely accepted across all disciplines

Limitations

- Disadvantageous for early-career researchers
- Does not reflect individual highly cited papers
- Varies depending on the database

Database Dependence

The h-index varies across different platforms due to differences in coverage:

- Web of Science
- Scopus

- Google Scholar
- SciVal

3.7.3 i10-Index

The i10-index is a straightforward metric developed by Google Scholar.

Definition: The i10-index is the number of publications that have each received at least 10 citations.

Example

- An i10-index = 12 means:
- 12 papers have received at least 10 citations

Characteristics

- Easy to calculate
- Useful for quick assessment
- Available only in Google Scholar profiles

Limitations

- Lacks depth and sophistication
- Not widely used by journals or funding agencies

3.7.4 g-Index (Egghe Index)

The g-index, proposed by Leo Egghe (2006), was developed to overcome a limitation of the h-index.

Definition: A researcher's g-index is g if their top g papers have received a combined total of at least g^2 citations.

Example

- A g-index of 15 means:
- The top 15 papers have received $\geq$225 citations in total.

Significance

- Gives more weight to highly cited papers.
- Better reflects overall citation performance.

- Is always greater than or equal to the h-index.

3.7.5 Databases for Research Metrics

Different databases yield different metric values due to:

- Coverage of journals
- Time span of indexed publications
- Included citation sources

Main Databases

- **Web of Science** – High-quality curated journals
- **Scopus** – Comprehensive scientific coverage (since 1996)
- **Google Scholar** – Widest coverage, includes preprints
- **SciVal** – Advanced analytics (Scopus-based)

Therefore, a researcher may have multiple h-index or g-index values depending on the database used.

3.7.6 Responsible Use of Research Metrics

While research metrics provide useful quantitative information, they must be applied ethically and responsibly.

Key Principles

- Metrics should complement peer review, not replace it
- Subject-specific citation behavior should be considered
- Individual articles should be evaluated based on the quality of their content
- Over-reliance on metrics can distort research priorities

3.8 Indexing and Abstracting Databases

Indexing and abstracting databases collect, organize, and provide systematic access to scholarly literature, including journal articles, conference papers, books, and research reports. Inclusion of research journals in reputable indexing databases enhances the visibility, credibility, discoverability, and citation impact of published research. These databases also play a crucial role in research evaluation, academic promotions, and funding decisions.

3.8.1 Scopus

Developed by Elsevier, Scopus is one of the largest abstract and citation databases of peer-reviewed research literature.

Key Features

- Citation tracking and analysis
- Author profiles with h-index and citation counts
- Journal metrics such as CiteScore, SJR (SCImago Journal Rank), and SNIP (Source Normalized Impact per Paper)
- Coverage of journals, books, and conference proceedings

3.8.2 Web of Science

Maintained by Clarivate Analytics, Web of Science (WoS) is a highly curated and selective research database.

Key Features

- Selection of high-quality journals
- Citation analysis and researcher profiling
- Basis for Journal Impact Factor (JIF) through Journal Citation Reports (JCR)
- Includes several indexes such as SCIE, SSCI, and ESCI

3.8.3 MathSciNet

MathSciNet is a leading database for mathematics, created by the American Mathematical Society (AMS).

Key Features

- Expert-written reviews of mathematical publications
- Mathematical Subject Classification (MSC) system
- Accurate author identification

Importance

- Considered the gold standard for pure and applied mathematics
- Highly reliable for literature surveys and research verification

3.8.4 Zentralblatt MATH (zbMATH)

Maintained jointly by European mathematical societies, Zentralblatt MATH provides comprehensive coverage of mathematical literature.

Key Features

- Abstracts and reviews of mathematical research
- Comprehensive international journal coverage
- Advanced search using MSC codes

Significance

- Complements MathSciNet
- Particularly strong in European and interdisciplinary mathematics

3.8.5 Google Scholar

Google Scholar is a free search engine that indexes scholarly literature across various disciplines.

Key Features

- Broad coverage including journals, theses, books, and preprints
- Citation counts and author profiles
- Easy access

Limitations

- Less rigorous quality control
- Citation counts may include non-peer-reviewed sources

8.6 Directory of Open Access Journals (DOAJ)

DOAJ indexes high-quality, peer-reviewed open access journals.

Significance

- Promotes the free and open dissemination of research
- Increasingly used as a quality indicator for open-access journals

3.8.7 Emerging Sources Citation Index (ESCI)

ESCI is part of the Web of Science Core Collection.

Role

- Covers high-quality journals being evaluated for inclusion in SCI/SSCI
- Increases early visibility of emerging research areas

3.8.8 Other Important Indexing and Research Discovery Platforms

- **Crossref** – Provides Digital Object Identifiers (DOIs) and enables citation linking in scholarly publications.
- **OpenAlex** – An open, comprehensive research metadata platform that supports large-scale analysis of scholarly output.
- **Semantic Scholar** – An AI-powered research discovery tool that improves literature search through citation context and relevance ranking.
- **WorldCat** – A global library catalog that helps researchers find books, journals, and other scholarly resources held in libraries worldwide.
- **INSPIRE-HEP** – A specialized database for mathematics and theoretical physics.
- **BASE (Bielefeld Academic Search Engine)** – A multidisciplinary academic search engine with good coverage of open-access research.
- **ResearchGate** – An academic social networking platform that allows researchers to share publications, track reads and citations, and collaborate with peers. While ResearchGate improves research visibility and networking, it is not considered a formal indexing or citation database for evaluation purposes.

3.8.9 Importance of Indexing for Researchers

- Improves discoverability and citation potential
- Enhances academic credibility
- Aids in research evaluation and assessment
- Facilitates systematic literature reviews

3.9 Ethical Issues in Citation and Indexing

3.9.1 Self-Citation

Some self-citation is acceptable when necessary, but excessive self-citation can be considered unethical.

3.9.2 Predatory Journals

Researchers should be wary of predatory journals that make false claims about indexing and metrics. Publishing in such journals can damage academic credibility.

3.9.3 Citation Manipulation

Practices such as coercive citation and citation cartels undermine the integrity of research metrics.

3.10 Summary

This chapter has discussed in detail the concepts of references, citations, referencing styles, bibliographic tools, research metrics, and indexing databases for M.Sc. For mathematics students, mastering these aspects is as crucial as developing technical proficiency. Proper referencing enhances the clarity, credibility, and ethical standards of research, while awareness of indexing and metrics helps students navigate the academic publishing landscape responsibly.

3.11 Self-Learning Exercise

1. What is referencing, and why is it important in research?
2. Explain the differences between APA and MLA referencing styles.
3. What is the role of citation management tools?
4. Explain the importance of citations in academic writing.
5. Define impact factor.
6. What is the h-index?
7. Explain the i10-index.
8. Why should research metrics be used with caution?
9. What are indexing and abstracting?
10. Name two major indexing databases and their importance.

3.12 Exercises

1. Define referencing and explain its role in maintaining academic integrity.
2. Compare APA and Harvard referencing styles with suitable examples.
3. Write short notes on MLA and Chicago referencing styles.

4. Explain the features and benefits of EndNote as a reference management tool.
5. Discuss how Zotero and Mendeley support collaborative research.
6. Describe the steps involved in effectively managing a bibliography.
7. Explain the concept of impact factor and mention its limitations.
8. Define the h-index with an example and discuss its advantages and disadvantages.
9. What is the i10-index? How is it different from the h-index?
10. Explain the importance of indexing databases like Scopus and Web of Science in academic research.
11. Differentiate between indexing databases and academic networking platforms like ResearchGate.
12. Discuss why citation-based metrics alone are insufficient for evaluating mathematical research.

3.13 References

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UNIT 4: Research Problem Identification and Formulation

Structure of the Unit

4.1 Objectives

4.2 Introduction

4.3 Research Problem

4.4 Selecting the Problem

4.4.1. Necessity of Defining the Problem

4.4.2. Technique Involved in Defining a Problem

4.5 Characteristics of a good research problem.

4.6 Summary

4.7 Glossary

4.8 References

4.9 Suggested Reading

4.10 Terminal Questions

4.11 Answers

4.1. Objectives

After completing this unit, the learner will be able to:

1. Understand the concept of a research problem.
2. Analyse the role of topic into a specific research problem.
3. Formulate clear, precise, and feasible research problem statements.
4. Develop research questions and objectives aligned with the identified problem.

4.2. Introduction

Dear learner's before this unit you should know a basic understanding of research concepts, common research terminology, fundamental academic writing skills, and the ability to critically analyze issues related to their field of study.

Research problem identification and formulation is the foundation of any meaningful research study. It is the process through which a researcher recognizes an area of concern, a gap in existing knowledge. A clearly defined research problem provides direction to the entire study by guiding the selection of objectives, research questions, methodology, and data analysis techniques.

For identifying a research problem careful observation, critical thinking, and an in-depth review of related literature involved. It also requires an awareness of social, scientific, or professional issues within a specific field. When we identified, the problem then it must be formulated into a clear, concise, and researchable statement. This formulation confirm that the problem is relevant, valuable and ethically sound.

This unit introduces learners to the meaning, importance, sources, and characteristics of a good research problem. It also explains the steps and techniques involved in narrowing a broad topic into a specific problem statement. By mastering these skills, learners will be better equipped to design effective research studies and contribute valuable knowledge to their discipline.

Some Research Problems in Mathematics:

Many secondary school learners struggle to understand algebraic concepts due to ineffective teaching methods. The lack of conceptual understanding of calculus affects learners' performance in higher-level mathematics. There is limited use of technology-based tools in improving problem-solving skills in mathematics classrooms. Learners show difficulty in applying mathematical concepts to real-life problem situations. Traditional assessment methods fail to accurately measure higher-order thinking skills in mathematics.

4.3. Research Problem

What is a research Problem?

A research problem, in general, refers to some difficulty which a researcher experiences in the context of either a theoretical or practical situation and wants to obtain a solution for the same. We can say also a research problem typically denotes a challenge that encounters within a abstract or feasible context, for which researcher seek a resolution.

Mainly we feel that a research problem does exist if the following conditions are met with:

i. There must be an individual (or a group or an organisation), let us call it $'I'$, to whom the problem can be attributed. The individual or the organisation, as the case may be, occupies an environment, say $'N'$ which is defined by values of the uncontrolled variables, Y_j.

ii. There must be at least two courses of action, say C_1 and C_2, to be pursued. A course of action is defined by one or more values of the controlled variables. For example, the number of items purchased at a specified time is said to be one course of action.

iii. There must be at least two possible outcomes, say O_1 and O_2, of the course of action, of which one should be preferable to the other. In other words, this means that there must be at least one outcome that the researcher wants, i.e., an objective.

iv. The courses of action available must provides some chance of obtaining the objective, but they cannot provide the same chance, otherwise the choice would not matter. Thus, if $P(O_j|I, C_j, N)$ represents the probability that an outcome O_j will occur, if *I* select C_j in *N*, then $P(O_1|I, C_1, N) \neq P(O_1|I, C_2, N)$. In simple words, we can say that the choices must have unequal efficiencies for the desired outcomes.

Over and above these conditions, the individual or the organisation can be said to have the problem only if $'I'$ does not know what course of action is best, i.e., $'I'$, must be in doubt about the solution. Thus, an individual or a group of persons can be said to have a problem which can be technically described as a research problem, if they (individual or the group), having one or more desired outcomes, are confronted with two or more courses of action that have some but

not equal efficiency for the desired objective(s) and are in doubt about which course of action is best.

We can, thus, state the components of a research problem as under:

- There must be an individual or a group which has some difficulty or the problem.
- There must be some objective(s) to be attained at. If one wants nothing, one cannot have a problem.
- There must be alternative means (or the courses of action) for obtaining the objective(s) one wishes to attain. This means that there must be *at least two means* available to a researcher for if he has no choice of means, he cannot have a problem.
- There must remain some doubt in the mind of a researcher with regard to the selection of alternatives. This means that research must answer the question concerning the relative efficiency of the possible alternatives.
- There must be some environment(s) to which the difficulty pertains.

Therefore, a research problem is defined as one that requires a researcher to identify the optimal solution for a specific issue, meaning to determine the course of action that can best achieve the objective within a particular situation. There are numerous factors that can complicate the problem. For example, changes in the situation may influence the effectiveness of the available courses of action or the values of the outcomes; the number of potential courses of action may be extensive; individuals not directly involved in the decision-making process may be impacted by it and may respond positively or negatively, along with other similar factors. All these elements (or at least the significant ones) should be considered in relation to a research problem.

It can be concluded that a research problem does not appear in a pre-existing form; it must be identified, acknowledged, and articulated by the researcher. In practical scenarios, there are merely challenges, voids, or points of interest. These scenarios only qualify as a research problem when the researcher explicitly defines, examines, and articulates them in a manner conducive to research. Therefore, a research problem is not merely found but is developed through meticulous observation, literature review, critical analysis, and comprehension of the subject matter. Adequate formulation converts an ambiguous issue into a precise and specific problem that is appropriate for scientific inquiry.

Self Learning Exercise -I (True /False)

1. A research problem exists in a ready-made form and can be picked directly from a book.
2. Identifying a research problem is the first step in the research process.
3. Any topic or question can be considered a research problem without further analysis.
4. A research problem should be clear, specific, and researchable.
5. Research problems can arise from practical issues, theoretical gaps, or personal interest.

4.4. Selecting the Problem

The research issue chosen for examination must be meticulously selected. This task is quite challenging, even if it may not seem so at first glance. Assistance can be sought from a research guide in this regard. However, it is essential for each researcher to discover their own solutions, as research problems cannot be simply borrowed. A problem should emerge from the researcher's intellect, akin to a plant growing from its own seed. Just as when our vision requires correction, it is not solely the optician who determines the appropriate lens strength we need. We must assess our own vision and collaborate with the optician to ensure he can prescribe the correct lens power. Therefore, a research guide can primarily assist a researcher in selecting a topic.

However, the following points may be observed by a researcher in selecting a research problem or a subject for research:

i. Subject which is overdone should not be normally chosen, for it will be a difficult task to throw any new light in such a case.
ii. Controversial subject should not become the choice of an average researcher.
iii. Too narrow or too vague problems should be avoided.
iv. 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. Even then it is quite difficult to supply definitive ideas concerning how a researcher should obtain ideas for his research. For this purpose, a researcher should contact an expert or a professor in the University who

is already engaged in research. He may as well-read articles published in current literature available on the subject and may think how the techniques and ideas discussed therein might be applied to the solution of other problems. He may discuss with others what he has in mind concerning a problem. In this way he should make all possible efforts in selecting a problem.

v. The importance of the subject, the qualifications and the training of a researcher, the costs involved, the time factor are few other criteria that must also be considered in selecting a problem.

We can say, before the final selection of a problem is done, a researcher must ask himself the following questions:

- **a.** Whether he is well equipped in terms of his background to carry out the research?
- **b.** Whether the study falls within the budget he can afford?
- **c.** Whether the necessary cooperation can be obtained from those who must participate in research as subjects?

If the answers to all these questions are in the affirmative, one may become sure so far as the practicability of the study is concerned.

vi. The selection of a problem must be preceded by a preliminary study. This may not be necessary when the problem requires the conduct of research closely similar to one that has already been done. But when the field of inquiry is relatively new and does not have available a set of well-developed techniques, a brief feasibility study must always be undertaken.

If the subject for research is selected properly by observing the above-mentioned points, the research will not be a boring drudgery, rather it will be love's labour. In fact, zest for work is a must. The subject or the problem selected must involve the researcher and must have an upper most place in his mind so that he may undertake all pains needed for the study. Choosing a research problem is very important, but it is not easy. Although a research guide can help, the researcher must select the problem himself. A research problem cannot be borrowed from others; it must come from the researcher's own thinking and interest. Just like an eye doctor cannot decide the power of our glasses without our help, a research guide can only assist, not decide for us. While selecting a research problem, the researcher should keep the main points in mind: Topics that have already been researched many times should be avoided because it is difficult to find anything new in them. Such topics are usually complex and risky for an average

researcher. A very narrow topic has little scope, while a very broad topic becomes unclear and difficult to handle. The researcher should select a topic he understands well and for which research materials, data, and sources are easily available.

He should consult teachers, experts, and professors, read research articles, and discuss ideas with others to improve his topic. If the research area is new or lacks proper methods, a small preliminary or feasibility study should be done before starting the main research. Before finalizing the topic, the researcher should ask:

- Do I have enough knowledge and training for this research?
- Can I afford the cost of the study?
- Do I have enough time to complete it?
- Will I get cooperation from people involved in the research?

If the answer to all these questions is "yes," then the study is practical. Simply we will say, if a research problem is selected carefully, research becomes interesting and enjoyable rather than boring. The topic should interest the researcher and keep him motivated, so that he is willing to work hard and complete the study successfully.

4.4.1. Necessity of Defining the Problem

The research issue chosen for examination must be meticulously selected. This task is quite challenging, even if it may not seem so at first glance. Assistance can be sought from a research guide in this regard. However, it is essential for each researcher to discover their own solutions, as research problems cannot be simply borrowed. A problem should emerge from the researcher's intellect, akin to a plant growing from its own seed. Just as when our vision requires correction, it is not solely the optician who determines the appropriate lens strength we need. We must assess our own vision and collaborate with the optician to ensure he can prescribe the correct lens power. Therefore, a research guide can primarily assist a researcher in selecting a topic. In summary, a clearly articulated research problem is vital for conducting effective research, as it addresses a significant portion of the task. Clearly defining the problem enables the researcher to distinguish pertinent data from irrelevant information and maintain focus on the study. A well-articulated problem aids in answering essential questions such as what data to gather, which characteristics to investigate, what relationships to explore, and which methodologies to employ. Conversely, a poorly defined problem can lead to

confusion and challenges. Thus, the accurate formulation of the research problem is a critical initial step. Indeed, the formulation of the problem is frequently more significant than its resolution, as it directs the research design and subsequent phases.

4.4.2. Technique Involved in Defining a Problem

The main points are given as follows:

a. Statement of the Problem in a General Way:

The first step in defining a research problem is to state it in a broad and general manner. This general statement should arise from either a practical concern or a scientific, social, or intellectual interest. At this stage, the problem need not be sharply focused; rather, it should reflect the overall area of inquiry. To accomplish this, the researcher must immerse himself thoroughly in the subject matter. In social science research, it is often advisable to conduct field observations or undertake a preliminary survey, commonly known as a pilot survey. This helps the researcher gain firsthand insight into the problem and its context. In many cases, the research guide or subject expert may suggest the problem in general terms. It then becomes the responsibility of the researcher to narrow it down and frame it in operational terms. Similarly, when a research problem is provided by an organization or authority, it must be clearly understood and stated accordingly. At this stage, the problem statement may contain ambiguities. These ambiguities must be resolved through careful thinking and repeated examination of the problem. Additionally, the feasibility of conducting the study—considering time, resources, and data availability—must also be taken into account while stating the problem.

b. Understanding the Nature of the Problem:

Once the problem is stated in a general way, the next step is to understand its origin and nature clearly. This involves identifying how the problem emerged, why it is significant, and what objectives it seeks to achieve. The best way to understand the nature of the problem is to discuss it with those who initially raised it. Such discussions help the researcher understand the background, motivation, and intended outcomes of the study. If the researcher has formulated the problem independently, he must reflect upon the factors that led him to identify the problem. Engaging in

discussions with experts, practitioners, or individuals who have experience with similar problems can provide valuable insights. These discussions help clarify the dimensions of the problem and identify relevant variables. Moreover, the researcher must consider the environment or context within which the problem exists, as social, economic, cultural, and institutional factors often influence the nature of a research problem.

c. Surveying the Available Literature:

A thorough survey of existing literature is a crucial step in defining a research problem. This includes reviewing books, research papers, journals, reports, theses, government publications, and other relevant documents related to the problem. The purpose of reviewing literature is multifaceted. It helps the researcher:

- Gain familiarity with existing theories and concepts
- Understand previous research findings
- Identify gaps or inconsistencies in existing knowledge
- Avoid duplication of research
- Determine the availability of data and research tools

Knowing what data and materials are already available often helps in narrowing down the research problem and selecting appropriate research techniques. Literature review also reveals whether existing theories adequately explain the problem or whether new perspectives are needed. Additionally, studies on related problems help the researcher anticipate potential difficulties and methodological challenges. They may also suggest new approaches, variables, or analytical techniques that can enrich the current study.

d. Developing Ideas Through Discussions:

Discussion is an effective tool for refining research ideas. Engaging in discussions with colleagues, experts, and experienced researchers often leads to the generation of new insights and perspectives. This process is commonly referred to as an experience survey. Individuals with rich experience in the field can offer practical advice on various aspects of the study, including problem formulation, methodology, data collection, and analysis. Their feedback helps the researcher sharpen his focus and identify the most relevant aspects of the problem. Such discussions should not be limited to defining the problem alone but should also address broader issues such as research design, feasibility, possible solutions, and

implications of the study. Constructive criticism and suggestions received during discussions are invaluable in refining the research problem.

e. Rephrasing the Research Problem into a Working Proposition:

The final step in defining a research problem is rephrasing it into a working proposition. After understanding the nature of the problem, reviewing literature, and engaging in discussions, the researcher is in a position to state the problem in specific, analytical, and operational terms. Rephrasing involves transforming the general problem statement into a precise formulation that can be empirically tested. This often leads to the development of research questions or hypotheses. A well-rephrased problem clearly indicates the variables involved, the population under study, and the scope of the investigation. At this stage, the research problem becomes operationally viable, meaning it can be investigated using available data, methods, and resources.

Self-Learning Exercise -II

1. A research problem must come from the researcher's own ……. and interest.
2. A topic that is already ……. should normally be avoided in research.
3. Very ……. or very ……. research problems should be avoided.
4. Before selecting a research problem, the researcher should consider time, cost, and his ……. and training.
5. When the field of research is new, a ……. or feasibility study should be conducted.

4.5. Characteristics of a good research Problem

A research problem is the foundation upon which the entire research study is built. The quality, relevance, and success of any research depend largely on how well the research problem is formulated. A good research problem provides clarity, direction, and focus to the study, ensuring that the research effort leads to meaningful and valid results. The following are the important characteristics of a good research problem.

i. **Clear and Unambiguous:**

A good research problem must be clearly stated and free from vagueness or ambiguity. The problem should be expressed in simple and precise language so that its meaning is easily understood by readers, researchers, and evaluators. Ambiguous terms and loosely defined concepts can lead to confusion and misinterpretation, which may affect the validity of the research findings.

ii. **Specific and Focused:**

The research problem should be specific rather than broad or general. A narrowly defined problem allows the researcher to concentrate on a limited number of variables and issues, making the study manageable and systematic. Overly broad problems often lead to scattered efforts and superficial analysis, whereas a focused problem enables in-depth investigation.

iii. **Researchable and Empirically Testable:**

A good research problem must be capable of being investigated using scientific methods. It should involve variables that can be observed, measured, and analysed. Problems that are purely philosophical, moral, or speculative in nature may not be suitable for empirical research. The availability of data and appropriate research tools is essential for ensuring research ability.

iv. **Feasible:**

Feasibility is an important characteristic of a good research problem. The problem should be solvable within the available time, financial resources, and technical expertise of the researcher. A research problem that requires excessive time, rare data, or advanced skills beyond the researcher's capacity may not be practical.

v. **Relevant and Significant:**

A good research problem should have relevance either in theory or practice. It should contribute to existing knowledge, address a real-life issue, or help in solving practical problems. The significance of the problem justifies the effort and resources invested in the research and enhances the value of the study.

vi. **Original and Novel:**

Originality is a desirable characteristic of a good research problem. While it may not always be possible to explore entirely new areas, the problem should ideally offer a fresh perspective, address unexplored dimensions, or attempt to fill gaps in existing literature. Avoiding unnecessary duplication of previous studies adds to the credibility of the research.

vii. **Clearly Defined Variables:**

A good research problem clearly identifies the variables involved and indicates the relationship among them. This clarity helps in formulating hypotheses, selecting appropriate research designs, and choosing suitable analytical techniques. Well-defined variables enhance the precision and reliability of the study.

viii. **Theoretically Grounded:**

The research problem should be grounded in existing theories or conceptual frameworks. A strong theoretical base helps in understanding the problem, interpreting results, and relating findings to existing knowledge. It also ensures that the research is logically structured and academically sound.

ix. **Ethically Acceptable:**

A good research problem must adhere to ethical standards. It should not involve harm, exploitation, or violation of the rights of individuals or communities. Ethical considerations such as informed consent, confidentiality, and integrity must be taken into account while selecting and defining the research problem.

x. **Clearly States Objectives:**

The research problem should clearly indicate the objectives or purpose of the study. A clear connection between the problem and the research objectives helps maintain focus and guides the entire research process, from data collection to analysis and interpretation.

xi. **Manageable Scope:**

The scope of a good research problem should be well defined and limited. Clearly stating the boundaries of the study—such as geographical area, time period, population, or variables—helps prevent unnecessary expansion of the research and ensures depth rather than breadth.

xii. **Leads to Hypothesis or Research Questions:**

A well-formulated research problem naturally leads to the development of research questions or hypotheses. This ensures logical continuity in the research process and provides a clear roadmap for investigation and analysis.

Self-Learning Exercise -III

Assertion and Reasoning Questions

Instructions: For each question, choose the correct option:

A: Both assertion and reason are true, and reason is the correct explanation of assertion.

B: Both assertion and reason are true, but reason is not the correct explanation of assertion.

C: Assertion is true, but reason is false.

D: Assertion is false, but reason is true.

1. Assertion (A): A research problem must be clearly defined before starting a study.
   Reason (R): A clearly defined problem provides direction, guides methodology, and prevents wastage of resources.
2. Assertion (A): Literature review is optional while defining a research problem.
   Reason (R): Surveying existing literature helps identify gaps in knowledge and narrows the research focus.

4.6. Summary

This unit focuses on the concept of the research problem, which forms the foundation of any research study. Research is a systematic and scientific process, and its success largely depends on how clearly and correctly the research problem is identified, selected, and defined. A research problem refers to an issue, gap in knowledge, or practical difficulty that requires systematic investigation. It provides direction to the entire research process and determines the objectives, methodology, and outcomes of the study. The unit begins with an introduction to the importance of a research problem in research methodology. It emphasizes that research cannot proceed meaningfully without a well-defined problem. A vague or poorly defined problem often leads to confusion, irrelevant data collection, and inconclusive results. Therefore, careful attention must be given to identifying and defining the research problem. The unit then explains the concept of a research problem in detail. A research problem may arise from practical experience, social issues, theoretical gaps, or a review of existing literature. Defining the research problem involves stating the problem clearly along with its scope, objectives, and limitations. It helps transform a general topic into a specific, researchable issue. Next, the unit discusses

the process of selecting a research problem. Selecting an appropriate problem requires consideration of several factors such as the researcher's interest, competence, availability of data, time constraints, and relevance of the problem. A well-chosen problem motivates the researcher and ensures smooth progress throughout the research process. The necessity of defining the research problem is also highlighted in the unit. A clearly defined problem provides direction, helps in formulating objectives and hypotheses, guides the selection of research methodology, and prevents wastage of time and resources. It also enhances the validity and reliability of research findings. The unit further explains the techniques involved in defining a research problem. These include stating the problem in a general way, understanding its nature, reviewing relevant literature, developing ideas through discussions, and finally rephrasing the problem into specific and operational terms. This systematic approach helps the researcher refine the problem and make it suitable for empirical investigation. Finally, the unit outlines the characteristics of a good research problem. A good research problem should be clear, specific, researchable, feasible, relevant, original, and ethically acceptable. It should have clearly defined variables, a well-defined scope, and a strong theoretical foundation. These characteristics ensure that the research problem is meaningful and capable of producing valuable results. Studying this unit is beneficial to learners in several ways:

i. It helps learners understand the importance of a research problem in the research process.

ii. It develops the ability to identify and select meaningful research problems.

iii. It provides a systematic approach to defining a research problem clearly and precisely.

iv. It improves critical thinking and analytical skills required for research.

v. It enables learners to avoid common mistakes in research planning.

vi. It lays a strong foundation for writing research proposals, projects, and dissertations.

Overall, this unit equips learners with essential knowledge and skills required to conduct effective, focused, and high-quality research.

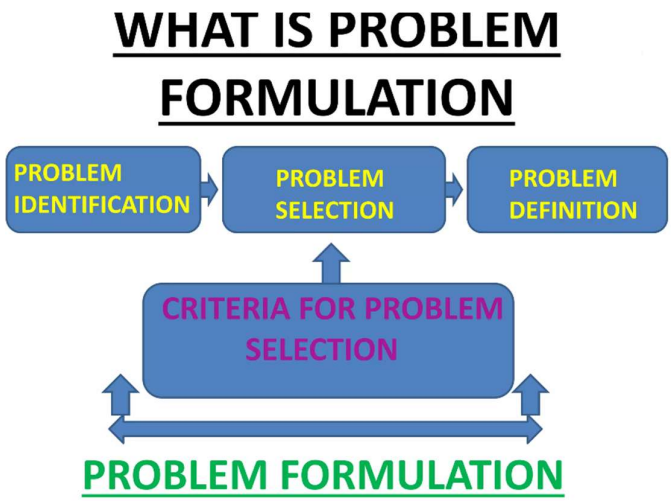


Fig1:Ref:https://www.slideshare.net/slideshow/formulation-of-research-problem-122264868/122264868

4.7. Glossary

ii. **Research**: A systematic and scientific process of inquiry aimed at discovering new knowledge, verifying existing knowledge, or solving practical problems.

iii. **Research Problem:** An issue, difficulty, or gap in knowledge that requires systematic investigation through research.

iv. **Problem Definition:** The process of clearly stating a research problem along with its objectives, scope, and boundaries.

v. **Researchable Problem**: A problem that can be investigated empirically using scientific methods and available data.

vi. **Feasibility**: The practicality of conducting research considering available time, resources, and expertise.

vii. **Research Objectives**: Specific goals or purposes that a research study aims to achieve.

viii. **Hypothesis**: A tentative statement or assumption that can be tested empirically through research.

ix. **Literature Review**: A systematic survey of existing books, articles, reports, and studies related to the research problem.

x. **Variables**: Elements, traits, or conditions that can change or vary in a research study.

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4.9. Suggested Reading

i. Sharma, S. R. (2017). *Research Methodology: Concepts and Cases*. New Delhi: *Macleods Publishing*.

ii. Wisker, G. (2015). *The Good Supervisor: Supervising Postgraduate and Undergraduate Research for Success*. Palgrave.

iii. Thomas, G. (2017). *How to Do Your Research Project: A Guide for Students in Education and Applied Social Sciences* (3rd ed.). Sage.

iv. Sekaran, U., & Bougie, R. (2020). *Research Methods for Business: A Skill-Building Approach* (7th ed.). Wiley.

4.10. Terminal Questions

i. Define a research problem. Explain why defining a research problem is considered a crucial step in any research study……

ii. Discuss the key factors to consider while selecting a research problem. Provide examples from social or business research……

iii. Explain the necessity of defining a research problem clearly. How does it impact the validity and reliability of a study?.....

iv. Describe the step-by-step technique involved in defining a research problem. Illustrate each step with a practical example……

v. What are the characteristics of a good research problem? Why is originality considered important among these characteristics?.....

vi. Compare and contrast a well-defined research problem with a poorly defined research problem. What are the consequences of neglecting problem definition?……..

vii. Explain the role of literature review in the process of defining a research problem. How does it help in narrowing down the research focus?……

viii. Discuss how discussions with experts and colleagues (experience survey) contribute to refining a research problem.……

ix. Explain the importance of specifying the scope, limitations, and operational terms while defining a research problem. Provide an example of each.……

x. A researcher wants to study "Employee Motivation in IT Companies." Draft a broad research problem statement and then rephrase it into a specific, operationally viable research problem.**……..**

4.11. Answer

Answer Self Learning Exercise -I (True /False)

1. **False** – A research problem does not exist in ready-made form; it must be identified and formulated by the researcher.
2. **True** – Identifying the research problem is the first step in the research process.
3. **False** – Not every topic/question is researchable; it must be clear, specific, and feasible.
4. **True** – A good research problem should be clear, specific, and researchable.
5. **True** – Problems can arise from practical issues, theoretical gaps, or personal interest.

Answer Self Learning Exercise -II

1. mind
2. overdone
3. narrow, vague
4. qualifications
5. preliminary

Answer Self Learning Exercise -III

1. A
2. D

Unit-15: Scientific Writing and Communication (Writing for journal formatting and submission guideline)

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15.1 Introduction

In this unit, We will learn about scientific writing and communication. Let's think about the question, why do people need to learn scientific writing ? Scientific writing is basically a creative process, that would make perfect to the science researcher, where creativity merge with logical thinking is the secret of success. Scientific writing helps

students and researcher to express their ideas, knowledge, and discoveries in accurate, clean, and well organized way. It allows people to sharing their knowledge on global level. It helps to communicate and publish their ideas into reputed global journal in the forms of research paper, thesis, books, and report.

Scientific writing is an established procedure of communication utilized by scientists, researchers, academician and scholar to share innovative discoveries with academic community. It is important to develop science and technology community, which allows to exchange and expand their knowledge. In the process of learning scientific writing and communication, we need to learns some points which are following:

- Scientific journal writing with choosing the right journal.
- Preparing manuscript and formatting them according to journal guideline.
- Submission, peer review, rejection and publication process.

15.2 Objectives

After studying this unit you should be able to

- Choose right journal for research paper, books, report, and thesis publication.
- Write proper manuscript for research paper, books, report, and thesis according to journal template.
- Submit of your article, research paper, and report in highly reputed journal.
- Replies the reviewer report and editor comment of your work.

15.3 Scientific journal writing and Choosing right journal

Scientific journal writing is the most important part to exchange and sharing your idea with global community in scientific way. It is an essential part of research communication. A well- structure scientific paper enhances the visibility of scientific work and research, and contributes to add knowledge into global knowledge. Scientific writing is different from ordinary writing because it focus on clarity, accuracy, concision, objectivity, precision, and fact based arguments. The details presented in scientific writing must be logical, accurate, and validate with published data. A well-written scientific documents increase the chance of publication into the highly reputed journal.

To choose right journal is equally important for publication as scientific journal writing. You can share your knowledge with global community by selecting right journal and can increase the reach and audience of your research work. Historically, choose a right journal has involved acceptance rate, relevance, prestige, publication time and circulation.

15.3.1 Scientific Journal Writing

Scientific journal writing is a necessary part of academic and research communication. It is the process from which researcher and academician present their discoveries, findings, experiments, and theories to the scientific and engineering community in a well structured and organized manner. It is platform to sharing and promoting innovative ideas with research community. In modern time, scientific

publication is viewed as evaluation of your academic achievement and career development. All higher research institutes, university, and funding agencies evaluate researcher on the basis of their published work. Therefore, expanding efficient scientific writing skill is much important for research scholar, students and professional academicians.

Purpose of Scientific Journal Writing: The purpose of scientific journal writing is to communicate new findings with scientific community, allowing researcher to build and reproduce new findings based on previous published findings. The main key points of scientific journal writing are :

- **Dissemination of knowledge :** Scientific writing is the way from which researcher share their new discoveries, research and findings with the global scientific and engineering community.
- **Academic communication :** Journals provide a path to researcher from which they can exchange and enhances their ideas, method, and innovations.
- **Preservation of research :** Published work become a permanent records of scientific writing and it can referred to other in their future studies.
- **Validation by peer review :** Published research work in highly reputed journal reviewed by many experts, which suggest some improvement in work and ensures quality and reliability of work.
- **Professional development :** Your professional development and academic reputation increases with your research publication and it enhances career opportunity between researcher.

Characteristics of Scientific Writing : Scientific writing follow some unique features that make it different from other forms of writing. The characteristic of scientific writer are :

- **Clarity :** Clarity means that it should be easily and quickly to understands. Rereading a passage, ideas multiple times shows clarity is missing.
- **Precision :** Precision means that the meaning of document written by writer and understood by reader are same. If their are lack of precision in documents, then reader can easily blamed us even reader is at fault. So precision in document is necessary for scientific writing.
- **Accuracy :** In scientific writing, accuracy means by all new findings claims are verified and validate by previous results. Claiming too little in document make question mark to the value of document. So, claiming right fact with accuracy is important for good scientific writing.
- **Objectivity :** Scientific writing is totally based on evidence and facts instead of personal opinions. So, the tone should be formal and unbiased in the documents.
- **Conciseness :** In scientific writing, the repetition of unnecessary words and lines should be avoided in documents. It should tells us maximum information in minimum words.
- **Evidence based presentation :** The arguments and outcomes must be discussed by experimental data, tables, graphs, observation and references.

Structure of a scientific journal writing : A research article must follow a particular standard structure, so that audience from various field can simply understand the objective, methods, results, and outcomes of the study. The structure also helps to manage accuracy, clarity, and consistency in academic communication. Most of scientific papers, books, reports, follow a standard configuration known as IMRAD format, which express as Introduction, Methods, Results, and Discussion. Together

with these sections, for a complete research paper we additionally need title, abstract, keywords, references, figures, tables, future work statement and acknowledgements. We will discuss it in details in next section 15.5. After following these structure, authors can communicate their thoughts and ideas with journal clearly and there are highly chance to publish their work into reputed journals.

Importance of Scientific Journal Writing : Scientific journal writing is must important for a academician for their academic and scientific progress. Some more importances are following:

- **Global visibility :** A published papers and books in scientific journal writing are globally visible for researcher and academician.
- **Knowledge sharing :** Scientific journal writing gives more options to researcher to sharing their knowledge in various countries and working with collaboration.
- **Researcher Evaluation :** In modern time, academic institutes and companies evaluate researcher on the basis of their quality published research work.

15.3.2 Choosing Right Journal

As we know, selecting a right journal is more important for your publication. Publishing your work in inappropriate journal causes of rejection of your work and also it reduce the visibility of your research work. First, we talk about all various types of research journals in which you can publishing your work.

Various types of research journal

- **International Journals :** These journals are publishing research work of researcher around all of the world. The reach of these journals are at global level. It is best journals if we are working in collaboration with researcher from various countries.
- **National Journals :** The main motive of these journal are publishing research from a particular country. These journals gives more option to researcher who study in that country where from this journal.
- **Peer-reviewed Journals :** These journal are publishing researcher work after deeply evaluation by field experts and journal editor. Publishing research work in these journal indicates more reliability and acceptability in researcher community.
- **Indexed Journals :** Indexed journals are those journal which are listed in authorized databases such as:
  Scopus-Indexed
  SCI- Indexed
  Web of Science
  UGC-Care
  MathSciNet- Indexed Journal
- **Open access journals :** In these journals articles are freely visible just after publishing for readers. Because of freely visibility more researcher easily reach out to published work. In most of open access journals, you have to pay APC(Article Processing Charge) for publish your work.
- **Subscription Journals :** In these journals readers or some times institute pay subscription fees to access their content. The published work are not freely accessible in these journal.
- **Conference Journals :** In these journals special issues are publishing the conference proceeding works. Some times you have to pay APC and some times it is totally free to publish research work.

Factor for choosing a journal are as following :

- **Scope and subject field :** Every journal have special aim and scope. We are selecting those journal which scope match with our topic and objective of research. Authors have to read journal scope before submitting manuscript.
- **Impact factor :** The impact factor which measures how many times articles from that journal are cited. If journal have high impact factor then it is more prestigious journal, but some times it have very strict acceptance criteria.
- **Target audience :** If you keeps readers in your mind as first priority, then you can get more benefit to audience from your research. We always want more audience read our work and further new study on that field.
- **Peer review process :** Those journal who follow peer review process are more reliable, and quality and validity of work is evaluated by field expert. It increases the credibility of your published research.
- **Publication Time :** Every journal have average publishing time which showing on journal website. Some of journals publish articles faster than others. So, researcher look the publication time as per need of their time line to publish work.
- **Open access or Subscription :** As we know, in open access journals the article are freely accessible just after the publishing which increases the readership and visibility of your work. Some of open access journal may charge APC. Subscription journal have limited accessibility and visibility. Your work is not freely accessible.
- **Acceptance rate :** Those journal which has low acceptance rates are more difficult for publishing our research work. But if your work is very good and discovered totally new findings then you have to submit your manuscript in good journal whatever their acceptance rate.
- **Indexing Status :** We check the journal indexing status whether it is indexed in reputed databases such as SCI, Scopus, and Web of Science.

Steps of journal selection :

- Select a journal related to your research field.
- Read the literature which published recently in your area of research.
- Comparing journals guidelines, audiences and the formatting requirements.
- You have to check journal authenticity and credibility.
- Read the journal scope and aim in their web page. Every journals have special area of interest and they are publishing research considering these aim and scope. Example- A journal which is focus on purely mathematics or experimental research may reject applied work or theoretical work.
- You have to look out journal impact factor. It helps researcher to check quality of journal.
- You have to check selected journals status as they are listed in Scopus, SCI, and Web of Science Indexed journal. These are database of highly reputed publishing research journals.
- Check the journal publishing policy. If it is open access then what is their APC. You have to read all these and after that sent your manuscript in open access, subscription journal or hybrid journal whatever your choice.

15.3.3 Self Assessment Questions-I

Q.1 What do you mean by Scientific Journal Writing.

Q.2 How can you choose right journal for publications.

Q.3 Why we need of Scientific Journal Writing in our academic.

15.3.4 Predatory Journals

A predatory journals are unethical journals whose motive are to gain money by exploitative publishing. They are promising to researcher for quick publication by spam email invitations and charge heavy APC for publication. These journals are not listed in indexed database. The open access move in publishing has rising the predatory journals. These journals have legitimate looking website, and also a reasonable-sounding name, but these are not real thing. To publish your work in predatory journal is worse than a waste of money. They are making same journals website with filling predatory entities on that website and collect open access Article publishing fees from researcher without giving any academic services.

Factor of recognizing predatory journals: There are many factors to recongnize the predatory journals. some of them are following:

- **Aggressive solicitation :** In this, they are appreciate researcher for their previous published research and promising to you for quick publication by spam-like emails. So, avoid these emails on spam folder.
- **Fake matrices :** In journal matrices they representing false impact factors and indexing status. In journal website many places they falsely claiming the inclusion in reputed indexed databases such as Scopus, SCI.
- **Guaranteed rapid publication :** They are claiming falsely peer review and publication in very short time like 24 hours.
- **Misinform editorial boards :** They are adding esteemed academics in their fake journal website without taking their permission, or writing dummy name of board members.
- **False website :** They make falsely websites on the name of prestigious and well established journals.

Results in publishing research into Predatory Journals are following :

- **Waste of money :** Authors are paying unexpected and hidden publication fees to predatory journals because they collect research from us, so it is totally waste of money.
- **Credibility loss :** If you are associating with low-quality or fake journals then it will harms your reputation and dignity, and question mark arise on validity of your research.
- **Corruption in research :** Because of lake of peer review and misinformation, these journals published false data in public domain which misguide new researcher.
- **Copyright traps :** Once you published your work into predatory journals then the owner of journal claim ownership of that work and it will make difficult to publish same work into reputed journals.

Factor for avoid predatory journal : There are many points and questions which you ask to journal or keep in your mind before submitting your articles into the journals.

- First you confirm you know about the journal ?
  - have you read any research paper in this journal before knowing their name ?
  - are you able to search easily latest paper in the journals ?
- Can you easily verify and reach out to publisher ?
  - is publisher name clearly visible on journal website ?
  - have you access and read the publisher details on publisher page ?
- have you check the journal indexing ?
  - you can verify journals directly to search on scopus and web of science by title and ISSN - number ?
- have you know about fees structure for article publishing ?

- does journal explain what fees you have to pay and when it will be pay by us ?

- Do you able to recognize the editorial board member ?
  - have you heard editorial board member name ?
  - is editorial board member mention journal name on their own website or their orcid id ?
- Is the publisher a member of satisfactory industry ?
  - Do the publisher follow the COPE(Committee on publication Ethics) ?
  - If the journal is open access then it is listed in DOAJ(Directory of Open Access Journals) ?
  - Is publisher is member of OASPA(Open Access Scholarly Publishers Association) ?

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15.3.5 Self Assessment Questions-II

Q.1 What do you mean by predatory journals .

Q.2 What do you mean by predatory journals .

15.4 Self Learning Exercise-I

1. What are the purpose of scientific journal writing.
2. What are the characteristics of scientific writing.
3. What standard structure follow by researcher to write documents into scientific manner.
4. Explain various types of research journals.
5. Which common factors are utilizing to choose best journal.
6. Explain all steps of journal selection for publish research work.
7. How can you recognize predatory journal.
8. What are the outcomes of publishing research in predatory journal.
9. How can you avoid predatory journal when you submit your research work.
10. Why do people need to learn scientific writing.

15.5 Manuscript Preparation and Formatting

Manuscript preparation and formatting ensures your research work is clean, professional, and now ready for review and publication. A manuscript for publication is new knowledge which you have write in scientific way and submit as article or book in journals. When you discovered some new finding, then you have to start writing your manuscript although all findings are not discovered yet. If you are not start writing manuscript on timely then in the end of the work you may forgot to write some results. Formatting of the manuscript is very important part of writing manuscript in which you have to decide font, margins, space, alignment, and page number as per requirement of journal guideline. Before submitting your manuscript in journal you have to read all guideline of journals and make all correction according to as per journal guideline.

15.5.1 Preparation of Manuscript

The standard structure of writing manuscript/articles is :

- Title
- Name of Authors and their Affiliation with Orcid id
- Abstract
- Keywords
- Introduction
- Problem Formulation
- Methodology
- Results and Discussion
- Conclusion
- Shortcoming
- Future work
- Acknowledgements
- Funding statement
- References

Many journals provide their journal templates, in that case you have to use that templates structure for writing manuscript. You should always follow journals standard guideline.

Title : Title is the first thing to make decision whether we read the document or not. There are not structure method to writing title. But their are some guideline which you keep in your mind when writing your title of paper. The title becomes shorts and concise and it reflects major finding terms which utilize in your manuscript. Before writing your manuscript you decide title of your paper which give a path to you writing the manuscript. But it will be modified as far as you are writing your manuscript. A good title is essential for good paper in which you have to mention aim and approach of your work. The title should be specific which highlight main findings.

Authors name and their Affiliations : After writing the title of manuscript you have to mention all authors names with their affiliation who have made significant contribution in the study. In affiliation name you have to mention department name, institute name, address, city, state, country and pincode. If there are more than one authors and have different affiliation then mention some indicator(like 1, 2, 3 or a, b, c) for different authors name with their respective affiliation. You have to mention corresponding author name and their email after affiliations. When you are writing authors name then you check the order of authors name are correct, because it has specific meaning in the contribution of study. Generally, the first name of author in manuscript known as first author. Try to add orcid id in front of respective authors names.

Abstract : The abstract of research paper should be concise, clear and short summary of paper that covers the following points :

- **Motivation/background/context :** What issues led in this work ? What is the key features that makes it important ?
- **Aim/objective/statement of problem :** What you want to achieve from this work ? What gaps is being filled ?

- **Method/approach/procedures :** What approach you applies to achieve your aims ? What methodology actually you use ?
- **Results/conclusion and implications :** What were the main finding of this study ? Why these results are important and where will they use ?

A typical abstract is about in 200-250 words, it depends on journal guideline. A good abstract contain more information in concise and precise way, it is easier to read and search and are preferred by researcher. Once you write all fours points then remove the subsection heading and write into paragraph without line break. Generally, the abstract should not contain citation of other papers. It should not contain directly figures and tables. You can mention results of tables and figures in words. Finally, important goal of abstract is to be specific and describing all of your work.

Keywords : Most of science journals request to mention keywords. These are helpful for classification of your paper in information system. The idea behind choosing the key words to be listed into the abstract as "Subject terms" is simple. If you were looking an article for topic of your manuscript, then what words would you type into search engine for find the article ? You should mention the words in such a way it will easy to search your content for researcher. After deciding good list of keywords, go back at your abstract and title. Are these keywords found into the abstract and title ? The most important keywords should be found into title, and in the abstract many times. You should mention only 4-5 keywords only.

Introduction : The introduction should express the motivation and the objective of the presented research work and summarize all literature relevant to your research. The introduction section should answer the question, what is the paper tell about, and why should the reader care ? Thus, an introduction section should tell about the reader as to what the article is about and it encourage the reader to further reading. The introduction section should contains scope, novelty and significance with research gaps. In the starting of introduction section, you discuss generals point and after move to specific point. In introduction you should have to mention three points. First, what is the domain of work, why is this domain important, and what have already been achieve ? Second, highlight clear gap in previous findings, what challenge in the prior work ? Third, highlight the purpose of new research and summarize the results ?
When you are discussing previous works of your field, then do not focus only on short coming, you acknowledge their achievements. You have to cite only relevant papers which you considered helpful in your research. Do not over cite of self citation. When you cite paper in introduction, then make sure what citation style journal need ? You have to mention gap between previous findings from your work and clearly state the objective or novelty of your work. In the end you have to mention, what you have achieved and what you want to present in this study. Avoid repetitions in your paper.

Problem formulation : In this section you formulate mathematical formulation of your problem. It is important section of a research paper, especially in mathematics, computational science, fluid mechanics, engineering and applied sciences. In this section you explain the physical problem, assumption, governing equation, boundary condition and mathematical modelling for this study. A well - structure problem formulation helps readers to understand

- what is being studied in this problem,
- how this problem is mathematical formulate.

- which hypothesis/ assumption you are considered,
- what mathematical equations you govern for this study,
- what conditions/approach are utilized for getting the solution.

In this section you discuss the geometry of problem. It increases the quality, credibil ity, and readability of the research work.

Methodology : In this section, you discuss how results were generated. If you are using well established methods, then telling the method name may be sufficient. From this section, readers should be reproduce the results and should be judge the results. Without this, it is impossible to validate of the publish work. The methodology section can include the development of a theory, or description of a scientific tools to be used, or discuss about the technique to reach near outcomes. A good methodology section describe why you use this technique, what are their benefit, and how it perfect to discover results of study.

Results and Discussion : In the past time, most of journals have demanded separate section of results and discussion. Some journals are still demanding their separation, in which first you have to present results and after that discussing about discussions. However, providing results and discussion simultaneously is perfect way of writing, and this text is easier for understanding. This section present a result described in previous section methodology, to make them readable for researcher. These results are presented by tables and graphs with their explanatory text in paragraph. An important goals of presenting results is to clearly explain new findings and properly cite the previously published work.
The use of discussion is to explaining all the results which give the answer of research question into the introduction section. In discussion, you interpreting and explaining the outcomes, comparing them to previous published work and tell about new findings of your work. In this section you also validate your results with previous published work by graphs and tables. In results and discussion section, it is necessary to demonstrate the results with clear references of tables and figures as per journal guidelines, and arrange a results into logical way. Figures and tables have proper caption, heading, numbering, should be easy to understand without reading text.

Conclusion : The conclusion section provides a short summary of results and discussion, you have to writes all new findings in briefly in this section. It is answer of research gaps and your objective of research. This section should be oriented to reader-focused, and avoiding the things that "we" or "I" have accomplished. The conclusion section should concise who provide the key messages of authors findings. It is collection of most and final conclusion of results and discussion section.

Shortcoming : After conclusion section you have to write shortcoming of your research work. Sometimes because of lake of instruments and resources you are able to done limited study, so if any part is remaining or not discovered by you then you have to mention it in shortcoming. Every research has some limitation, behind it results may be applicable or not, so you have to write clear statement about it in the end.

Future work : Once you have write your manuscripts then you should mention the statement about future work. It will help to new researcher to further study on your work, what they can be do further study in your work. Sometimes, when you are

working on some objective, But in process of achieve of objective, some new ideas comes in your mind which you not elaborate in your work. So, you should hint that idea which has not been accomplished.

Acknowledgements : In acknowledgements, authors express their gratitude or thankful note to individuals person or institutes who provided significantly support the authors through out their research, but it do not meet criteria of authorship. You can also add funding source who helps in your research. You have to give gratitude to institute for administration or material support.

Funding statement : Most of journals do not demand separate statement for funding, it should be mention into acknowledgements. But some journals require separate statement. If you get some funding or financial support from anywhere, then you have to mention their name, Grants no, or specific project numbers. If you do not get any financial support, then you can write "This work was supported without any funding".

Conflict of Interest : This is formal declaration which disclose any personal, financial, or professional relationship that could be influence a person's research, objectivity, or professional judgement inappropriately manner. If you have no any conflict of interest then write statement "The authors declare no conflict of interest".

References : In references you included all those article/books which you considered helpful in your study. Generally, when you are writing references then once you read journal guideline. References shows your work credibility because you validate your result with these references paper. There are so many references style's. In mathematics related journal's preferred APA, Vancouver, and Chicago style. Few of them are following:

APA : For journal articles in APA style looks like

Author's last name, first initial name. (year of publication). Title of article. Journal Name, Volume(Issue), page no. DOI

Example- Kumar, B., & Gupta, R. (2026). Heat transfer and thermal radiation inspection of MHD flow of hybrid nanofluid with variable viscosity and thermal conductivity using various shapes. ICCK Journal of Applied Mathematics, 2(2), 173-194. doi.org/10.62762/JAM.2026.636964. **Vancouver :** For journal articles in Vancouver style looks like

Last name Initial name. Title of article. Journal's name. Year ; Volume(issue) ; pages. DOI.

Kumar B,Gupta R. Heat transfer and thermal radiation inspection of MHD flow of hybrid nanofluid with variable viscosity and thermal conductivity using various shapes. ICCK Journal of Applied Mathematics. 2026 ; 2(2) ; 173-194. DOI-doi.org/10.62762/JAM.2026.636964.

15.5.2 Formatting Requirements

Formatting is essential part of writing manuscript. When you start writing manuscript then make sure about journal guidelines. But every journal may have different template and formatting requirement. It refers to presentation and arrangement of the research work in prescribed standard way. It include page layout, spacing, font style, heading, tables, figures, citations, equations, and references.

- **Page Layout :** In this, you have to fix margins around the text on paper. Generally, most of journals follow A4 paper size with 1 inch margins on all sides. You also check journal guidelines for authors for single or double column format.
- **Font style and size :** You check on journal website, what font style and size is require for whole documents. Most of journal used Times new Roman and Arial font style, But some of them require different font style in section heading, title, main text etc. You should also set-up font size of title, heading, main text, section, section heading, and author's name and affiliations. The consistency and accuracy in font style is very important in manuscript.
- **Line spacing :** You should have to check how much line spacing require between two lines as per journal guideline. It can be single spacing, double spacing, or 1.5 spacing for easy reviewing the manuscript. You should also ensure how much spacing require in abstract, nomenclature, and between section heading to paragraph.
- **Heading and Subheading :** Heading and subheading is most attractive part of manuscript. You have use section for heading and subsection for subheading, You should also ensure their font size, bold text, centre/left alignment text for heading and subheading as per journal guidelines. You have to use consistent numbering and good formatting throughout the manuscript.
- **Paragraph formatting :** You have to maintain paragraph length, it should not be very large. The text of paragraph should be justified and their are proper indentation or spacing in paragraphs. You always use formal academic language in paragraph as per journal guideline.
- **Tables :** You should make tables in such a way it is self explanatory. The table layout and order of table entries have create huge difference for reader to comparison of data and understanding the table. The entries in table within a row and column arranged in such a way it can be easier for reader understanding to compare row and column entries. All tables should have good captions, and items presented into tables are clearly defined with their units. You should make horizontal and vertical lines around tables as per journal guideline. You also check journal guideline for caption, it should be come above the table or below the table, and what should their font style. Always place tables to next to the relevance text or end of the you article.
- **Figures :** All figures should have self explanatory text. You should follow standard journal guideline for making figures. All figures should have clear caption which clearly explain the figures. If you are drawing lines or writing text into figure, then you look what is their font and other things require as per journal guideline. Give proper numbering to all figures and refer them into the text. You have to maintain good quality and high resolution(600 dpi) for all figures. For making better figures you have to include four point in it which are description, number, a unit, and uncertainty estimate. You can also use different color in the figures for explaining various data into one figure, but the information will not change when printed in black and white. You have to mention proper labelling, title, caption, line width, color and axis length. You should always submit full size figures, and can be reduced according to page layout. Try to upload TIF or PNG file of figures in your manuscript. You should always read journal guideline before making and formatting figures.
- **Equation and Mathematical expression :** All mathematical equations should be proper numbered and aligned. If journal require then equation and mathematical expression should be inserted into the main text. You can use two style for writing equations : In line style and Display style. Always write equation using math editor so that it should be editable text. Do not uploaded image of mathematical equation. Generally, equation numbers are placed on right side. You should also ensure about

their numbering, which can be written in two way, with section wise number or general numbering for all manuscript.

- **Citation and referencing :** References are essential to acknowledge research work related to your study, highlight the research gaps, and illustrated the novelty of your work. The reference should be relevance to the arguments explained into the manuscript. There are many references styles, you should always follow specific journal guideline for your manuscript. The citation acknowledge the work of other researcher. There are many types of citation which are In-text citation, numerical citation, author year citation. Most of journal used numerical citation style but you will confirm from journal guideline. The improper citation may cause of plagiarism in your manuscript.
- **Latex typesetting tools :** As you know, Latex is widely used by researcher for scientific writing manuscript in mathematics and engineering field. It is helping to you for writing manuscript in easier way. In Latex you can formatting your manuscript in very easy way by writing command and install packages. It has so many advantages such as excellent equation formatting, easy bibliography management, better handling large documents, professional appearance and easy for revised the manuscript.

Manuscript formatting is a major component of scientific writing and academic. A properly formatted manuscript increase readability, consistency and quality of presentation. It has included structure organization, proper citation, accurate equation, appropriate heading and proper presentation of tables and figures. Authors must follow journal guideline for standard formatting to increase the chance of successful publication. It is important part of professional scientific communication.

15.5.3 Plagiarism

Plagiarism remains an important and difficult issue in scientific publishing. It is defined as stealing someone ideas, images, or words and representing them as your own. This is intellectual theft. Let's discuss it in details.

- **Copying another's ideas :** As you know, every works builds on the basis of past work, so it encourage you to discover something new on the basis of past work ideas. The ethical lapse is by presenting these ideas, models, designs process, and results are as original work without citation them. So, the plagiarism of ideas comes when you are not citing another works. A missing citation are not evidence of plagiarism. As you know many ideas formulate by different researcher independently, and you read limited literature so some of your new ideas may be discovered previously by someone. But you didn't know about it. so you have to find out relevant literature and cite them appropriately, But those missing citation indicating your work into plagiarism.
- **Coping another's images :** As you know figures are an important part of scientific writing. As such, using another's figure requires not only citing the original publication, you have to take permission from figure's authors or publisher. Some images have no creative content, and it is common diagrams so you have no need to take permission. So, when you are using figures then it will be your own figures not stealing from other sources, otherwise it will comes in plagiarism.
- **Coping author's words :** This is most common plagiarism problem that is comes from coping of author's words. Some of authors stealing whole papers and write it by paraphrasing of a few sentences. While copying text without quoting is never allowed. If you are copied text without cite them it comes in plagiarism. Some authors are coping text for background of their study in introduction section, But if you didn't write it in

your own word or without quotation then it will comes in plagiarism. If words are not your own then you always writing them into quotation with proper citation.

- **Self plagiarism :** self plagiarism terms described as misrepresenting previously published your work as new. You cannot steal work from yourself. Such duplication without proper citation is used by authors to increase their research publication. It is harmful for reviewer and reader who waste their time to reviewing them. The duplication research work is a serious ethical violation. If your new work is continuation of your old work then cite it and clearly distinguish between new and old work. The idea of coping and reusing your own work become more complicated if the list of authors are not identical in new and old papers. You cannot steal your own work from your old paper if some authors are not found in new study.

We are using generally 3-4 tools for plagiarism checking which are turnitin, ithenticate, grammarly, plagscan. The most widely used tools for plagiarism in world wide is turnitin. In turnitin if your manuscript similarity index are below 10% then it is excellent and between 10-20% usually acceptable, but above 20% you should need revision when check upto 6 words. In similarity index three types of sources shown which are internet sources, publication, student papers and also shown primary sources one by one in report. In plagiarism check report from internet sources percentage of plagiarism always be minimum and separately sources of plagiarism come less than 1%.

15.5.4 Self Assessment Questions- III

Q.1 Write the standard structure of manuscript.

Q.2 Why references are important to make manuscript.

15.6 Self Learning Exercise-II

1. Explain the steps of preparation of manuscript in detail.
2. What do you mean by manuscript formatting ? How can you formatting a manuscript.
3. What is plagiarism ? How plagiarism appear in your manuscript.

15.7 Submission, Peer Review and Publication

Submission process is very important part in your publication. Once your manuscript is ready for submission, then you submit it into selected journal. You should ensure that all files related to submission process is ready for without delay in submission. You should also make a cover later for journal editor. After submission, journal editor look your work for peer review consideration. If editors feels that work is relevance to journal scope with good quality work, then it can be considered for further review and it will be sent to reviewer. Sometimes, editors may reject your work because of poor quality work or not into the scope of the journal. After reviewing your work by reviewer, if editor and reviewer are satisfy with your work then it can be sent to journal production team for publication.

15.7.1 Submission Process

The submission process is very important step in scientific publishing. Before submit your manuscript, you have to select appropriate journal for submission which you already learn in the starting of this chapter. After that you have to prepare

manuscript for submission which you already learn. Now, we need some supporting documents such as

- **Cover letter :** It is simple one page letter which looked by editor as for first impression. On the behalf of cover letter journal editor take decision, is this manuscript sent for peer-review or it should be declined without review. So, cover letter is most important indication for editor's to taking decision on manuscript. A structure cover letter contains manuscript information in which you have to write title and type of article, and if is for special issue then mention special issue name in cover letter. After that you have to addressed your problem, novelty of your work, significance of the work, and why it is fit for your journal. After all these you have to write sentence regarding double publication and finally give all authors approval. Finally in the end, you must mention the name of corresponding author.
- **Author contribution statement :** You have to mention statement regarding of all authors contribution in which you have to tell about, what is done by which authors. You have to mention these points into your manuscript in front of each authors name in the end of conclusion section which are problem formulation, writing original draft, methodology, investigation, software, data curation, visualization, writing review & editing, formal analysis, validation, conceptualization, supervision, and resources.
- **Orcid Id details :** You have to mention all authors orcid id with hyperlink in the end of manuscript or on authors name. Before submission you once again verify your orcid record.
- **Graphical abstract :** If journal require then you have to add graphical abstract. In graphical abstract you have to made figure which represent your abstract and it is self explanationatory. If journal ask to submit graphical abstract, it means that journal editor first look your graphical abstract with cover letter to take first decision on your manuscript.

Now a days, many journals used online manuscript submission system. Some of these are :

- **Editorial manager :** It is cloud based manuscript submission and peer review system for all scholarly journals, books, reference works, and other publications. In this you can submit new manuscript and check status that it is submitted, or submission sent back them to author, or incomplete submission, or waiting for author approval. There is also revisions option in which status of your revision is showing, and in the ending there is option of submission with a decision.
- **Scholar one :** It is unified portal for submitting your research work, tracking peer review, and accessing academic publishing work through various journals and conferences. It can be create with your orcid id filling all necessary details.
- **Elsevier submission system :** It is totally unique submission system in which you have to create your account on Elsevier which contains many scopus indexed journal dataset. After creation your account you can submit your manuscript by login your account.

After creation your account on one of them as per specific journal, Now you can submit your manuscript. First, they ask about manuscript/article types, after that they give option to attach files in which you have to upload manuscript files, all figures and tables, cover letter, supplementary files, manuscript tex file and all other required documents. After all these they have ask to submit title, abstract, keyword, authors name with their affiliation, corresponding author name, any other comment. After that they make a manuscript build file for you and it will take some time and they ask to corresponding

author for final submission. After clicking on final submission your manuscript sent to journal and system generate a manuscript id for future communication.

15.7.2 Peer Review Process

After submission your manuscript, the journal editor would initial check your manuscript, and editors determine suitability of work for publication in his journal. For that editor view the cover letter and manuscript, and concluded about further review process. In the first screening, the editor check the relevance of work to journal scope, formatting correctness, language quality, plagiarism check and novelty of work. If they found all are appropriate then they sent your manuscript for peer review. If their are some technical mistake then they inform to corresponding author for technical correction. If they are not considering for peer review then they can rejected your manuscript immediately and give reason of rejection with some suggestion to improve the manuscript.

Now, we discuss about peer review process done by reviewer. The peer review system validate academic work, help into improving the quality of research, and increases network into research communities. It is widely accepted method for validation of research. There are four types of peer review, so before submitting your work once you have to confirm about peer review process.

- **Single anonymized review :** In this, the identity of the reviewer is not disclosed for author, but reviewer know the authors identity. The reviewer evaluate the manuscript with known the authors identity. It gives a option to reviewer providing honest opinions without any pressure. It is generally used by engineering journals, medical journals and social science publication.
- **Double anonymized review :** In this, the identity of the authors and reviewer are not disclosed to each other. The authors remove their identity from the manuscript before submission. The advantages of double-blind review is to reduce personal bias and promotes fairness in evaluation process.
- **Open peer review :** In this the identity of both authors and reviewer are disclosed. In some journal, reviewer comments are also includes with published article. The reviewer comments and their name appear publicly on article pages, and readers can also access the reviewer history. It is generally used by open-access journals, and interdisciplinary research journals.
- **Triple-blind peer review :** The identity of author, editor and reviewer are not disclosed to each other. It is best way to eliminate all possibility of biasness. It reduces the personal and institute influence. It is less commonly used by journals.

The peer review process helps the editor decision on manuscript which to publish and which to reject, it also give authors advise how can authors improve their paper. It is good advise to all authors to think about your manuscript like a reader. In the review process, reviewer must follow respectful and constructive tone. There is no specific format of review, but reviewer follow some key points which are :

- In the starting paragraph of review report, reviewer provide a brief introduction of synopsis in 1-2 sentences, then reviewer explain what is new in the paper, and he also explain about the significant of work into 1-2 sentences.
- In the second paragraph reviewer tell about the quality of research. If any logical, method base and conclusion related mistake is found then reviewer address this into the review report for authors to fix them.

- In the third section reviewer address some specific points for authors. This points can be large or small, and reviewer wants replies of all points with proper justification to go further publication process. The reviewer include all flaws in this paragraph after reviewing the manuscript.

  In the end of review report, reviewer mention the statement regarding a revision which can be minor or major, and acceptance or rejection of manuscript. Once a review has been done by reviewer then review report will be sent to journal editor. This review report looked by journal editor, and it will be sent to corresponding author of the manuscript. After getting review report, author will be revise his manuscript according to review report. You have to made all correction in your manuscript which is suggested by journal editor and reviewer, and highlighted them into your manuscript. You have to made separate file of reviewer comments replies which is suggested in review report and gave proper justification of all these comments.
  Once a revised manuscript prepared by yours then you have to submit it to journal with reviewer replies report and all files related to manuscript, also you have to submit manuscript of highlighted text to journal. After that reviewer and journal editor take decision on your manuscript. It can be sent again for revise, or may be accept by editor for publication with minor revision.

15.7.3 Reason of Rejection

Your manuscript be declined mainly on two stage, without peer review or after peer review. There are mainly four reason to declined your manuscript without review. First, your work may not perfectly fit within the scope of the journal. The journal editor can decline good manuscript also because of out of scope of journal. But, if work is good then it is recommend to you by editor to sent your work into appropriate journals. Second, If your manuscript language is very poor, which does not match the standard of journal. If reviewer feels so much difficulty to understand sentences, then they will not considered your manuscript for review. They would not waste their time to reading poor language work. If new researcher are facing this problem, then they can take help of native english speaker, or english editing service and resubmit it. Third, your manuscript can be declined without review if paper is not discover new findings or not significant result. Fourth, the manuscript does not follow the plagiarism, ethical and technical guidelines of journal. If your work showing high similarity index, or their is technical mistakes in your manuscript then editor directly reject your manuscript.
There are many reasons to reject your manuscript by reviewer which are following:

- **Lack of novelty :** If your research does not provide new finding, or significant knowledge, or similar work has already been published, or there is limited contribution in your manuscript, then it may be rejected by reviewer.
- **Poor literature review :** If in literature review, most recent research are not cited, or it is incomplete, or not relevance to find research gap clearly, then your manuscript can be rejected.
- **Weak research design and methodology :** If in your manuscript, you are using insufficient sample data, or inappropriate research method, or not include table, or figure for validation and use insufficient mathematical tools, then it can be rejected.
- **Bad writing :** If in your manuscript, their are lots of grammatical and language error, or lack of clarity in language, repeated text and result presented, then your manuscript can be rejected.

- **Insufficient results and discussion :** If in your work, you are not explaining your findings properly, or do not give proper justification behind results, or not validate with previous findings, or not novel in the results, then it can be rejected by reviewer.
- **Insufficient theoretical or practical contribution :** If in your manuscript, their are lack of theoretical or practical knowledge according to reviewer, or research objective and hypothesis are not clearly explained then it can be rejected by reviewer.
- **Reviewer and editor concerns :** After revision of your manuscript, if reviewer is not satisfy with your answer of their comments, or responses to reviewer is still incomplete, then editor and reviewer declined your work.

There are many way to reduce the chance of rejection of your manuscript which are:

- Choose a appropriate journal which is related to scope of your field of research.
- Check plagiarism of your manuscript before submission, it follow journal guideline.
- Follow the journal's author guideline strictly and carefully.
- Highlight the novelty and significant of your research into the manuscript.
- Mention relevant recent studies in literature review and find gap from their.
- Focus on your manuscript writing and improve the english language for writing.
- Before submission you have to take feedback from your colleagues or guide of your research.
- In revised manuscript addressed and highlight the reviewers comments carefully.

15.7.4 Publication

Once your manuscript is accepted by editor for publication, then it will be sent to pro duction team of the journal. The production team/journal editor ask you to submit all relevance files of your manuscript if it has not been already submitted. After, receiving all relevance files, production team made necessary changes according to their journal publication. They make front page of manuscript as per their template and arrange text and figures in your manuscript as per their journal standard. Once, production team convert your manuscript to final paper for publication, then they sent you proof read pdf of your article. You have to check your title, authors name and their order, affiliation and corresponding author, and other necessary details carefully. If their is no mistake found in proofread pdf, then you approve it with no change button. If any mistakes found in final proofread pdf then you have to mark them into the pdf and write correction along with them. Sometimes, you also have to submit separate pdf of these correction. Once again you have to sent corrected pdf to journal. After revising the proofread pdf, journal editor sent it again to corresponding author to verify all correction, and he gave you 24-28 hours time for them. Once you confirm proofread pdf of article with no changes, then journal production team published your paper on their website. For publication they follow terms and condition on which corresponding author gave their agreement. Now, you can look your paper on journal website. After publication of your article, you can add your article on your google scholar, research gate, and orcid account be search them.

15.7.5 Self Assessment Questions- III

Q.1 What do you mean by peer review process ?

Q.2 What are the online manuscript system ? explain.

15.8 Self Learning Exercise-II

1. What supporting documents you have to submit in submission of manuscript.
2. What are the step of submitting manuscript on journal submission system.
3. What is peer review process ? explain different types of peer review process.
4. Explain the peer review process in detail.
5. What are reason of rejection of your manuscript.
6. How can you reduce the chance of rejection of your manuscript.
7. What is publication process after acceptance of your manuscript.

15.9 Summary

In this unit, we studied about scientific writing and communication. We studied about choosing right journal to publish our paper in good journal. We also studied about manuscript preparation and their formatting. We discussed submission process, peer review process, and publication of article in good journal.

15.10 References

1. Chris A. Mack, “How to Write a Good Scientific Paper” Society of Photo-Optical Instrumentation Engineers, Bellingham, Washington, USA 2018.
2. Fritz Scholz, “Writing and publishing a scientific paper” Chem Texts, 8(8), 2022. https://doi.org/10.1007/s40828-022-00160-7.

UNIT 14: Scientific Writing and Communication: Structure of a Research Paper

14.1 Learning Objectives

In this chapter, the learning objectives for scientific writing and communication in structure of a mathematical research paper are as follows:

- To be able to explain the IMRaD (Introduction, Methods, Results, and Discussion) structure of a mathematical research paper.
- To be able to identify the key elements of each section of IMRaD structure in the context of mathematical research.
- To be able to develop the ability to write clear, concise and informative abstracts and select appropriate keywords.
- To structure mathematical arguments using definitions, theorems, lemmas, and proofs.
- To be able to apply advanced principles of scientific writing including coherence, precision and clarity in mathematical presentations.
- To be able to identify and apply ethical standards in academic writing, including avoiding plagiarism and giving proper credit.

14.2 Introduction

Effective scientific communication is essential for sharing research findings. In most scientific domains, research articles have the IMRaD structure which includes an Introduction, Methods, Results, and Discussion [1,2].

This framework enables authors to organize and present their research in a clear and systematic manner. However, in mathematical research papers, its structure often deviates from the traditional format; this is because it incorporates definitions, lemmas, theorems, and proofs within sections titled 'Methods' which serve to elucidate the underlying methodology and analytical processes. A well-structured mathematical research paper should

clearly explain the origin and formulation of the equation, specify the assumptions and conditions under which the model is valid, present the step-by-step derivation of the solution using appropriate mathematical reasoning, and provide a meaningful interpretation of the obtained results within the context of the problem under investigation.

In the upcoming sections, we examine how to structure a mathematical research paper. We explain each IMRaD section's purpose, and discuss writing techniques specific to mathematics. We also cover writing of abstracts and keywords, methods for structuring arguments, principles of clear exposition, and ethical issues like plagiarism. By the end of this chapter, you will know how to write a coherent and formatted and structured publication ready article or chapter of mathematical research according to academic standards.

14.3 IMRaD Structure

IMRaD framework is a standard structure in research writing. It consists of four major sections-Introduction, Methods, Results, and Discussion. The forthcoming sections discuss them one by one.

14.3.1 Introduction

The Introduction is the first stage of the IMRaD framework. It explains the problem and its important. An introduction describes the topic under investigation, summarizes relevant prior research, identifies unresolved issues that the current research will address, and outlines the objectives of the research paper. In mathematical research, the Introduction section presents the central problem or research question, such as a real-world phenomenon modeled through mathematical equations, a conjecture to be investigated, or a geometric and analytical construction to be studied. It also provides the necessary background, motivation, and theoretical context, highlighting the significance of the problem and its relevance within the broader field of mathematics or its applications.

Ideally, the introduction summarizes existing knowledge (citing earlier theorems or findings), identifies any gaps or restrictions, and then outlines the objectives of the current work. It may mention the main theorem informally or state the key result, and generate scholarly understanding about the problem. The idea is to motivate the reader: emphasize

the significance of the work and novelty before delving into details. An effective introduction, thus, sets up a good balance between literary background of the problem or gap and a clear explanation of the research objectives.

14.3.2 Methods

The methods section of a scientific research paper occupies a central position within the IMRaD structure as it includes the analytical techniques, assumptions, definitions, and proof strategies used to investigate the research problem. It provides a logically structured framework that enables readers to understand the mathematical approach and verify the validity of the results. In the experimental sciences, the methods section describes laboratory procedures, instrumentation, data collection mechanisms, sampling strategies, and statistical analyses. However, in mathematics, the meaning and structure of the methodology differ significantly. Mathematical inquiry is primarily deductive rather than experimental, consequently this section emphasizes logical reasoning, analytical frameworks, assumptions, theorem-proving strategies, modeling principles, computational techniques, and symbolic manipulations. The objective of this section is not merely to recount what was done, but to provide sufficient conceptual and technical clarity to enable another mathematician to understand, verify, replicate, or extend the investigation. This section also provides the scope for new notations or definitions that are required for the proposed research. In practice, many mathematical articles incorporate methods within the argument, typically at the beginning of proofs, but the author must still ensure that the reader understands the general strategy.

The explanation of proof techniques is a crucial component of the methods section in mathematical research. Mathematical proof is the fundamental mechanism through which truth is established in mathematics. Different branches of mathematics employ distinct proof strategies, and this section introduces the primary proof methodology utilized in the research paper. Common proof techniques include direct proof, proof by contradiction, mathematical induction, contrapositive reasoning, constructive methods, variational arguments, and fixed-point approaches. For instance, if a research paper is primarily based on induction, this section might explain how recursive structures are analyzed step-by-step. Similarly, if the study employs arguments by contradiction, this section may indicate how the negation of the desired conclusion leads to an inconsistency with established assumptions.

In advanced mathematical research, this section often includes a discussion of the existing theorems and fundamental results upon which the research is based. The nature of mathematics is cumulative, and therefore, new results often depend on previously established principles. A researcher working in functional analysis might draw upon the

Banach fixed-point theorem, Hahn-Banach theorem, or the spectral theorem. Similarly, a research paper on differential equations might utilize Gronwall's inequality, the Sturm comparison theorem or Lyapunov's direct method. The section should clearly articulate how these existing tools have been incorporated into the current research. Such integration demonstrates scholarly continuity and situates the research within the broader context of mathematical literature.

Another significant feature of this section is to explain the mathematical approach adopted to investigate the problem. Many mathematical problems can be solved through various approaches like as optimization procedures, analysis of variance, algebraic techniques, geometric reasoning, topological methods, numerical approximations, or computational simulations. Therefore, in this section, it is absolutely essential to provide an explanation as to why adopting a particular approach is appropriate. Here, we discuss an approach for stability analysis in biomathematics research. This section describes the analytical techniques used to study the qualitative behaviour of the proposed model. A standard approach involves equilibrium and stability analysis of the governing system of differential equations. First, the biologically feasible equilibrium points are determined by setting the time derivatives equal to zero. These equilibrium states generally represent important biological conditions such as disease-free, endemic or coexistence states [5]. To investigate the local stability of each equilibrium point, the Jacobian matrix of the system is constructed and evaluated at the equilibrium points. The characteristic equation associated with the Jacobian matrix is then obtained, and the eigenvalues are analyzed. If all eigenvalues possess negative real parts, the equilibrium is considered locally asymptotically stable, otherwise, it is unstable. For higher-dimensional systems, criteria such as the Routh–Hurwitz conditions are often applied to determine stability without explicitly solving eigenvalues. In epidemiological and population dynamics models, threshold quantities such as the basic reproduction number are also derived to describe the persistence or extinction of a disease or species population. Furthermore, global stability may be examined using Lyapunov functions or LaSalle’s invariance principle [9].

Also, the role of assumptions in mathematical methods cannot be underestimated. Every theorem, model, or proof relies on assumptions that determine its validity. In mathematical writing, assumptions must be stated explicitly and systematically. Hidden assumptions create logical flaws, thereby undermining the robustness of the research. Therefore, in the methods section, conditions such as continuity, differentiability, boundedness, compactness, linear independence, invertibility, or positivity should be carefully identified whenever necessary. For instance, a theorem concerning the convergence of a numerical algorithm is valid only if its underlying function satisfies the condition of 'Lipschitz continuity.' Failure

to explicitly state this assumption may lead readers to misapply the result in inappropriate contexts.

For instance, consider a population growth model represented by the differential equation

$$\frac{dP}{dt} = rP\left(1 - \frac{P}{K}\right).$$

Here, P denotes the population size, r represents the intrinsic growth rate, and K indicates the carrying capacity. In the methods section, the researcher should clarify not only the equation itself but also the underlying assumptions of the model. These assumptions may include a homogeneous mixing of the population, stable environmental conditions, or the absence of migration effects. Such clarifications are crucial, as they define the scope and limitations of the mathematical investigation.

Clarity of notation is also crucial in mathematical methods. Vaguely defined symbols create confusion and hinder understanding. Therefore, researchers must maintain consistency in notation throughout the research paper. If, in a particular context, the symbol 'x' denotes a variable, then in another context, it should not be abruptly used without any explanation to represent a parameter or a vector. Similarly, the use of exponents, subscripts, and superscripts should also be systematic. This section often includes a notation table or an introductory sub-section that standardizes terminology and symbols. Such practices significantly enhance readability and minimize interpretive errors.

Computational mathematics adds an additional dimension to the methods section. Modern mathematical research increasingly relies on symbolic computation software, numerical simulations, and algorithmic analysis. When computational tools are employed, it is essential to provide detailed information in the methods section regarding the algorithms, convergence criteria, software environment, and computational parameters. Suppose a researcher is investigating the eigenvalues of a large matrix using iterative methods. In such scenario, it must explicitly state whether the Power Method, QR Algorithm, Jacobi Iteration, or Arnoldi Process was utilized. Furthermore, the researcher should discuss issues such as computational complexity, stability, truncation error, and numerical precision. Such clarifications ensure that the computational process remains transparent and reproducible.

The organization of the methods section is another important aspect of scientific writing. A well-structured methods section proceeds in a logical sequence- ranging from a general overview to detailed analysis. This section begins with definitions and assumptions, followed by methodological tools, analytical procedures, proof strategies, computational

techniques, and validation mechanisms. Logical continuity is of utmost importance, as mathematics is based on cumulative reasoning. Each step of the methodology must be naturally linked to its preceding step, enabling the reader to follow the sequence without any confusion.

Consider a study involving eigenvalue analysis of matrices. Suppose the matrix under consideration is

$$A = \begin{pmatrix} 2 & 1 \\ 1 & 2 \end{pmatrix}.$$

In this type of study, the methodology section may explain how eigenvalues are determined using characteristic equations. The researcher can clarify that eigenvalues are derived from the determinant equation.

$$\det(A - \lambda I) = 0.$$

This section could further discuss why spectral analysis is crucial for understanding the stability, modes of vibration, or long-term behavior of dynamical systems. Rather than merely presenting calculations, the methods section frames this process within the context of a broad mathematical objective.

In research involving differential equations, the methods section frequently explains existence and uniqueness techniques. Suppose a researcher studies the initial value problem

$$\frac{dy}{dt} = f(t, y), y(t_0) = y_0.$$

The methods section may state that the Picard–Lindelöf theorem is employed to establish existence and uniqueness of solutions under Lipschitz continuity conditions. The researcher may further explain iterative approximation procedures and convergence arguments used to construct the solution. Such methodological explanations reveal the logical pathway connecting assumptions to conclusions.

In the brief, the explanation provided in this section must be sufficiently precise to enable another mathematician to replicate the proof or calculation. Each theorem (along with its associated corollaries) should be clearly presented and subsequently proven. Mathematical equations must be numbered and referred to by their names or descriptions, rather than merely by their numbers. Equations and formulas should be integrated alongside the main narrative, rather than being left in isolation. If there are calculations, such as solving an equation or examining a matrix, it should be presented in a logical order with explanations for each step.

14.3.3 Results

The Results section presents the principal findings of the research and addresses the fundamental question: what has been discovered through the study? In experimental or empirical research, this section typically contains observational data, computational outputs, and statistical analyses. In contrast, mathematical research emphasizes rigorous theoretical outcomes in the form of theorems, lemmas, propositions, corollaries, and analytical results, often supported by detailed proofs or proof sketches.

The presentation of results should remain clear, objective, and logically organized, without unnecessary interpretation or personal bias. Each result must directly follow from the methods and assumptions introduced earlier in the paper. For example, in mathematical biology and related applied fields, this section may also include equilibrium analysis, stability conditions, bifurcation results, numerical simulations, graphs, or comparative tables that illustrate the behaviour of the model under different parameter settings.

14.3.4 Discussion

Generally, the Discussion section in a scientific paper provides an interpretation and explanation of the findings. It answers ‘What do the results mean?’. It highlights how the obtained findings compare with existing theories, previous studies, or known mathematical results. In this section, numerical simulations could be included to validate the analytical findings. For example, a study on an epidemic model may present results showing the existence of disease-free and endemic equilibrium states, derive conditions for local or global stability, and demonstrate through numerical simulations how variations in transmission or recovery rates influence disease dynamics over time [8].

Finally, recommend future research or open challenges. Mention if the findings lead to new conjectures or applications.

14.4 Abstract

An abstract is a brief overview of the entire research paper very much like the trailer of a film. It should include the motivation, key goal, and primary results in a few sentences. Before reading the full research article, researchers, reviewers, editors, and indexing systems examine its abstract to determine the study's significance, originality, and relevance. Therefore, an effective abstract must present the main objective, methodology, key findings, and results of the research in a clear, logical, and organized manner. In mathematical writing, an abstract begins with a concise description of the research problem or the broader mathematical context. This introductory section provides a clear indication of the field of

investigation such as differential equations, matrix theory, numerical analysis, optimization, probability, dynamical systems, or topology. For instance, an abstract in mathematical research may begin as follows:

> In this study, we examine the first-order linear differential equation $y' + p(x)y = q(x)$ and analyze its qualitative behavior under suitable assumptions on the coefficient functions. By employing the method of integrating factors, we derive the general analytical solution and apply the results to a population growth model. Furthermore, we establish an existence and uniqueness theorem for solutions corresponding to a broad class of functions $p(x)$ and $q(x)$.

In mathematical research, an abstract should avoid unnecessary notation and utilize easy-to-understand language. It should clearly establish the problem being addressed along with its context, state the main outcomes in simple terms, and describe the methods utilized.

14.5 Keywords

Keywords are a set of 4-6 important terms that are crucial in the context of the paper. Keywords are significant terms or phrases that enhance the searchability and retrieval value of a research paper for both the readers and the indexing systems. Good keywords are specific, not wide. For example, in the sample abstract given in section 14.4 the keywords can be: Differential Equation, Integrating Factor, Existence and Uniqueness, Population Growth Model.

One should avoid generic terms like ‘Mathematics’ and instead use precise terms related to the topic. Keywords such as ‘Analysis’ or ‘Equations’ are often ineffective as they fail to distinguish the paper from thousands of other, unrelated studies. A general method to identify keywords is through the frequency of occurrence of the term/s in the entire paper. If a research paper introduces a new numerical algorithm, the name of the algorithm or its methodological framework should be included in the keywords. Similarly, if the research relates to eigenvalue analysis, optimization, stochastic modeling, or bifurcation theory, such terms should be explicitly included. For example, in a research paper related to nonlinear differential equations and stability analysis, appropriate keywords might include ‘Nonlinear dynamical systems, Lyapunov stability, Differential equations, Equilibrium Analysis.’ Many journals or disciplines also have standard keyword lists, which authors may use.

Now we discuss about the writing technique of a mathematical research paper in the following section.

14.6 Mathematical Writing Techniques

A good mathematical exposition balances explanatory text with symbolic expressions so that formulas are properly interpreted and connected to the discussion. Instead of presenting long sequences of equations without explanation, authors should introduce concepts in words, display the relevant mathematical expressions, and then explain their significance. Proper punctuation and smooth transitions improve readability and coherence of the research paper.

For example, while discussing a linear first-order differential equation, a well-structured explanation may write: Consider the differential equation of the form $y' + p(x)y = q(x)$. To solve it, we use the integrating factor $\mu(x) = e^{\int p(x)\,dx}$. Now, multiplying the equation by the integrating factor transforms the left-hand side into an exact derivative, which can then be integrated directly to obtain the general solution

$$y(x) = e^{(-\int p(x)dx)}\left(C + \int e^{(\int p(x)dx)} q(x)dx\right),$$ where C is constant.

In this presentation, the formulas are fully connected to the surrounding explanation, enabling the reader to follow the reasoning process naturally. We present the final solution after defining the integrating factor and demonstrating how it makes the equation simpler. It is important to note that the final formula is embedded in the sentence, and after deriving it, one would comment on its meaning or how it is used in the paper. Rather than presenting the formula separately, this description fully explains the method and results in prose form.

Let us understand it through another example in applied mathematics and mathematical biology. One may write: Consider the autonomous system $\dot{x} = -x,\ \dot{y} = -y$. To study the stability of the equilibrium point, we construct a Lyapunov function [5] and evaluate its derivative along system trajectories. The Lyapunov function may be expressed as

$$V(x, y) = \mathrm{x}^2 + y^2.$$

Here, the derivative of $V(x, y)$ is $\dot{V} = 2x\dot{x} + 2y\dot{y}$ which is negative for non-zero equilibrium. Therefore, non-zero equilibrium point is asymptotically stable. Such writing clearly explains the purpose of the Lyapunov function, the meaning of the computation, and the significance of the stability result.

Another important technique is the use of signposting and structural guidance. Each section should clearly state its purpose, and proofs should include brief explanations so that the readers can understand logical argument. Every new term, notation, and variable should be clearly defined before use [3,4]. The use of examples, diagrams, graphs, and counterexamples can further enhance understanding by illustrating abstract mathematical

ideas in a more intuitive manner. Overall, effective mathematical writing combines rigor with clarity, making complex ideas accessible and logically connected.

Further, the importance of advanced writing principles and ethical writing is discussed. It is also crucial part of research paper.

14.7 Advanced Writing Principles

Coherence and logical rigor should be the goals of mathematical writing at a higher level. The organized approach as discussed in this chapter (Section 14.3) emphasizes clarity, coherence, and logical flow. Each sentence and paragraph must link to the one before it in order to accomplish this, creating a narrative chain. It is important to maintain consistency in the language and notations, as well as in the way to present findings [3].

Precision in writing means that every statement must be logical. Avoid unnecessary details that obscure the main idea. One must note insert a conclusion without reasoning. The level of explanation should be tailored as per the audience. For example, postgraduate students may require more details than specialist researchers. As an author, resist the temptation to cram many ideas into one long sentence. Breaking them apart often improves clarity. Use short paragraphs, each focusing on a single idea. In short, write with the reader in mind, present the content with a clear and logical flow like a story. Good mathematical writing is not only technically sound but also leads the reader through the beginning, middle and ending of the research problem.

14.7.1 Ethical Writing

Academic writing is based on the principle of ethical behavior. Reproducing another person's words or ideas without giving them the due credit is unethical. This comes under the plagiarism which is a serious offense [7]. According to the ethical guidelines of the American Mathematical Society (AMS), "the knowing presentation of another person's mathematical discovery as one's own" constitutes a serious ethical transgression, known as plagiarism in mathematics. The standard definition of plagiarism is the adoption of another person's ideas, methods, or written words without acknowledgment. Authors are required to provide proper citations to all the results, methods, and phrases that they have borrowed from prior literature. Even ideas that are rephrased must be attributed. Copying without attribution is widely considered a serious form of ethical misconduct and can damage author’s credibility.

Another ethical concern is authorship. The list of authors should only include those who have made intellectually significant contributions to the work. The AMS guidelines state that "each co-author should have made a significant contribution" and "all such contributors should be given the opportunity to be listed as authors". Additionally, each of the mentioned authors is accountable for the content.

Misconduct is another ethical concern. It includes submitting the same work to several journals or dividing results incorrectly [6]. Maintaining integrity requires that all references be properly cross-checked, results be presented honestly and attribution guidelines be followed. Ethical writing can be understood more clearly by examining examples of unethical writing practices. Unethical writing occurs when a researcher presents borrowed ideas, data, or language as original work, manipulates results, or fails to acknowledge sources properly. The following examples illustrate common unethical practices and explain why they violate academic ethics. Unethical Sentence: **‘w**e developed the classical Lotka–Volterra predator–prey model’. This statement is unethical because the model was originally developed by Alfred J. Lotka and Vito Volterra.

In short, ethical writing means being truthful and transparent, both in terms of content and attribution. Acknowledge the efforts of others, report results honestly, and give due credits to everything that is not your own.

14.8 Summary

This chapter explains how to write a mathematical research paper in a systematic and professional manner. The IMRaD framework—Introduction, Methods, Results, and Discussion, as a guide provides the structure for the overall content of a research paper to be organized in the field of mathematical research. The Introduction should motivate the readers to understand the problem and identify the goals. Methods section explains the analytical techniques, assumptions, definitions, and proof strategies employed to investigate the research problem. It provides a logically structured framework that enables readers to comprehend the mathematical approach and verify the validity of the results. The discussion section interprets the mathematical findings in the context of the original problem, existing theories, or practical applications. It highlights the significance, limitations, and potential extensions of the results while the Results section provides the outcome of the research which may include theorems or proofs rather than just the experimental data. An abstract and keywords help readers recall the main points of a research paper.

This unit highlights key strategies for mathematical research such as organizing content into coherent sections, using consistent notation, and guiding the reader through previews and

summaries. Finally, ethical concerns like citing re/sources and honestly attributing authorship are addressed.

Self-Assessment Questions

1. What is the IMRaD structure and what is its purpose in structuring a research paper?
2. What key elements should be included in the Introduction section?
3. How would you describe the role of a Methods section in a mathematics research paper?
4. What does a Results section contain in a mathematical research article?
5. What kind of content should be included in the Discussion or Conclusion section of a mathematical research article?
6. List the key components of a well-written abstract and how keywords should be selected.
7. Why is consistent notation important in a mathematical manuscript? Give an example.
8. Define plagiarism in the context of academic writing and explain why it is considered serious misconduct.

Exercises

1. **Abstract Writing:** Write an abstract (including 3–5 keywords) for a hypothetical study introducing a new analytic method for solving the logistic differential equation $y' = ay(1 - y/K)$. Summarize the problem, approach, and main result in clear, accessible language.
2. **Section Identification:** Imagine you have an outline for a research paper titled 'Stability Analysis of a size structure Population Model' Briefly outline what information should appear in the Introduction, Methods, Results, and Discussion sections of this paper.
3. **Discussion Writing:** Suppose you have a research paper on Lyapunov stability of nonlinear control systems, write a short discussion paragraph explaining the significance of the result.
4. **Keyword Selection:** Suppose you have a paper on Lyapunov stability of nonlinear control systems. List 4–5 appropriate keywords for this paper and justify each choice briefly.

5. **Attribution Exercise:** Rewrite the following sentence to properly credit the source/author: ‘the number e is the unique number whose exponential series has these coefficients.’ (Assume the author is Euler.)
6. **Introduction Outline:** Draft an outline of topics to be covered in the Introduction of a paper on ‘Eigenvalues of Symmetric Matrices.’ Indicate at least three main points (e.g., background context, known results, the main goal) that should be addressed.

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Unit-17: Peer Review Process in Mathematical Research

Structure of Unit

17.0 Objective
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17.2 The Concept of Peer Review
17.3 The Importance of Peer Review
17.4 Types of Peer Review
17.5 Contributors to the Peer Review Process
17.6 Stages of the Peer Review Process
17.7 Common Reviewer Comments in Mathematics
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17.0 Objective

This chapter aims to provide a comprehensive understanding of the peer review process in academic research, emphasizing its purpose, stages, and ethical foundations. It also seeks to develop students' ability to understand and respond effectively to reviewer comments, and to revise and resubmit manuscripts professionally. By the end of this chapter, students will possess the practical knowledge and critical perspective necessary to participate confidently and responsibly in the international scholarly publishing process.

17.1 Introduction

The peer review process is a crucial component of modern academic research and scholarly publishing. In mathematics, where accuracy, logical consistency, originality, and clarity are paramount, peer review plays a vital role in ensuring the quality and credibility of published research for the M.Sc. Mathematics students understand that the peer review process is essential not only for publishing research papers but also for developing critical thinking, academic writing skills, and professional research ethics.

This chapter provides a comprehensive and detailed discussion of the peer review process, including its importance, the various stages involved, types of peer review, the roles of authors, reviewers, and editors, and practical guidance on responding to reviewer comments and revising manuscripts for resubmission.

17.2 The Concept of Peer Review

17.2.1 Definition of Peer Review

Peer review is a systematic evaluation of a research manuscript by experts (peers) in the same or similar fields before it is accepted for publication. These experts assess the quality, originality, accuracy, relevance, and significance of the submitted work.
In mathematics, peer review typically focuses on:

- Mathematical accuracy and rigor
- Novelty of results
- Sufficiency of proofs
- Relevance to existing literature
- Clarity of definitions, theorems, and notation

17.2.2 Historical Background

The concept of peer review can be traced back to the 17th century with the establishment of scientific journals such as the *Philosophical Transactions of the Royal Society*. Over time, peer review has evolved into a formalized system adopted by virtually all reputable mathematical journals and academic publishers.

17.2.3 Peer Review in Mathematics vs. Experimental Sciences

In experimental sciences, the primary emphasis of peer review is on the reproducibility of experiments, the validity of data, and the appropriateness of experimental design and

statistical analysis. Reviewers assess whether the reported results can, in principle, be independently replicated under similar conditions.

In contrast, peer review in mathematics is primarily concerned with logical rigor and theoretical soundness. Since mathematical results are derived through deductive reasoning rather than empirical experimentation, reviewers focus on the accuracy and completeness of proofs, the consistency of definitions, and the clarity of arguments. Each step of a proof may be examined in detail to ensure that the conclusions logically follow from the stated assumptions.

Consequently, the peer-review process in mathematics is often more time-consuming than in many experimental disciplines. This extended duration reflects the high level of precision required, rather than inefficiency. The result is an exceptionally rigorous review process that contributes to the long-term reliability and enduring validity of the mathematical literature.

17.3 The Importance of Peer Review

17.3.1 Quality Assurance

Peer review serves as a quality control mechanism, ensuring that only accurate, meaningful, and original mathematical results reach the research community.

17.3.2 Validation of Results

Reviewers verify the accuracy of proofs, assumptions, and logical arguments. This is particularly crucial in mathematics, where even minor logical flaws can invalidate an entire result.

17.3.3 Manuscript Improvement

Constructive feedback from reviewers helps authors improve the clarity, structure, and presentation of their work. Many high-quality papers achieve their final form only after several rounds of peer review.

17.3.4 Filtering and Selection

Given the large number of submissions journals receive, peer review helps editors identify manuscripts that meet the journal's scope and standards.

17.3.5 Academic Credibility and Trust

Peer-reviewed publications are widely considered reliable and trustworthy sources of knowledge. Academic degrees, promotions, grants, and recognition often heavily depend on peer-reviewed output.

17.3.6 Ethical Safeguard

Peer review acts as an essential ethical checkpoint in the research publication process. Reviewers help identify instances of plagiarism, improper citation practices, mathematical misrepresentation, and the reuse of existing results without attribution. They can also detect unintentional errors, unsupported claims, or misleading interpretations that could compromise the integrity of the research. By enforcing ethical standards, peer review promotes honesty, transparency, and responsible scholarly conduct within the mathematical community.

17.3.7 Preventing Unnecessary Research

Peer review helps prevent the publication of unnecessary or previously established results by ensuring that new submissions offer genuine originality or a meaningful extension of existing work. As experts in their field, reviewers are often familiar with the relevant literature and can identify overlap with known theorems or previously published findings.

17.4 Types of Peer Review

17.4.1 Single-Blind Peer Review

In a single-blind review, reviewers know the authors' identities, but the authors do not know the reviewers' identities.

Advantages:

- Reviewers can assess potential conflicts of interest
- Reviewers can evaluate the work in the context of the author's previous research
- Disadvantages:
- Potential bias based on the author's reputation or institution

17.4.2 Double-Blind Peer Review

In a double-blind review, both the authors and reviewers remain anonymous.

Advantages:

- Reduces bias related to gender, institution, or seniority
- Commonly used in mathematics journals
- Disadvantages:
- Complete anonymity can be difficult in specialized fields

17.4.3 Open Peer Review

In open peer review, both the authors and reviewers know each other's identities, and sometimes the review reports are published alongside the article.

Advantages:

- Transparency
- Accountability of reviewers

Disadvantages:

- Reviewers may be hesitant to provide critical feedback

17.4.4 Post-Publication Peer Review

Post-publication peer review refers to the evaluation of research after it has been made publicly available. In this model, manuscripts are often disseminated through preprint servers or open-access platforms before formal journal review. The broader research community can then assess, comment on, and critique the work.

In mathematics, platforms like arXiv, along with specialized review services such as MathSciNet and zbMATH, play a significant role in post-publication evaluation by providing detailed reviews, classifications, and scholarly commentary. This approach promotes the rapid dissemination of results while allowing for the identification of errors or shortcomings over time.

Advantages:

- Encourages open scholarly discussion and community engagement
- Accelerates the sharing of new mathematical ideas
- Allows for continuous evaluation after initial publication

Limitations:

- Quality control may be delayed
- Not all comments undergo formal editorial moderation
- Cannot replace traditional peer review for academic evaluation

17.4.5 Editorial Peer Review

In editorial peer review, the journal editor evaluates the manuscript without sending it to external reviewers. This model is typically used for invited articles, surveys, explanatory papers, or opinion pieces.

Advantages:

- Faster decision-making
- Suitable for authoritative or overview articles

Limitations:

- Limited external scrutiny
- Not suitable for original research articles

17.4.6 Cascading Peer Review

In cascading peer review, when a manuscript is rejected but deemed suitable for another journal, the reviewer reports are transferred between journals within the same publisher.

Advantages:

- Reduces repeated review efforts
- Speeds up the publication process

Limitations:

- Limited acceptance among traditional mathematics journals

17.5 Contributors to the Peer Review Process

The peer review system operates through the coordinated efforts of several contributors, each with clearly defined responsibilities. The integrity, quality, and reliability of scholarly publishing depend on the ethical and professional conduct of all participants involved in this process.

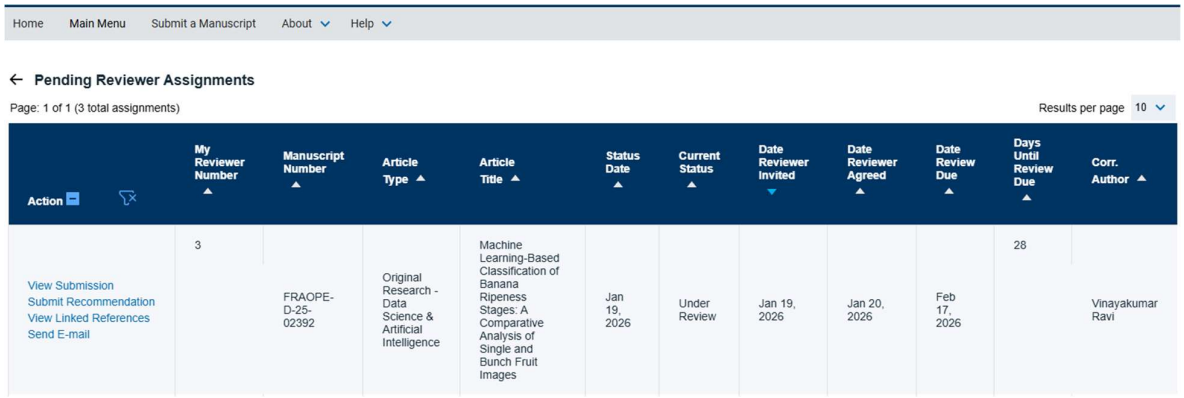
17.5.1 Role of Authors

Authors are the primary contributors to scholarly discourse and bear the initial responsibility for upholding academic standards. Their role includes:

- Submitting original research that makes a meaningful contribution to the existing body of knowledge
- Ensuring the accuracy of results, proofs, and references, especially in mathematical research
- Strictly adhering to the journal's guidelines regarding format, scope, and ethical policies
- Avoiding plagiarism, data manipulation, and duplicate submissions
- Responding to reviewers' comments respectfully, clearly, and within the specified timeframe

5.2 Role of Reviewers

Reviewers serve as subject-matter experts who critically evaluate manuscripts and assist editors in decision-making. Their responsibilities include:



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← Pending Reviewer Assignments

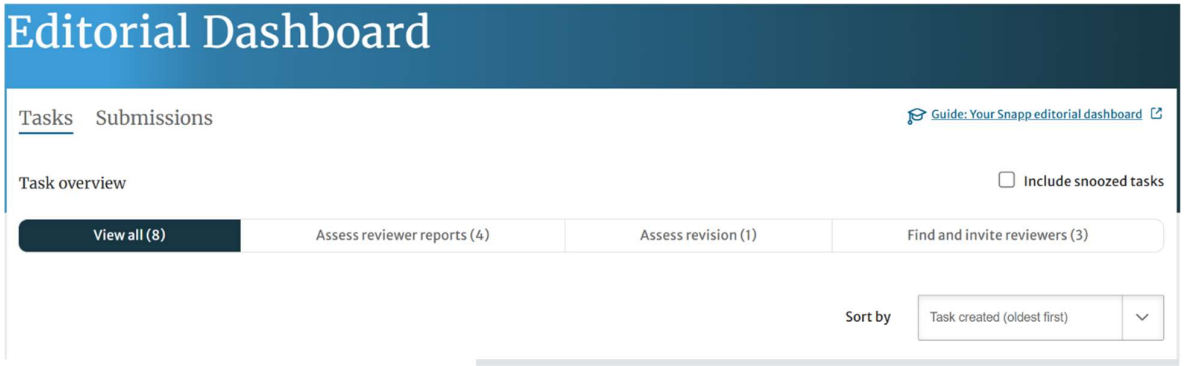
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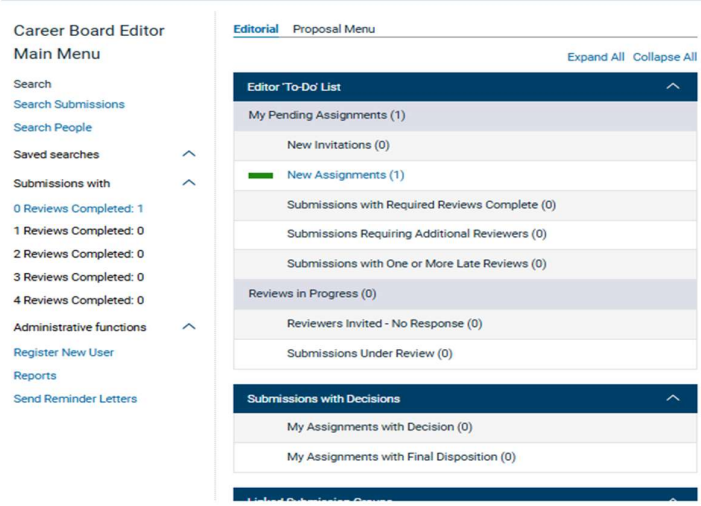
Action	My Reviewer Number	Manuscript Number	Article Type	Article Title	Status Date	Current Status	Date Reviewer Invited	Date Reviewer Agreed	Date Review Due	Days Until Review Due	Corr. Author
View Submission Submit Recommendation View Linked References Send E-mail	3	FRAOPE-D-25-02392	Original Research - Data Science & Artificial Intelligence	Machine Learning-Based Classification of Banana Ripeness Stages: A Comparative Analysis of Single and Bunch Fruit Images	Jan 19, 2026	Under Review	Jan 19, 2026	Jan 20, 2026	Feb 17, 2026	28	Vinayakumar Ravi

- Providing an objective, unbiased, and constructive evaluation of the manuscript
- Assessing the originality, accuracy, and significance of the results
- Carefully verifying logical arguments and mathematical proofs
- Maintaining the confidentiality of the manuscript and the review process
- Promptly declaring any potential conflicts of interest

17.5.3 Role of Editors

Editors oversee and coordinate the entire peer review process. They play a key role in ensuring fairness and quality in scholarly publishing. Editors are responsible for:





- Conducting initial screening of submissions for suitability and scope
- Selecting qualified and impartial reviewers
- Monitoring the review process to ensure timely completion
- Making final decisions based on reviewer reports and editorial judgment
- Upholding ethical standards and resolving conflicts or ethical concerns

17.5.4 The Role of Publishers

Publishers provide the infrastructure and policies that support the peer review system. Their responsibilities include:

- Establishing clear editorial and ethical guidelines
- Providing manuscript submission and review platforms
- Ensuring long-term accessibility and archiving of published work
- Supporting editorial independence and ethical publishing practices

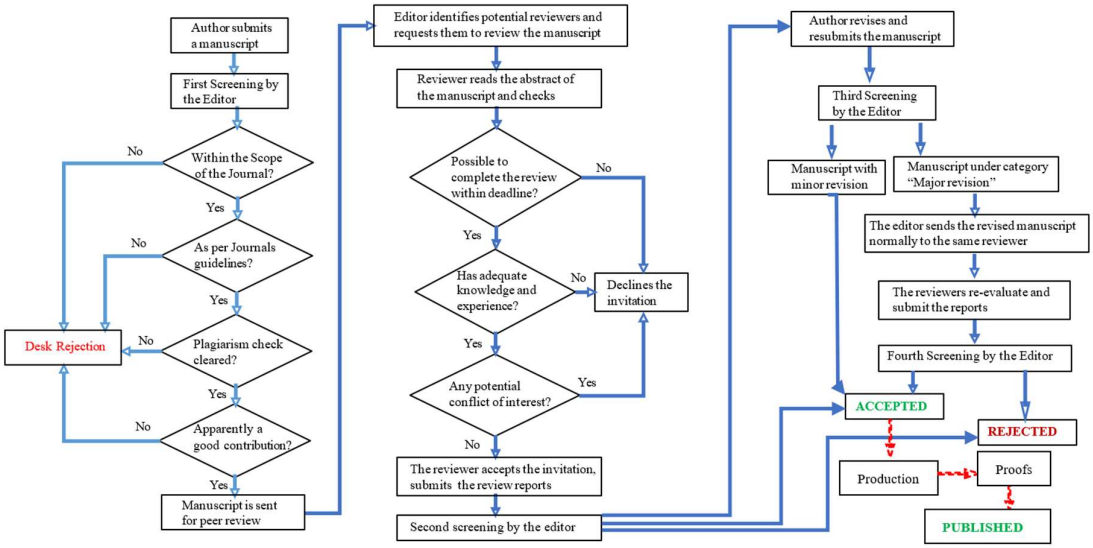
17.5.5 The Role of the Research Community

The broader research community contributes indirectly to the peer review process by:

- Engaging in post-publication discussion and critique

- Citing relevant and reliable peer-reviewed work
- Upholding standards of academic integrity and scholarly discourse

17.6 Stages of the Peer Review Process



17.6.1 Manuscript Preparation

Before submission, authors must ensure that the manuscript:

- is complete and well-structured
- follows the journal's formatting guidelines
- includes correct references and citations

17.6.2 Submission to the Journal

Manuscripts are submitted through the online journal management system. Authors are required to provide metadata, a cover letter, and declarations regarding originality and ethics.

17.6.3 Editorial Screening (Desk Review)

The editor conducts an initial assessment to check for:

- Scope and relevance
- Basic quality and originality
- Adherence to ethical standards

Manuscripts that fail at this stage may be rejected at the desk.

17.6.4 Reviewer Assignment

The editor selects experts with relevant expertise. Typically, two or more reviewers are invited.

17.6.5 Reviewer Evaluation

Reviewers evaluate the manuscript based on:

- Novelty and significance
- Accuracy of results
- Quality of presentation
- Adequacy of references

17.6.6 Review Reports and Recommendations

Reviewers submit detailed reports and recommend one of the following:

- Accept
- Minor revisions
- Major revisions
- Reject

17.6.7 Editorial Decision

Based on the reviewer reports, the editor communicates the decision to the authors.

17.7 Common Reviewer Comments in Mathematics

During the peer review process, reviewer comments on mathematical manuscripts typically focus on technical accuracy, logical structure, presentation quality, and connection to existing literature. Understanding common reviewer comments helps authors anticipate concerns and effectively improve their submissions.

17.7.1 Technical Comments

Technical comments are crucial to the review of mathematical research and often determine a manuscript's acceptability.

Common technical comments include:

- **Errors in proofs:** Reviewers may identify incorrect reasoning, improper steps, or logical flaws that compromise the validity of results.
- **Missing assumptions:** Necessary conditions or hypotheses may be omitted, leading to incomplete or misleading statements of theorems.
- **Incorrect or inconsistent notation:** Inconsistent symbols or non-standard notation can create ambiguity and hinder understanding.

Such comments require careful revision, as even minor technical flaws in mathematics can invalidate key conclusions.

17.7.2 Presentation-Related Comments

In addition to correctness, reviewers place great emphasis on a manuscript's clarity and readability.

Typical presentation-related concerns include:

- **Lack of clarity in definitions:** Definitions should be precise, unambiguous, and presented before use.
- **Poor organization:** A weak logical flow between sections, theorems, and proofs can obscure the main contributions of the work.
- **Inadequate explanations:** Overly brief proofs or missing intuitive explanations can make the paper inaccessible even to experts.

Addressing these comments often significantly improves the manuscript's overall quality and impact.

17.7.3 Literature Review Comments

A well-developed literature review places new results in a broader mathematical context.

Reviewers often comment on:

- **Missing key references:** Failure to cite original or recent relevant work may suggest insufficient familiarity with the field.
- **Insufficient comparison with existing results:** Authors are expected to clearly explain how their contributions advance, refine, or differ from previous studies.

Fully addressing these comments strengthens the research's scholarly standing and originality.

17.8 Responding to Reviewer Comments

Responding to reviewer comments is a crucial step in the scholarly publication process. A thoughtful and systematic response not only increases the likelihood of acceptance but also demonstrates the author's academic maturity and commitment to improving the quality of their work. In mathematics, where precision and logical rigor are paramount, reviewer feedback must be carefully addressed.

17.8.1 General Principles

Authors should view reviewer comments as constructive guidance rather than criticism. Effective responses are characterized by professionalism, clarity, and completeness.

Key principles include:

- Maintaining a polite and respectful tone throughout the response
- Addressing every comment raised by the reviewers, without exception
- Avoiding emotional, defensive, or dismissive language
- Viewing the review process as a collaborative effort to strengthen the manuscript

Even when comments seem critical, they often highlight genuine issues that require clarification or correction.

17.8.2 Preparing the Response Document

In most journals, authors are required to submit a separate response document to the reviewers along with the revised manuscript.

This document typically includes:

- Listing the reviewer's comments verbatim, often numbered for clarity
- Providing a point-by-point response to each comment
- Clearly indicating where changes have been made in the manuscript (page and line numbers, where possible)

This structured approach helps editors and reviewers assess how the manuscript has been improved.

17.8.3 Agreeing with Reviewers

When reviewer suggestions are valid and helpful, authors should openly embrace them. In such cases, authors should:

- Clearly acknowledge the reviewer's contributions
- Revise the manuscript as suggested
- Clearly state the nature of the revisions in the response document

Accepting constructive feedback improves the quality, clarity, and credibility of the mathematical work.

17.8.4 Disagreeing with Reviewers

Sometimes, authors may disagree with a reviewer's comments due to differences in interpretation or mathematical approach. In these situations, authors should:

- Provide a logical and well-explained justification
- Support their point using formal arguments, proofs, or authoritative references
- Maintain a respectful and objective tone even when expressing disagreement

A reasoned academic response is more effective than simply dismissing a comment without justification.

17.8.5 Example of a Reviewer Response

A clear and professional response helps reviewers understand how their feedback has been addressed.

Example:

- **Reviewer's Comment:** The proof of Lemma 3.2 lacks clarity and omits intermediate steps.
- **Author's Response:** We thank the reviewer for this valuable suggestion. The proof of Lemma 3.2 has been revised to improve clarity, and additional intermediate steps have been included to make the argument more explicit.

Such responses demonstrate attentiveness and a willingness to improve the manuscript.

17.8.6 Common Mistakes to Avoid

Authors should be careful to avoid these mistakes:

- Ignoring or only partially addressing reviewer comments
- Using dismissive or argumentative language

- Making revisions without clearly documenting them
- Submitting a revised manuscript without a response document

Avoiding these mistakes makes the revision process smoother and more successful.

17.9 Revising the Manuscript

Revision is a crucial part of the scholarly publication process. In mathematics, manuscript revision often involves both technical corrections and improvements in presentation. A carefully revised manuscript not only addresses the reviewers' concerns but also strengthens the logical structure, clarity, and overall impact of the research.

17.9.1 Types of Revisions

Revisions requested by journals are generally categorized as minor or major, based on the extent of changes required.

Minor Revisions:

These typically involve improvements in language, typographical errors, formatting changes, better word choice, or minor clarifications to definitions and explanations. Minor revisions do not alter the main results or conclusions of the manuscript.

Major Revisions:

Major revisions require significant changes, such as restructuring proofs, correcting significant logical issues, adding new lemmas or results, modifying assumptions, or reorganizing entire sections. These revisions can substantially enhance the mathematical accuracy or originality of the work.

Understanding the nature of the requested revisions helps authors allocate appropriate effort and time.

17.9.2 Strategies for Effective Revision

Effective revision requires a systematic and disciplined approach. Authors should:

- Carefully and clearly address all reviewer comments, ensuring that no points are overlooked.
- Improve clarity and logical flow by refining explanations, reorganizing arguments, and strengthening transitions between sections.

- Ensure consistency in notation, terminology, and formatting throughout the manuscript.
- Double-check proofs and arguments to confirm that the revisions have not introduced any new errors.

A revised manuscript should appear as a coherent and polished piece of scholarly work, rather than a collection of patched-together corrections.

17.9.3 Time Management

Most journals specify a deadline for submitting revised manuscripts, which can range from a few weeks to several months. Authors should:

- Develop a revision plan based on the scope of the necessary changes.
- Prioritize major conceptual or technical issues before addressing minor corrections.
- Allocate sufficient time for proofreading and final verification.

Effective time management is essential to meet the deadline while maintaining the mathematical quality and integrity of the manuscript.

17.9.4 Final Check Before Resubmission

Before resubmitting the manuscript, authors should:

- Confirm that all reviewer comments have been adequately addressed.
- Ensure that the revised manuscript adheres to the journal's formatting and submission guidelines.
- Double-check references, equations, and figures for accuracy.

A careful final check increases the likelihood of a favorable editorial decision.

17.10 Resubmitting the Manuscript

Resubmission is the final stage of the peer review cycle, during which authors submit a revised version of their work for further editorial review. A carefully prepared resubmission demonstrates scholarly responsibility, respect for the review process, and commitment to academic standards.

17.10.1 Preparing the Revised Manuscript

The revised manuscript should be prepared with meticulous attention to detail, ensuring transparency and adherence to the journal's requirements. Authors should:

- Clearly highlight all changes, using either tracked changes, colored text, or detailed references to the revised sections.
- Follow the journal's instructions regarding formatting, file naming, and revision presentation.
- Ensure that the revisions are consistent throughout the manuscript and do not introduce any contradictions or new errors.

A well-prepared revised manuscript helps editors and reviewers efficiently evaluate the changes.

17.10.2 Cover Letter for Resubmission

The cover letter accompanying the resubmitted manuscript plays a crucial role in communication. The cover letter should include:

- A summary of the main revisions made in response to the reviewers' comments.
- A reference to the attached response to the reviewer’s document.
- An expression of gratitude to the editor and reviewers for their constructive feedback.

A clear and courteous cover letter demonstrates professional academic conduct and facilitates editorial decision-making.

17.10.3 Second Round of Review

Following resubmission, the manuscript may undergo a second round of evaluation. This may involve:

- Review by the original reviewers, who assess whether their comments have been adequately addressed.
- Review by new reviewers, particularly if significant revisions have been made or if additional expertise is needed.

In some cases, if the revisions are deemed satisfactory, the editor may make a final decision without further external review.

17.10.4 Editorial Decision After Resubmission

Following the second round of review, the editor may decide to:

- Accept the manuscript
- Request further minor revisions
- Reject the manuscript if significant concerns remain unresolved

A clear and thorough resubmission significantly increases the likelihood of acceptance.

17.11 Rejection and Its Role in Research

Rejection is an essential part of scholarly publishing and plays a constructive role in shaping high-quality research. Understanding rejection as part of the academic process helps researchers grow intellectually and professionally.

17.11.1 Understanding Rejection

Manuscript rejection is common in academic research and should not be viewed as a failure on the researcher's part. Rejection can occur due to reasons such as a mismatch with the journal's scope, lack of novelty, presentation issues, or methodological concerns. Even strong mathematical results can be rejected if they don't align with a journal's objectives. Viewing rejection as a learning opportunity allows authors to reflect on the feedback and strengthen their work.

17.11.2 Improving After Rejection

A rejected manuscript often benefits from careful revision before resubmission elsewhere. Authors can:

- Improve the clarity and structure of proofs and arguments
- Address shortcomings identified by reviewers
- Strengthen the literature review and the relevance of references
- Submit the revised manuscript to a more suitable journal

17.11.3 Emotional and Professional Aspects

Rejection can be discouraging, especially for early-career researchers. Emotional resilience is crucial for maintaining motivation over the long term. Professional researchers learn to separate personal feelings from scholarly criticism and utilize feedback constructively. Persistence, patience, and continuous improvement are key characteristics of a successful research career.

17.11.4 Rejection as a Quality Enhancement Mechanism

From an academic perspective, rejection helps maintain the overall quality of scholarly literature. By filtering submissions and promoting improvements, the peer review system helps ensure that published research meets accepted standards of rigor, originality, and clarity.

17.12 Ethical Issues in Peer Review

Ethical conduct is fundamental to the integrity and credibility of the peer review process. Since reviewers and editors are entrusted with unpublished scholarly work, adherence to ethical standards ensures fairness, trust, and professionalism in academic publishing.

17.12.1 Confidentiality

Confidentiality is a cornerstone of peer review. Reviewers must treat submitted manuscripts as privileged documents and should not share, discuss, or use the ideas, data, or results contained within them for personal or professional gain. Any information obtained through the peer review process must remain confidential even after the review process is complete. Breaches of confidentiality undermine trust in the academic system and can have serious professional consequences.

17.12.2 Conflicts of Interest

Conflicts of interest arise when personal, professional, or financial relationships could influence the objectivity of authors, reviewers, or editors. All stakeholders have a responsibility to disclose potential conflicts promptly. Reviewers should decline to review manuscripts when conflicts of interest arise, such as close collaborations with the authors or direct competition in the same research area. Transparent disclosure helps maintain fairness and credibility in editorial decisions.

17.12.3 Reviewer Misconduct

Reviewer misconduct includes biased evaluations, unfair criticism, intentional delays, or misuse of confidential information. Editors play a crucial role in identifying and addressing such behavior. Journals may take corrective actions such as assigning new reviewers, issuing warnings, or removing reviewers from the editorial panel. Ensuring ethical reviewers conduct protects authors and maintains the integrity of the peer review system.

17.12.4 Editors' Ethical Responsibilities

Editors must ensure that the peer review process is fair, impartial, and timely. They are responsible for selecting qualified reviewers, managing conflicts of interest, and making decisions based solely on scholarly merit. Editors also act as guardians of ethical standards, addressing complaints and ensuring transparency throughout the publication process.

17.13 Peer Review in the Age of Preprints

The emergence of preprint servers like arXiv has transformed scholarly communication by enabling the rapid dissemination of research findings before formal peer review. Preprints are particularly popular in mathematics, physics, and computer science, where sharing results quickly fosters discussion and collaboration.

While preprints offer advantages such as increased visibility and faster feedback, they do not replace traditional peer review. Preprint manuscripts have not been evaluated yet; therefore, they should be interpreted with caution. Peer review remains essential for verifying correctness, originality, and academic rigor. In modern research practice, preprints and peer-reviewed publications coexist, complementing each other in the dissemination of scientific knowledge.

17.14 Summary

This chapter provides a detailed explanation of the peer review process, emphasizing its importance, stages, and ethical considerations. Particular attention is given to responding to reviewer comments and revising the manuscript—essential skills for M.Sc. mathematics students. A thorough understanding of peer review prepares students for successful participation in the global research community.

17.15 Self-Learning Exercise

1. What is the main purpose of peer review?

2. Why is peer review so rigorous in mathematics?

3. List the main stages of the peer review process.

4. How does double-blind peer review reduce bias?

5. Why are reviewer comments still important even when a paper is rejected?

6. What is the role of editors in the peer review process?

7. Why should authors respond to every reviewer's comment?

8. What is the difference between minor and major revisions?

9. Why is emotional restraint important when responding to reviews?

10. How are preprints related to peer review?

11. What are the ethical responsibilities of reviewers regarding confidentiality?

12. Why is rejection considered a normal part of research?

13. How can authors respectfully disagree with reviewers?

14. What is the importance of consistency in notation during revisions?

15. How does peer review contribute to academic credibility?

17.16 Exercises

1. Describe the entire peer review process followed by a typical mathematics journal.

2. Compare single-blind and double-blind peer review with examples.

3. Explain why proof verification is central to mathematical peer review.

4. Draft a professional response to a reviewer requesting clarification of a theorem.

5. Discuss the ethical issues that arise during peer review.

6. Differentiate between minor and major manuscript revisions.

7. Analyze the advantages and limitations of open peer review.

8. Explain the role of editors in handling reviewer misconduct.

9. Discuss how rejection can improve the quality of research output.

10. Write a short note on peer review in the age of preprint servers.

11. Explain why reacting emotionally to reviewer comments is discouraged.

12. Examine the importance of time management during manuscript revision.

17.17 References

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Unit-20: Scientific Methods

Structure of Unit

20.0 Objective
20.1 Introduction
20.2 Steps of Scientific method
20.3 Origins of Scientific Methods
20.4 Key Principles of Scientific Method
20.5 Hypothesis Formulation
20.6 Role of Critical Thinking and Skepticism
20.7 Skepticism Thinking in Mathematical Research
20.8 Interrelationship between Critical Thinking and Skepticism
20.9 Case Studies of Scientific breakthroughs
20.10 Summary
20.11 Answers to Self-learning exercises
20.12 Exercises
20.13 References

20.0 Objectives

This unit introduces scientific methods, principles of scientific methods as well as origin and steps required in scientific methods. We shall study about data collection, hypothesis formulation and its types. Role of critical thinking and skepticism in mathematical research and case studies having importance for explaining various problems

20.1 Introduction

The Scientific method is the method of quantitatively creating realities through analysis as well as investigation. The elementary process involves creating statement, forming a hypothesis, making forecast, conducting an experimentation and finally analysing the outcomes. The Principles of the scientific method can be functional in various parts, including scientific research, commercial and equipment.

20.2 Steps of Scientific method

The scientific method customs successions of steps to create realities or generate information. The global development is well recognized, nonetheless the essentials of each step can change conditional on what is being scrutinized and who is accomplishment it. The scientific method can solitary answer queries that can be accepted or rejected over testing.

20.2.1 Make an Observation

The first step is to observe roughly that you would like to study about or ask a question that you would like answered. These may be rigorous or broad. Roughly examples would be “I observe that our total available network bandwidth drops at noon every weekday” or “How can we increase our website registration number ? ” Compelling the time to create a well-defined question will support you in future steps.

20.2.2 Collect Background Evidence

It involves liability investigation into what is already recognized approximately the topic. This can also include discovery if somebody has previously asked the similar question.

20.2.3 Create a Hypothesis

A hypothesis is a clarification for the opinion or inquiry. If established later, it be able to develop a fact. Roughly examples would be “Our employees watching online videos during lunch is using our internet bandwidth” or “Our website visitors do not see our registration form”

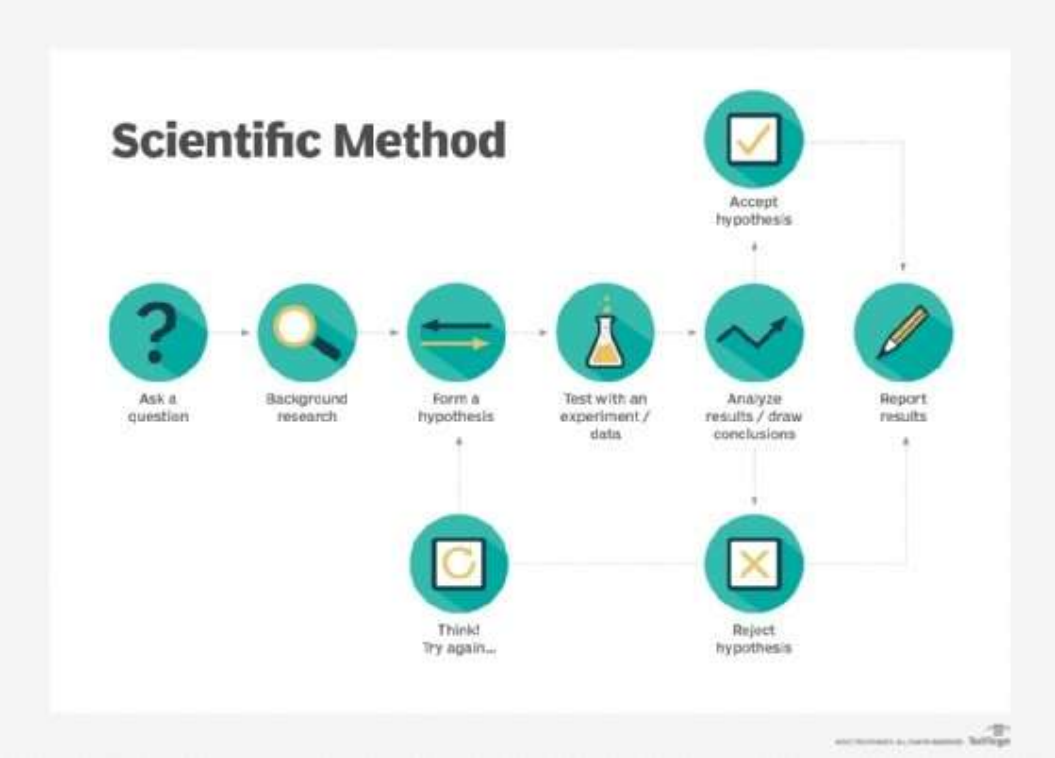
20.2.4 Create a prediction and perform a test

Generate a scrutinize forecast based on the hypothesis. The assessment should inaugurate a perceptible change that may be controlled or distinguished by realistic investigation. It is too significant to regulator for additional variables throughout the assessment. Approximately examples would be “if we block video-sharing sites, our available bandwidth will not go down significantly during lunch” or “if we make our registration box bigger, a greater percentage of visitors will register for our website than before the change”

20.2.5 Analyze the Results

Custom the metrics, which are well-known before the examinations see if the consequences match the prediction. Consider an example: “After blocking video sharing sites, our bandwidth consumption just went down by 10% from previously; it is not sufficient enough to be the primary cause of the network congestion” or “After increase in

size of the registration box, the %age of sign ups went from 2% of total page views to 5%, showing that making the box bigger results in more registrations”



The scientific method appeared during the Modern Period as an organized approach to understanding the natural work. It represented a shift from trusting on expert to observation and experimentation, laying the foundation for quick scientific progresses. Key point of scientific method include statement, hypothesis formulation, experimentation and investigation. This designed approach highlights objectivity, reproducibility, and observed suggestion in knowledge achievement, serving as a basis of modern scientific inquiry across various disciplines.

20.3 Origins of Scientific Methods

Scientific method appeared as an organized approach to accepting the natural world during the modern period. Laid the substance for quick scientific and technical progresses in the modern era.

20.4 Key Principles of Scientific Method

- Scientific method provides an organized approach to inspecting natural occurrence
- Highlights objectivity, reproducibility, and experimental indication in knowledge acquisition
- Assists as a keystone of contemporary scientific inquiry across various disciplines

20.4.1 Observation and Hypothesis

- Initiate with careful remark of natural occurrence or existing data
- Express a testable hypothesis clarifying the experiential designs or associations
- Certify that Hypothesis is explicit, falsifiable, and based on prior knowledge
- Deliberate substitute explanations and competing hypothesis
- Custom inductive intellectual to generate hypotheses from observed patterns (bottom-up approach)

20.4.2 Experimentation and Data Collection

- Intention controlled experiments to examine the hypothesis thoroughly
- Operate independent variables while controlling for impenetrable factors
- Apply suitable sampling techniques to ensure representative data
- Apply various data assembly methods (quantitative measurements, qualitative observations)
- Certify proper calibration and adjustment of measurement instruments
- Preserve detailed records of experimental measures and raw data

20.4.3 Analysis

- Apply statistical methods to analyse collected data and identify patterns
- Use inferential statistics to determine the significance of results
- Interpret findings in the context of the original hypothesis and existing knowledge
- Consider alternative explanations and potential source of error
- Revise or refine the hypothesis based on experimental outcomes

20.5 Hypothesis Formulation

The word hypothesis consists of two words hypo and thesis. Hypo means tentative or subject to the verification and thesis means statement about solutions of the problem.

Thus, it can be defined as a tentative explanation of the research problem, a possible outcome of the research. According to ***Good and Hatt*** "A hypothesis is a proposition which can be put to test in order to determine its validity." While ***Kerlinger*** defines hypothesis as a hypothetical while statement of the correlation between two or more variables.

The hypothesis is a powerful research process to achieve dependable knowledge. It is the reasonable statement of a suggestion or a reasonable guess based upon the available indication, which the researcher seeks to prove from side to side his study. Hypothesis is verbalized only as a suggested solution to the problems, with an objective that the ensuring study may lead either to rejection or to retention.

20.5.1 Features of Hypothesis

- It should be clearly and precisely stated
- It should be testable
- It should state the expected relationship between variables
- It should be consistent with most known facts
- It should be stated in simple terms

20.5.2 Significance of Hypothesis

- It confirms that the whole research methodologies are systematic and valid
- It helps to assume the probabilities of research failure and progress
- It supports to afford link to the fundamental theory and detailed research question
- It benefits in data investigation and measure the strength and consistency of the research
- It affords a foundation or suggestion to prove the strength of the research
- It helps to define research learning in existing terms rather than hypothetical expressions

20.5.3 Types of Hypothesis

(i) Directional and Non-Directional Hypothesis: Directional hypothesis states the direction of the differences or association. It tends to be more specific about the outcomes. On the other hand non-directional hypothesis states only the differences or association between variables and not the direction.

(ii) Declarative Hypothesis: It is a hypothesis developed as a declarative statement. It generally states relationship between the variables

concerned. When the researcher makes a positive statement about the outcome of the study, the hypothesis takes a declarative form

(iii) Complex Hypothesis: It shows the relationship between two or more dependent variables and two or more autonomous variables. Like eating more fruits and vegetables leads to bulk loss, glowing skin and diminishes the risk of many diseases.

(iv) Statistical Hypothesis: A statistical hypothesis is generally called confirmatory data analysis. It is an assumption about a population restriction

(v) Descriptive Hypothesis: It is a declaration about the presence, dimension, form or circulation of a variable. It encourage researchers to think about the consequences of a sustained or prohibited finding.

(vi) Relational Hypothesis: An interpersonal hypothesis is a statement about the association between two variables with respect to some case. Relational hypothesis may be correlational or instructive(casual)

(vii) Correlational Hypothesis: It is an announcement representing that variables occur together in approximately quantified manner without suggesting that one foundations the other

(viii) Explanatory Hypothesis: It is a report that defines a connection between two variables in which one variable leads to a quantified effect on additional variable

(ix) Null Hypothesis: It means zero hypothesis. A researcher has nothing to do in developing it. The null hypothesis advises that no statistical consequence exists in a set of given remark.

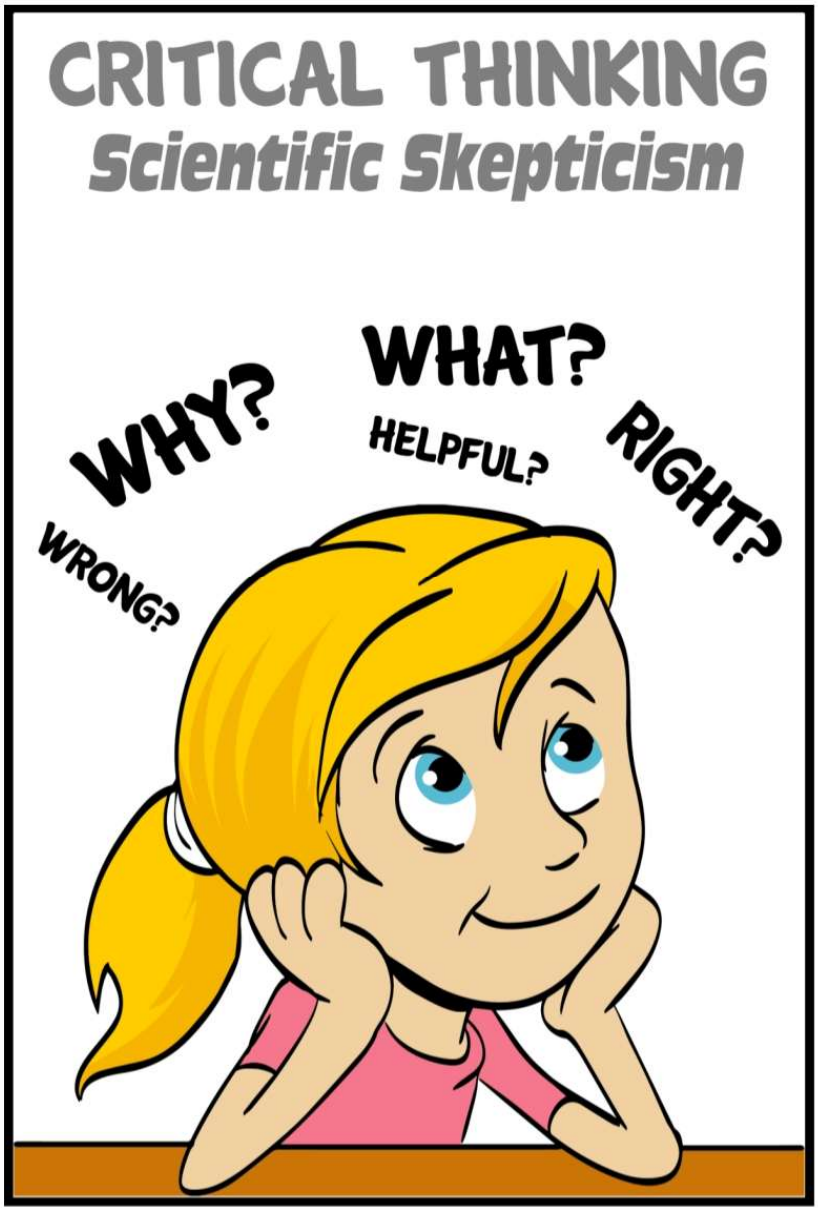
(x) Alternative Hypothesis: An alternative hypothesis is the opposite of null hypothesis where we can find some statistical importance or relationship between variables. Here, the researcher wants to show or prove some relationship between variables.

- Develop a testable prediction based on existing knowledge and observations
- Ensure the hypothesis is specific falsifiable, and addresses the research question
- Consider alternative hypothesis

20.6 Role of Critical Thinking and Skepticism

Critical thinking and skepticism are essential components of mathematical research methodology. In mathematics, where deductions trust on reasonable reliability and proof,

researchers must continuously question assumptions, authenticate opinions, and examine results quantitatively. Research methods highlights these skills to ensure consistency, novelty, and dependability in mathematical investigations.



20.6.1 Critical Thinking in Mathematical Research

Critical thinking in mathematics is the organized investigation and assessment of perceptions, proofs, methods, and results to ensure accuracy and consistency.

20.6.2 Role in Research

(i) Problem Formulation

- Classifying meaningful and study mathematical problems
- Characteristic about trivial, known, and original problems

(ii) Reasonable Reasoning and Proof Construction

- Confirming each step in a proof follows sensibly
- Sidestepping circular reasoning and secreted assumptions

(iii) Method Selection

- Picking appropriate techniques (algebraic, analytical, numerical, or probabilistic)
- Associating alternative approaches for efficiency and simplicity

(iv) Evaluation of Results

- Examination internal consistency
- Challenging results against known exceptional cases or counterexamples

(v) Generality and Perception

- Finding patterns and spreading results to wider frameworks

20.7 Skepticism Thinking in Mathematical Research

Skepticism denotes to a questioning arrogance towards privileges, results, and methods until they are checked thorough.

20.7.1 Role in Research

(i) Confirmation of Proofs

- Self-sufficiently checking proofs for breaches or errors
- Authenticating accuracy under all stated assumptions

(ii) Questioning Traditions

- Investigative whether assumptions are necessary or overly obstructive
- Challenging toughness of results under feebler conditions

(iii) Reproducibility of Results

- Confirming results can be independently derived
- Cross-checking with substitute methods

(iv) Recognition of Errors and Misconceptions

- Classifying wrong overviews
- Avoiding dependence on sensitivity without proof

(v) Peer Review and Academic Integrity

- Cheering inspection by the mathematical community
- Avoiding propagation of incorrect results

20.8 Interrelationship between Critical Thinking and Skepticism

Critical Thinking	Skepticism
Builds logical arguments	Questions their validity
Develops proofs	Tests proofs for weakness
Generalizes results	Checks limits of generalization
Proposes new ideas	Demands rigorous justification

Together, they ensure rigorous and reliable mathematical research.

20.8.1 Importance in Research methods

- Encourages research originally
- Certify logical consistency and exactness
- Diminishes errors in proofs and modelling
- Boosts quality of dissertations and publications
- Align mathematical research with Scientific methodology

20.8.2 Self-Learning exercise

(a) Non-Euclidean Geometry
(b) Gödel's Incompleteness Theorems
(c) Counterexample Method

20.8.3 Limitations and Balanced Approach

- Extreme skepticism may slow progress
- Critical thinking must be productive, not dismissive
- Balance between originality and verification is vital

Finally, Critical thinking and Skepticism are fundamental to sound mathematical research. They guide researchers in problem selection, proof validation, and theory development. These skills ensure that mathematical research remains laborious, credible, and innovative.

20.9 Case Studies of Scientific breakthroughs

Scientific Method in Mathematics: Case Studies

1. Fermat's Last Theorem-Conjecture to Theory-Building
   Methodological Focus: Conjecture, failed proofs, theory expansion
   Observation: Fermat Conjecture that $x^n + y^n = z^n \quad (n > 2)$ has no integer solutions.

   Hypothesis Testing:

   - Partial proofs for special cases
   - Computational verification for large n

Theory Development:

- Introduction of algebraic number theory
- Development of elliptic curves and modular forms.

Verification (1994):

Wiles proved a deep modularity theorem implying Fermat's claim

Scientific Method Parallel:

- Long-term hypothesis
- Accumulation of Evidence
- Theory-driven proof

Lesson: Mathematical truth may require new theories, not just clever arguments.

2. **Non-Euclidean Geometry –Falsification of an Axiom Methodological Focus:** Axiom testing and model construction

Problem: Euclid's fifth postulate appeared less intuitive than others.
Hypothesis:
Is the parallel postulate derivable from the others?
Verification:
Logical consistency was shown via models inside Euclidean geometry.
Outcome: Multiple consistent geometries exist.
Scientific Method Parallel:

- Assumption variation
- Model testing
- Theory comparison

Lesson: Axioms are hypotheses, not absolute truths.

3. **Classification of Finite Simple Groups-Large-Scale-Collaboration**
   Methodological Focus: Accumulation of empirical structure
   Observation: Known simple groups exhibited recurring patterns.
   Hypothesis: All finite simple groups fit into a small number of families
   Evidence Collection:
   - Construction and classification of examples
   - Elimination of hypothetical cases

Verification: Complete proof spread across thousands of pages

Scientific Method Parallel:

- Community Validation
- Incremental Confirmation
- Consolidation into a theory

Lesson: Mathematics can be collaborative and cumulative like science.

20.10 Summary

This unit explores scientific methods, how hypotheses formed. It includes the importance of skepticism and critical thinking. The unit

shows how scientists and researchers observe, test ideas and think about evidence to reach reliable conclusions

20.11 Answers to Self-learning exercises

(a) Skepticism about Euclid's axioms led to new geometries
(b) Critical examination of formal systems revealed their limitations
(c) A single counterexample can invalidate a conjecture

20.12 Exercises

1. Outline classification of finite simple groups
2. Discuss Case Studies of Riemann Hypothesis-experimental Mathematics
3. Discuss Case Studies of The Poincare Conjecture-Hypothesis and Analytical Verification
4. Discuss Case Studies of Gödel's Incompleteness Theorems-Meta-Scientific-limits
5. Write scientific case studies of Development of Probability Theory

References

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