MEV-019

Research Methodology for Environmental Science

School of Interdisciplinary and Trans-Disciplinary Studies
(SOITS)

Indira Gandhi National Open University
New Delhi

PROGRAMME DESIGN COMMITTEE

Dr. Himanshu Pathak,
Director, ICAR-National Rice
Research Institute Cuttack, Odisha

Prof. P.A. Azeez,
Director, SACON,
Coimbatore

Prof I.S. Thakur,
School of Environmental Sciences,
JNU, New Delhi

Prof Uma Melkania,
Dean, College of Basic
Sciences and Humanities,
GBPUAT, Pantnagar

Prof. Nidhi Rai,
University College of Science,
M.L. Sukhadia University, Udaipur

Prof. Jitendra Pandey,
Department of Botany,
Faculty of Science, BHU

Prof. R. Baskar,
Department of Environmental
Science & Engineering,
Guru Jambheshwar University of
Science & Technology, Hisar, Haryana

Dr. Surendra Singh Suthar,
School of Environment &
Natural Resources,
Doon University, Dehradun

Dr. Tanushree Bhattacharya,
Department of Civil and
Environmental Engineering,
Birla Institute of Technology,
Mesra, Ranchi

Dr. Pulak Das,
School of Human Ecology,
Ambedkar University, Delhi

Prof. Jaswant Sokhi,
SOS, IGNOU, New Delhi.

Prof Neera Kapoor,
SOS, IGNOU, New Delhi.

Prof. Vijay Kumar Baraik,
SOS, IGNOU, New Delhi.

Prof. P.K. Biswas,
STRIDE, IGNOU, New Delhi.

Prof. S.K.Yadav,
SOA, IGNOU, New Delhi.

Prof. Shachi Shah,
Director SOITS, IGNOU, New Delhi.

Prof. Nandini Sinha Kapoor,
SOITS, IGNOU, New Delhi.

Prof. Shubhangi Vaidya,
SOITS, IGNOU, New Delhi.

Prof. B. Rupini,
SOITS, IGNOU, New Delhi.

Dr. Sadananda Sahoo,
SOITS, IGNOU, New Delhi.

Dr. Sushmitha Baskar,
SOITS, IGNOU, New Delhi.

Dr. V. Venkat Ramanan,
SOITS, IGNOU, New Delhi.

Dr. Deeksha Dave,
SOITS, IGNOU, New Delhi.

Dr. Y.S.C. Khuman,
SOITS, IGNOU, New Delhi.

PROGRAMME COORDINATORS

Prof. Shachi Shah, School of Interdisciplinary and Transdisciplinary Studies, IGNOU

Dr. V. Venkatramanan, School of Interdisciplinary and Transdisciplinary Studies, IGNOU

Dr. Deeksha Dave, School of Interdisciplinary and Transdisciplinary Studies, IGNOU

COURSE COORDINATORS

Dr. V. Venkatramanan, School of Interdisciplinary and Transdisciplinary Studies, IGNOU

COURSE PREPARATION TEAM

	Unit	Unit writer
BLOCK 1 BASICS OF RESEARCH METHODOLOGY		
Unit 1	Introduction to Research Methodology for Environmental Science	Dr. Deepika Pandey,Amity School of Earth and Environmental Sciences, Amity University, Haryana
Unit 2	Research Formulation	Dr. G.Uma, SOGDS, IGNOU, New Delhi
Unit 3	Research Design	Dr. G.Uma, SOGDS, IGNOU, New Delhi
BLOCK 2 COLLECTION OF DATA		
Unit 4	Data Collection	Dr. G.Uma, SOGDS, IGNOU, New Delhi
Unit 5	Data Management	Prof. Manish Trivedi, School of Sciences, IGNOU, New Delhi.
Unit 6	Geospatial Tools	Prof. Benidhar Deshmukh, School of Sciences, IGNOU, New Delhi.

BLOCK 3 STATISTICAL ANALYSIS		
Unit 7	Descriptive Statistics-I	Prof. Manish Trivedi, School of Sciences, IGNOU, New Delhi.
Unit 8	Descriptive Statistics-II	Prof. Manish Trivedi, School of Sciences, IGNOU, New Delhi.
Unit 9	Sampling Distributions	Prof. Manish Trivedi, School of Sciences, IGNOU, New Delhi.
Unit 10	Statistical Analysis-I	Prof. Manish Trivedi, School of Sciences, IGNOU, New Delhi.
Unit 11	Statistical Analysis-II	Prof. Manish Trivedi, School of Sciences, IGNOU, New Delhi.
Unit 12	Analysis of Variance	Prof. Manish Trivedi, School of Sciences, IGNOU, New Delhi.
BLOCK 4 SCIENTIFIC REPORT		
Unit 13	Organisation of Reports and thesis	Dr. Anitha R, Former Faculty, Rajiv Gandhi National Institute of Youth Development, Chennai, Tamil Nadu. Dr. Thilaga Devi R
Unit 14	Research Paper	Dr. G.Uma, SOGDS, IGNOU, New Delhi
Unit 15	Ethics and Intellectual Property Rights	Dr. M.S. Dhanya, Centre for Environmental Sciences and Technology, School of Environment and Earth Sciences, Central University of Punjab, Bathinda.

CONTENT EDITORS

Prof. Shachi Shah, Environmental Studies, School of Interdisciplinary and Trans-disciplinary Studies, IGNOU, New Delhi.

Prof. V.K. Singh, Retd. BHU, Varanasi. (Units 5, 7-12).

Dr. V. Venkatramanan, Environmental Studies, School of Interdisciplinary and Trans-disciplinary Studies, IGNOU, New Delhi.

FORMAT EDITORS AND LANGUAGE EDITORS

Prof. Shachi Shah, Environmental Studies, School of Interdisciplinary and Trans-disciplinary Studies, IGNOU, New Delhi.

Dr. V. Venkatramanan, Environmental Studies, School of Interdisciplinary and Trans-disciplinary Studies, IGNOU, New Delhi.

PRINT PRODUCTION

Mr. Rajiv Girdhar
Assistant Registrar,
MPDD, IGNOU, New Delhi-110 068

Mr. Hemant Kumar Parida
Section Officer,
MPDD, IGNOU, New Delhi-110 068

September, 2022

ISBN :

Further information about the School of Interdisciplinary and Trans-Disciplinary Studies (SOITS) and the Indira Gandhi National Open University courses may be obtained from the University's office at Maidan Garhi, New Delhi-110 068.

Printed and published by **The Registrar,** MPDD, IGNOU, New Delhi on behalf of the Indira Gandhi National Open University, New Delhi.

Laser Typesetting : Akashdeep Printers, 20-Ansari Road, Daryaganj, New Delhi-110002

Printed at :

ignou
THE PEOPLE'S
UNIVERSITY

COURSE INTRODUCTION

The course "Research Methodology for Environmental Science" deals with research formulation, research design, data collection and management, statistical analysis and research paper writing.

Objectives

After studying this course, you will be able to:

- explain the types and approaches of research;
- explain various research designs;
- describe various sampling techniques;
- discuss the process of data collection;
- explain methods and tools of data collection;
- explain the diagrammatic method of representation of data;
- explain the measures of central tendency and dispersion;
- explain correlation and regression analysis;
- explain the sampling distribution;
- describe the procedure of testing a hypothesis;
- describe the small sample test procedures for a single population mean and the difference between two population means based on t-distribution;
- explain the chi-square test for the goodness of fit and independence of attributes;
- describe the test for the equality of two variances using F- distribution;
- explain the Analysis of Variance technique;
- explain the process of writing a research paper;
- describe the process and types of peer review; and
- explain ethical issues in research conduct and publication process.

We hope that you would enjoy reading the self-learning material.

ignou
THE PEOPLE'S
UNIVERSITY

Indira Gandhi National Open University
School of Interdisciplinary and
Trans-Disciplinary Studies

MEV - 019
Research Methodology for Environmental Science

ignou
THE PEOPLE'S
UNIVERSITY

Block 1

Basics of Research Methodology

ignou
THE PEOPLE'S
UNIVERSITY

BLOCK 1 INTRODUCTION

Block 1 "Basics of Research Methodology" aims to provide detailed information onresearch methodology, research formulation and research design.

Unit 1 "Introduction to Research Methodology for Environmental Science" deals with the types and approaches of research.

Unit 2 "Research Formulation" deals with the formulation of research questions, research objectives, hypotheses and conceptualization of different stages of research.

Unit 3 "Research Design" deals with the need for research design, principles of design research design, types of research designs and sampling techniques.

Objectives

After studying this block, you will be able to:

- explain the types and approaches of research;
- explain the significance of formulating research questions, objectives and hypotheses;
- analyse factors affecting the research topic in research;
- explain various research designs; and
- describe various sampling techniques.

We hope that after studying this block, you will acquire an understanding of the basics of research methodology.

Wishing you success in this endeavour!

ignou
THE PEOPLE'S
UNIVERSITY

UNIT 1 INTRODUCTION TO RESEARCH METHODOLOGY FOR ENVIRONMENTAL SCIENCE

Structure

1.1 INTRODUCTION

Environmental science, an interdisciplinary subject, has developed research methods adapted from scientific methods incorporating theories from other disciplines, including science and social sciences. Environmental science research incorporates data from biology, sociology, geography, economics, civil engineering, clinical research and even history. The techniques or the specific procedures which help the students to identify, choose, process, and analyse information about a subject is called “Research Methodology”. In simple words, it describes what you did and what made you reach this obtained result. The research methodology allows us to know (a) What data should be collected and what data should be avoided, (b) What method should be used to collect the data and (c) What method should be used to analyse the data.

Research methodology in environmental science has developed itself to be imparting interdisciplinary knowledge for the benefit of diverse fields such as urban planners, policymakers, architects, social workers, and the government. The research in environmental science serves for generating quantitative data for the evidence to the speculations and theories of various environmental issues across the world. The research is mostly conducted to develop

methods, and systems or find a solution to a social problem. It also helps to observe and analyse long-term changes in the environment and their effect, and predict future environmental problems and disasters through careful data collection and cause and effect relationships.The scientific method of research involves the systematic and planned collection of data, and its interpretation and evaluation to find new solutions to a problem or create new knowledge.The role of methodology in research problem are: (a) It helps in deciding the best method as per the research objective and resolve the difficulties of research. (b) Describes the efficiency of the method to solve the research problem (c) It helps to decide the accurate way of research method to be applied for the required outcome. Hence, the detailed study of the methodology of research facilitates to choose the best method, proper data or information, and scientific approach and educates the techniques to solve the problem.

1.2 OBJECTIVES

After studying this unit, you should be able to:

- explain the objectives of the research;
- explain the types and approaches of research; and
- explain the use of statistics in research.

1.3 OBJECTIVES OF RESEARCH

The objective of research in environmental science is to understand the unknown in nature. A lot of natural processes are still not understood well, hence their interlinking and interdependence may cause major threats to the environment if not handled properly and in time. Finding solutions to the existing environmental problems is another objective of research in environmental science. Potential environmental challengescan be predicted through proper research and provide for mitigation of imminent environmental concerns. The research methods designed for environmental science are required to be aimed at understanding the processesof nature,exploring and establishing a relationship between environmental problems and human activities, and finding a solution to wide-ranging environmental issues of the present times and their looming predictions.

Research provides answers to the questions through scientific procedures.Research especially in the field of environment aims to find the concealed truth from the data in the surroundings which is significant and has not come to light directly. Each research study is designed for its specific purpose. However, the research objectives can be categorised into the following main groups:

1. Exploratory or Formulative Research Studies: Exploratory research studies endeavour to attain a better understanding of a known phenomenon or to become familiar with an unknown phenomenon. Such research is carried

out by collecting a large sample size to verify the unknown fact and supporting data to establish the fact.

2. Descriptive Research Studies: Descriptive research studies aim to disclose the characteristics of a particular process more accurately. Different aspects of a phenomenon are studied to understand and describe the complete process or phenomenon. In environmental science, this approach is important because natural phenomena are interconnected and affected by each other.

3. Diagnostic Research Studies: Diagnostic research studies aim to determine the prevalence or recurrence of a process or interconnection between different things.Several natural phenomena are caused or triggered due to some other processes, and the root cause of a problem can be established through well-designed research.

4. Hypothesis-testing Research Studies: The hypothesis-testing research studies endeavour to check the theory of the cause-and-effect relationship between different variables.A simulation model is an effective way to achieve the objective of the hypothesis, which can be projected for the natural environment.

1.4 TYPES OF RESEARCH

1.4.1 Descriptive and Analytical Research

The research methods differ according to the nature of the study. Descriptive research involves surveys, interviews etc. and carries out the study to identify the facts on that basis. It is a primary data collection method and usually generates a large quantity of data which can be used for future research as well. The quantitative data is measured, classified, described, orcompared, and results are obtained by statistical analysis. In this method, different sections of the same group can be studiedwithout being affected by each other. Surveys and interviews are performed with the help of questionnaires which can cover several aspects of a problem and can convert non-quantifiable descriptions into measurable interpretations. The causes of the problem under study can be deciphered even though the factors involved are not in the control of the researcher. The descriptive method may be carried out in three different ways:observational method, case study method and survey method. The observational method in descriptive research does not go deep into the cause of the problem but describes the characteristics of the phenomenon under study. Case studies bring different aspects of a problem in a particular region and provide data for comparative studies. Such studies help to describe the problem and help to identify specific features of a particular group or region. Surveys are conducted on the population that can provide specific experiences and descriptive qualities of thelocalised or global problem. However, there are certain limitations to the descriptive method due to its data collection process. There can be misleading or incorrect responses by the respondents to protect their privacy or may get

affected by the presence of the observer. The survey may not reach representative people or there may be biases of the experimenter which may not bring correct observations.

In analytical research, the researcher uses facts or information already available and analysethese to make a critical evaluation of the problem.Analytical research focuses on cause and effect and the questions like 'how' and 'why' are answered in analytical research.The data in analytical research are used to support an idea or prove a hypothesis using critical thinking skills and careful assessment of the facts.The precise details are brought together to prove assumptions. It can be used to find missing links in the study.

1.4.2 Applied and BasicResearch

According to the purpose of the study, the research method can be applied or basic research.Applied research studies tofind a solution to the specific observed problem faced by society.This form of research is intended to identify environmental, social, economic or political trends that may affect a particular community or institution or to understand whether certain resolutions will be effective. The research is done in the marketing field and evaluation research is a form of applied research.

Research concerning directly to a natural phenomenon or relating to pure natural science or mathematics are examples of fundamental research. It is mainly concerned with overviews and simplifications and commences with the formulation of a theory.This type of research finds a significant place in the field of environmental science, it provides a basic understanding of nature. Well-understood physical and biological science and dissemination of knowledge in society is a key aspect in the field of environmental science, on which, the behaviour of a group of individuals and modification of public policy depends.

1.4.3 Quantitative and Qualitative Research

The type of data for variables used in the study classifies research as quantitative or qualitative.Quantitative research is done by the collection of numerical data sets of different variables and arriving at the solution based on the statistically obtained trend of the data. This type of research is deductive, objective, uses numbers and requires a hypothesis. This method is generally usefulin finding cause and effect relationships of any environmental problem. A quantitative dataset is usually analysed using statistical tools.

This type of research methodology tests the importance of the research hypothesis. This is a systematic research methodology and is in numbers. This methodology includes laboratory experiments, econometric, mathematical calculations, surveys, simulation etc. and involves number-basedresearch which measures attitude, behaviour, and performance in numbers. This method makes data easier to interpret. It requires those

techniques which can apply to a larger view. The data received for the purpose to use quantitative research methodology can effectively convert into graphs or charts. So, there will be difficult for an interpreter to influence it. Large-scale and representative sets of data are required for adopting this type of research methodology. This method is comparatively expensive.

Qualitative methodsrequire participant involvement and finding a solution through thoughts and experiences. The non-numerical unmeasurable traits are taken into consideration, based on people's opinions and narratives. These are inductive, use words and do not require a hypothesis. This is a common research method in humanities, education, sociology and anthropology. The qualitative changes in the surroundings and peoples' experiences are significant factors in environmental concerns and their solutions.Observation and description are more important in this type of methodology. The main aim of this type of methodology is to evaluate the knowledge, attitudes, behaviours, and opinions of people about the research topic. The method works using grounded research, case study, action research, disclosure analysis, ethnography, etc. The qualitative research methodology is based on the quality of the phenomenon.

In qualitative methods, the intensity, amount or frequency of data is immaterial. It focuses on the non-rigorous examination or measurement of data. For qualitative research, size doesn't matter. It understands feelings, viewpoints, and impressions. The useful qualitative method encompasses highly focused, flexible, and provides quick results. However, there is a scope of misunderstanding and misuse of qualitative methods.

1.4.4 Conceptual and Empirical Research

Conceptual research is related to some abstract concepts or ideas. It does not involve any practical experiment but is conducted by observing and analysing information already present. It is generally used by philosophers and thinkers to develop new theories or to re-explain existing perceptions. This type of research is used to solve real-world problems. The conceptual framework is developed by researchers by a combination of previous researchers and associated work and organizes ideas to make conceptual distinctions. This is the type used by most scientists such as Copernicus, Galileo, Newton and Einstein.

Empirical research, on the other hand, trusts experiences or observations, commonly without consideration of system or theory. This is data-based research, specific, observable and logically tested. Generally, quantitative data sets are required to carry out this type of research and the conclusions drawn are verifiable through observation or experiment, in the light of the wider body of knowledge on the subject. The standard component of empirical research includes methods, results, and discussion.

CHECK YOUR PROGRESS 1

Note: i) Use the space given below for your answers.

ii) Check your answers with those given at the end of the unit.

1. What are the objectives of the research?

…….

…….

……..……

……..……

2. What is analytical research?

…….

…….

…..……

……..……

3. What is applied research?

…….

…….

……..……

……..……

1.5 RESEARCH APPROACHES

The basic approach in research is either quantitative or qualitative. The quantitative approach involves the generation of quantitative data which can be subjected to meticulous quantitative analysis. This approach can be further sub-classified into inferential, experimental and simulation approaches to research.

The inferential approach to research is about inferring characteristics or relationships of a population with the help of a collected database. It is generally done using the survey research method and inferring the characteristics of the population based on the survey results. The experimental approach of research has much stronger control over the research environment and the variables are reduced by manipulating some to study their effect on other variables. The simulationapproach is a step ahead in controlling the environment as it involvesbuilding an artificial environment for the research problem by imitating the real problem, within which the required information can be generated by collecting relevant data. It is usually a dynamic system and allows the observation and tracking of the whole system under research. Well-structured simulation labs are constructed

to study major climatic disturbances or processes of the earth system. A simulation model can help to predict and understand future environmental issues.

1.6 RESEARCH METHODS

Research methods include experiments, tests, and surveys, on the topics. "Research Methodology" is confused with "Research Methods", and often beginners use both terminologies interchangeably and sometimes consider them one. However, both are different from each other and have noticeable differences between them. Research methodology teaches the various techniques which help in research and teaches how to perform tests, experiments, surveys, and critical studies of the subject or a topic. In simple words, finding a solution to a problem is the main target of research methods, while research methodology is adopting the correct procedures to reach out to the answers. Research methodology shows the right way research methods to be applied correctly for the best result.

Concept of Measurement Errors and Replication

Measurement error refers to variation in the measurement values that produce the difference between observed and true values. These are random variations arising from the complexity of the environment or measurement methods. Such uncontrolled variations and measurement error in research adds noise to the data. The predictions are less accurate in presence of measurement errors and add uncertainty to result estimates. The chances of observing new phenomena becomes little and it is more difficult to distinguish between opposing research theories. It most likely exaggerates the result estimates, which is far from the actual effect. Data with noise is unreliable. It is difficult to perform a reliable statistical analysis in presence of measurement errors to obtain a significant result. However, if the research is carried out under unavoidable noisy conditions leads to some findings, it is implied to be highly effective and robust.

Replication is a fundamental aspect of any research. It refers to the repetition (at least triplication for proper statistical analysis) of an experimental condition, process, and measurement. This step estimated the variability in the data arising at different steps of the experiment. Measurement replication refers to obtaining the same measurement values when the original study is repeated with the same research design and steps, using original samples or the same population. This is equally important for both qualitative and quantitative research and discovers the measurement errors in the research. The importance of replication increases when the data is noisy. Non-replicability of measurement generates doubt about the authenticity of the research findings.

1.7 VALIDITY AND RELIABILITY OF RESEARCH

Validity means how close is the result to reality, it is about the accuracy of a measurement, whereas the reliability of a result is about its consistency. A measurement is reliable if itis carefully taken and replicable, but it may or may not be valid. But if a measurement is valid, it is usually reliable too.Validity refers to the accuracy of the measurement and process of research. A valid result corresponds to closeness to the real situation, properties, or behaviour. It also accounts for variations in the measurement. The reliability of a result cannot ensure its validity. It is more important to ensure the validity of research results along with the reliability of measurement.

Reliability is one of the several indicatorsto show that the measurement is valid, but if a method doesn't have reliability, it is most likely not valid. Reliability is not enough to prove the validity of the method, process, or result. In a research problem, the reliability of a method, process or measurement is established if the same result is obtained on repeated trials. A consistent result or its tendency toward consistency proves its reliability. For a quantitative study, reliability is an important requirement, however, in qualitative research, reliability depends upon the objectives of a problem and the accuracy of observation. Obtaining reliability is an important goal for any research problem.

1.8 USE OF STATISTICS IN RESEARCH

Statistics is a scientific approach to analysing numerical data to enable us to maximise our interpretation, understanding and use. Statistical knowledge and application have become indispensable for any research. Statistics tools are used in the collection, organisation and analysis of data and help to draw inferences to obtain meaningful data. To get a reasonable outcome, a researcher is required to use at least basic analytical tools for the smaller objectives such as measuring things, examining relationships, exploring issues, explaining activities or attitudes, describing what is happening, presenting information, and making comparisons to find similarities and differences, making predictions, testing hypotheses, concept formation and developing theories or drawing conclusions about populations based on sample results.A proper plan and design of the research problem are required to obtain a meaningful result from the samples collected, which represent the whole population. Selection of samples and applying appropriate statistical tools is crucial, and it is only possible with adequate knowledge of statistics. Hence a basic understating and training of statistics is a need for all researchers.

Statistics not only reduces the errors and increases the reliability of results but also is a convenient tool to collect the data, analyse the data and present the results more effectively. Some of the most common and fundamental statistical tools required in almost all quantitative research studies are sample size determination, measures of central tendency, standard deviation,

standard error and hypothesis testing.The use of a large sample size is recommended for the accuracy of the result, and it becomes impossible to handle large data without statistical analysis. Statistics help to filter the vast data and correctly interpret the findings. Laboratory experimental results can be examined for significance and understood using tools such as t-test, F-test, and regression analysis.Several computer programming languageshave developed modern statistical tools that have improved the calculations, comparisons, and analysis of comprehensive datasets to derive reliable results and more accurate predictions. R and Python are such tools in modern research problems.

Descriptive and Inferential Statistics

Descriptive statistics describe the relationship between variables in a sample or population and provide a summary of data in the form of mean, median and mode. Descriptive statistics are used in everyday life in data obtained in many areas such as government, healthcare, business and sport. Inferential or analytical statistics use a random sample of data taken from a population to describe and make inferences about the whole population. It is valuable when it is not possible to examine each member of an entire population. Inferential statistics start with a hypothesis (a statement of, or a conjecture about, the relationship between two or more variables under study), and investigates whether the data are consistent with that hypothesis.

Measures of central tendency are the tools to describe where most of the values in a data set are located. There are three main measures of central tendency:

1. Mean: Mean is defined as the sum of all values divided by the number of values.
2. Median: Median is defined as the middle of distribution in ranked data, arranged in order of low to high (with half of the variables in the sample above and half below the median value).
3. Mode: Mode is the most frequently occurring variable in a distribution.

Out of the three measures, only one or two may be appropriate, depending on the shape of the distribution and level of measurement. Many demographic characteristics can only be described using the mode or proportions, while a variable like reaction time may not have a mode at all.

Mean (or the arithmetic average) is the sum of all the scores divided by the number of scores. The limitation of the mean is that it may be influenced by extreme variables. The extreme values are called outliers. The formula for the mean is

$$\bar{x} = \frac{\sum x}{n}$$

where x = each observation and n = number of observations.

Measures of variability describe the spreadof the values in a data set.However, the shape of the distribution and level of measurement decide which variability statistics should be used. Four main measures of variability are used:

1. Range: It is described by the minimum and maximum values of the variables. The highest value minus the lowest value of the data set is called the range. Range defines the spread, or variability, of a sample.
2. Percentile: Percentiles give better information about the pattern of spread of the variables. In percentiles, the observations are ranked into 100 equal parts, of which25%, 50%, 75% or any other percentile amount can be described. The median is the 50th percentile.
3. Interquartile range: The range of middle half of the data set is called the interquartile range. The interquartile range will be the observations in the middle 50% of the observations about the median (25th -75th percentile).
4. Variance:Variance is another measure of how spread out is the distribution. It indicates how close an individual observation clusters to the mean value. The variance of a population is defined by the following formula:

$$\sigma^2 = \frac{\sum(X_i - X)^2}{N}$$

where σ^2 is the population variance, X is the population mean, X_i is the i^{th}element from the population and N is the number of elements in the population.

The variance of a sample is defined by a slightly different formula:

$$s^2 = \frac{\sum(x_i - x)^2}{n - 1}$$

where s^2 is the sample variance, x is the sample mean, x_i is the ith element from the sample and n is the number of elements in the sample. The formula for the variance of a population has the value 'n' as the denominator. The expression 'n−1' is known as the degree of freedom and is one less than the number of parameters. Each observation is free to vary, except the last one which must be a defined value. The variance is measured in squared units. To make the interpretation of the data simple and to retain the basic unit of observation, the square root of the variance is used.

Standard deviation: The square root of the variance is the standard deviation (SD). The average distance between each value in the data set and the mean is called standard deviation. Standard deviation is a measure of spread in statistics, that is how much data is spread out around the mean or average.

The SD of a population is defined by the following formula:

$$\sigma = \sqrt{\sum(X_i - X)^2/(N)}$$

where σ is the population SD, X is the population mean, X_i is the i^{th} element from the population and N is the number of elements in the population. The SD of a sample is defined by a slightly different formula:

$$s = \sqrt{\sum (x_i - x)^2/(n-1)}$$

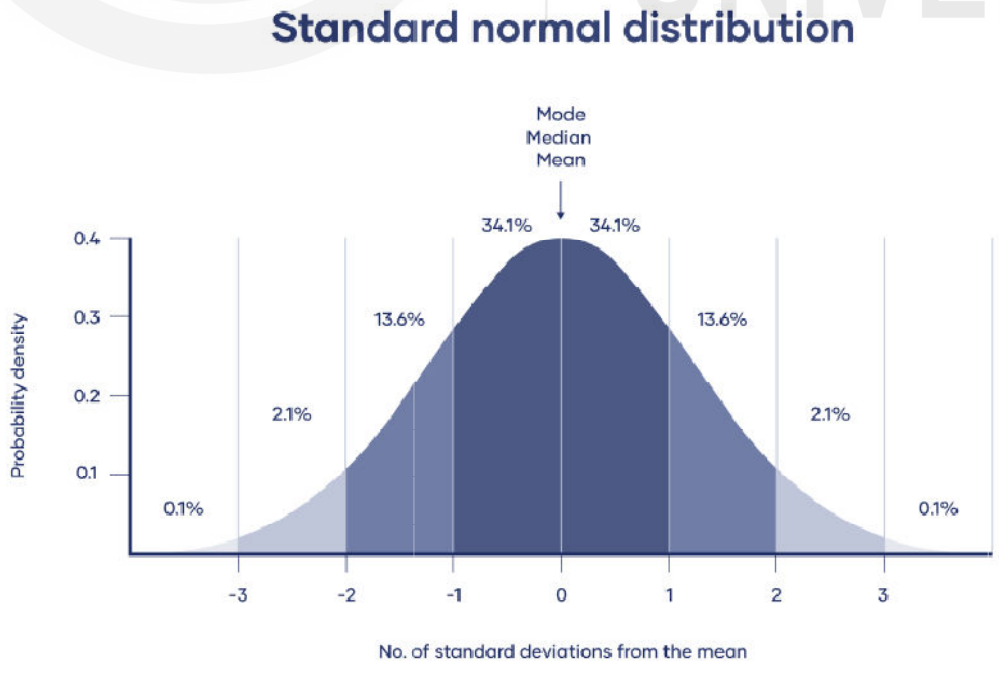
where s is the sample SD, x is the sample mean, xi is the i^{th} element from the sample and n is the number of elements in the sample.

The interquartile range is the best measure for skewed distributions, while standard deviation and variance provide the best information for normal distributions.

Normal distribution or Gaussian distribution

The Gaussian distribution (also called "Normal distribution") is the most important continuous distribution in statistics. Repeated measurements of many quantities in nature follow close approximation to Gaussian distribution. The graph of the normal distribution is characterized by two parameters: the mean, or average, which is the maximum of the graph and about which the graph is always symmetric; and the standard deviation, which determines the amount of dispersion away from the mean. A small standard deviation (compared with the mean) produces a steep graph, whereas a large standard deviation (again compared with the mean) produces a flat graph.

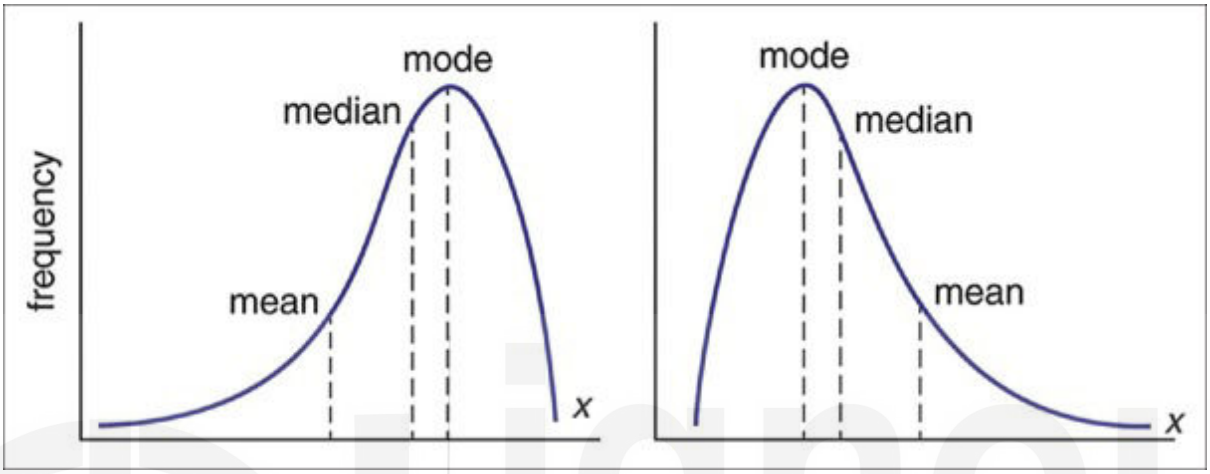
The standard normal distribution curve is symmetrical bell-shaped. In a normal distribution curve, about 68% of the scores are within 1 SD of the mean. Around 95% of the scores arewithin 2 SDs of the mean and 99% within 3 SDs of the mean.



(**Source:** Ali and Bhaskar, 2016)

Skewed distribution

It is a distribution with an asymmetry of the variables about its mean. Unlike the familiar normal distribution with its bell-shaped curve, these distributions are skewed or asymmetric. In a negatively skewed (or left-skewed) distribution, the mass of the distribution is concentrated on the right, in a positively skewed (or right-skewed) distribution, the mass of the distribution is concentrated on the left of the figure leading to a longer right tail.



(**Source:** Ali and Bhaskar, 2016)

A skewed distribution is asymmetric and has more values on one end than the other. The mean of positively skewed data will be greater than the median. In a negatively skewed distribution, the mean of negatively skewed data will be less than the median.

Test hypotheses

A number that describes a sample is called a statistic, while a number describing a population is called a parameter. Inferential statistics help to make conclusions about population parameters based on sample statistics. There are two main methods to make inferences in statistics and can be used simultaneously.

(i) Estimation: This involves calculating population parameters based on sample statistics.Two types of estimates of population parameters can be made from sample statistics: a point estimate and an interval estimate. A value that represents the best guess of the exact parameter is a point estimate and a range of values that represent the best guess of where the parameter lie is an interval estimate. For implying population characteristics from sample data, it's best to use both point and interval estimates. A sample statistic, a point estimate for the population parameter can be considered when there is a representative sample. There's always error involved in estimation, so a confidence interval should be provided as an interval estimate to show the variability around a point estimate.A confidence interval uses the standard error and the z score from the standard normal distribution to convey where the population parameter is expected most of the time.

(ii) Hypothesis Testing: It is a formal process for testing research predictions about the population using samples.Hypothesis testing starts with the assumption that the null hypothesis is true in the population, and statistical tests are used to assess whether the null hypothesis can be rejected or not.Statistical tests determine where the sample data would lie on an expected distribution of sample data if the null hypothesis were true. These tests give two main outputs:A t-test statistic tells how much the data differs from the null hypothesis of the test.A p-value tells the likelihood of obtaining results if the null hypothesis is true in the population.

Statistical tests come in three main varieties:Comparison tests assess group differences in outcomes.Regression tests assess cause-and-effect relationships between variables.Correlation tests assess relationships between variables without assuming causation.The choice of statistical test depends on research questions, research design, sampling method, and data characteristics.

At-test is for exactly 1 or 2 groups when the sample is small (30 or less). A z test is for exactly 1 or 2 groups when the sample is large.An ANOVA is for 3 or more groups.The z and t tests have subtypes based on the number and types of samples and the hypotheses.

The only parametric correlation test is Pearson's r. The correlation coefficient (r) tells the strength of a linear relationship between two quantitative variables. However, to test whether the correlation in the sample is strong enough to be important in the population, you also need to perform a significance test of the correlation coefficient, usually, a t-test, to obtain a p-value. This test uses your sample size to calculate how much the correlation coefficient differs from zero in the population.

In hypothesis testing, statistical significance is the main criterion for forming conclusions. You compare your p-value to a set significance level (usually 0.05) to decide whether your results are statistically significant or non-significant. A statistically significant result doesn't necessarily mean that there are important real-life applications or clinical outcomes for a finding.In contrast, the effect size indicates the practical significance of your results. It's important to report effect sizes along with your inferential statistics for a complete picture of your results. Type I and Type II errors are mistakes made in research conclusions. A Type I error means rejecting the null hypothesis when it's true, while a Type II error means failing to reject the null hypothesis when it's false.You can aim to minimize the risk of these errors by selecting an optimal significance level and ensuring high power.

Software Based Tools

Today, we have much software that helps visualise and analyse large data-set within a short period. You can use these tools to analyse descriptive statistics.Software that is designed for statistical analysis can make this process as smooth and as easy as possible. A great number of tools are available to carry out statistical analysis of data. Microsoft's Excel is an

excellent tool for statisticians. Excel is used more as a data storage software. However, the Excel formulas can be of great value to researchers, they can predict the future trend of an event or process and create various charts. Other latest statistics software used today are SPSS, Stata, SAS, R, and MATLAB.

CHECK YOUR PROGRESS 2

Note: i) Use the space given below for your answers.

ii) Check your answers with those given at the end of the unit.

1. Write a short note on research methods.

……

……

……

……

2. Write a short note on the application of statistics in research.

……

……

……

……

1.9 LET US SUM UP

Environmental science, an interdisciplinary subject incorporates data from biology, sociology, geography, economics, civil engineering, clinical research and even history. The research in environmental science serves for generating quantitative data for the evidence to the speculations and theories of various environmental issues across the world. Research methodology in environmental science has developed itself to be imparting interdisciplinary knowledge for the benefit of diverse fields such as urban planners, policymakers, architects, social workers, and the government. The research methodology allows us to know (a) What data should be collected and what data should be avoided, (b) What method should be used to collect the data and (c) What method should be used to analyse the data. The detailed study of the methodology of research facilitates to choose the best method, proper data or information, and scientific approach and educates the techniques to solve the problem. We have discussed in this unit the objectives of research, types and approaches of research and use of statistics of research.

1.10 KEY WORDS

Methodology : A system of techniques of investigation, methods for applying the techniques, and general principles for how the methods should be used in scientific inquiry.

Scientific Method : The purpose of the scientific method is to place the subjective process of developing new ideas into a logical framework of challenge and questioning to develop objective knowledge.

1.11 SUGGESTED FURTHER READING/ REFERENCES

Ali, Z. and Bhaskar S.B. (2016). Basic statistical tools in research and data analysis. Indian J Anaesth. 60(9): 662–669.

Begum K.J. and Ahmed A. (2015). The Importance of Statistical Tools in Research Work. International Journal of Scientific and Innovative Mathematical Research. Volume 3, Issue 12, December 2015, PP 50-58

Ford E.D. (2000). Scientific Method for Ecological Research. Cambridge University Press. 560pp.

Jonker J. and Pennink B. (2010). The Essence of Research Methodology. A Concise Guide for Master and PhD Students in Management Science. Springer-Verlag Berlin Heidelberg. 171pp.

Kothari C.R. (2004). Research Methodology, methods and techniques. New Age International Publishers (P) Limited, 401pp

Loken E. and Gelman A. (2017). Measurement error and the replication crisis. Science. Vol 355, Issue 6325 pp. 584-585.

McGraw−TaylorHarris Chapter 1. Why you need to use statistics inyour research/production/mcgraw−hill/booksxml/brownsaunders/ch1. PAGE: 1-10

Middleton F. (2019). Reliability vs Validity in Research: Differences, Types and Examples. Article published in Scribbr. July 3, 2019, revised on February 17, 2022. https://www.scribbr.com/methodology/reliability-vs-validity/

Reiter D. (2020) Measurement Replication in Qualitative and Quantitative Studies from Part IV - Appraisal. Published online by Cambridge University Press.

Satake EB. Statistical Methods and Reasoning for the Clinical Sciences Evidence-Based Practice. Ist ed. San Diego: Plural Publishing, Inc; 2015. pp. 1–19.

Sprent P. Statistics in medical research. Swiss Med Wkly. 2003; 133:522–9.

Winters R, Winters A, Amedee RG. Statistics: A brief overview. Ochsner J. 2010; 10:213–6.

Web Links

https://eduvoice.in/types-research-methodology/

https://imotions.com/blog/statistical-tools/

https://www.britannica.com/topic/normal-distribution

https://www.cambridge.org/core/books/abs/production-of-knowledge/measurement-replication-in-qualitative-and-quantitative-studies/F64A97CEE265A146DF8D2D096DE6083F

https://www.educba.com/types-of-research-methodology/

https://www.statisticshowto.com/probability-and-statistics/skewed-distribution/

https://www.voxco.com/blog/types-of-research-methodology/

1.12 ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress 1

1. Please refer to section 1.3
2. Please refer to section 1.4.1
3. Please refer to section 1.4.2

Check Your Progress 2

1. Please refer to section 1.6
2. Please refer to section 1.8

UNIT 2 RESEARCH FORMULATION

Structure

2.1 INTRODUCTION

There are several sources of inspiration for good research ideas. Still, as a beginning exercise, it is perhaps most helpful to select a topic, problem, issue, group, individual, or a set of behaviours and attitudes in which you have some personal interest. Whatever topic a researcher chooses, personal interest plays a vital role. As a postgraduate student, the topic you have chosen to study/research on may lead to further exploration or provide you with the scope for professional development and employment. So, several factors play a crucial role in selecting the research topic. There are scientific research methods to convert the topic into a researchable form. In this unit, we will discuss a viable topic, formulate relevant research questions, develop objectives, develop a hypothesis, identify essential variables and conceptualize the different stages of research.

2.2 OBJECTIVES

After studying this Unit, you should be able to:

- explain the significance of formulating research questions, objectives and hypotheses;
- analyse factors affecting the research topic in research; and
- explain the unit of analysis and types of variables.

2.3 DEFINING THE RESEARCH PROBLEM

Conceptualization is necessary once your topic has been chosen and a more specific research problem formulated. The researcher will need to discover:

1. Which concepts are most appropriate to the chosen topic?
2. Which variables follow these concepts, and how are they defined?
3. How do the variables relate to one another?
4. What are the specific sources of data? Ideally, in *inductive* scientific inquiry, each task is accomplished gradually after research is initiated. The answers emerge as the investigator proceeds. By contrast, the more *deductive* the strategy for inquiry, the more likely it is that all four issues will be tackled together at an early stage in research design before the investigator goes into the field.

There are two significant types of reasoning deduction and induction. The difference between the two depends on the researcher's strength and claim on a particular research problem and how they conclude based on his idea. According to **Singleton and Straits** (1999, p.) "*When a person uses deductive reasoning, they are deductive argument; they claim that the conclusion absolutely must be true if all the premises are true (all the syllogisms that we have considered henceforth are deductive arguments). When a person argues inductively, they claim that the conclusion is probably true but not necessarily true if all the premises are true*".

Box No. 2.1

The distinction between Inductive and Deductive Forms of Logic

The deductive method takes a few axioms or so-called factual statements to prove other true statements or theorems, which logically emanate from them. On the other hand, the inductive method makes many observations about nature, intending to discover a few but strong statements about how nature works or the laws and theories at the back of how nature appears to us.

In the deductive method, logic is the primary operating tool. If a statement emanates logically from the axioms, it must be true. In the inductive method (often called the scientific method), observation of nature is the primary operating tool. If an idea conflicts with what occurs in nature, the idea has to be given up as useless.

Adherents of traditional logic, who were the descendants of Aristotlean Logic, became rivals of those following the new inductive method of natural sciences, with different notions of reasoning or logic.

You may be interested in knowing that although science is inductive by definition (in the sense that observations are the only valid evidence of truth),

the process of science can be deductive, as per the Stanford Encyclopaedia of Philosophy (updated August 23, 2004). Aristotle's Logic mentions that 'more-recent scholarship has often applied the very techniques of mathematical logic to Aristotle's theories, revealing (in the opinion of many) several similarities of approach and interest between Aristotle and modern logicians'.

Source: Adopted/adapted from MSO 002, *Unit 1- Logic of inquiry in social research*, IGNOU: SOSS

2.4 FACTORS AFFECTING THE SELECTION OF THE TOPIC

The selection of a topic is the first step in doing research. As we have learnt, any problem which affects society could be the topic of research in environmental sciences. It could be an issue about which we desire more knowledge, like the situations in which people adopt risky behaviours due to adverse climate change, or it could be a practical issue like reducing climate change vulnerabilities by sensitizing masses in society. The following factors play a crucial role in selecting topics in environmental science research.

- The researcher chooses a topic to advance the scientific knowledge in the existing discipline. The organization of disciplines helps the researcher choose the field of interest and select a specific topic. For example, in environmental studies, learners can choose the topic which can trace the history of food production and the impact of climate change on food production due to climate change. The topics like food security and insecurity due to climate change, the significance of crop diversity, changes in lifestyles among young people and their impact on sustainability can be chosen. They can study the facets of the environmental movement in the present context, examine society's environmental problems, dispose of biodegradable and degradable wastes, innovate new material alternatives to plastics, disposable plastic, electronic waste, etc.
- The focus and development of environmental science research are closely connected to societal problems and human beings' problems in general. Inequality of society due to lack of resources, the significance of using existing resources sustainably, the contribution of women and forest dwellers for the sustainable use of forest resources, and exploring alternative resources are some areas of environmental science research in different disciplines.
- Personal interest and motivations also play a crucial part in selecting research areas/topics. Research involves a lot of time, money and hard work. Research fellowships or assistance are hard to come by. The amounts may not be sufficient for sustenance. Formulating a research problem requires a lot of reading and thinking, especially when identifying gaps in the existing scholarship, which can become the

starting point of new research. Personal interest and motivation play a crucial part in topic selection.

Social premiums will influence the section of the topic. This includes the availability of funds, the popularity of the topic and prestige. For example, the international agencies, national and transnational institutions, and United Nations play an essential role in integrating environmental issues as a national significance issue. It became part of the development of member states. The 1972 United Nations Conference on the Environment in Stockholm was the first world conference to make the environment a significant issue. After the Stockholm conference, the United Nations Environmental Programme (UNEP) was established as a catalyst and coordinator for environmental issues within the United Nations (UN). UNEP established the Senior Women's Advisory Group on Sustainable Development to enhance women's environmental management participation. In the Nairobi International Women's Conference, 1985, ELCI organized a parallel conference, Women and Environmental crisis.

During this period, most of the research concentrated on the issues related to the environment. At present, climate change is the topic that is attracting social and natural scientists' attention. Gender issues are also integrated into climate change: individuals and institutions researching the topic examine the impact of climate change on women and their livelihoods. They consider climate change as the biggest threat in the 21st century. The international scientific community has urged the world community to stabilize carbon emissions in the atmosphere to avoid future ecological disasters. Several international summits like the Inter-Governmental Panel on Climate Change (IPCC) have been organized to find solutions to the problem of climate change primarily due to global warming. Researchers tend to research climate change by looking at the gravity of the problem and the temporary, relatively easy availability of funds. Existing disciplines like Economics, Women's and Gender studies and Development studies integrate climate change into research agendas. Researchers are encouraged to explore the different dimensions of the phenomenon and propose concrete strategies to address the problem to avert a global disaster.

- Apart from individual skills and interests and social necessities, availability and accessibility of reliable data, availability of laboratory for experimental research, expertise in identifying and developing the research plan, and the state of development of a particular discipline also exert their influence. The choice of a research topic may be affected by any factors mentioned above. Initially, personal interest may play a role in selecting the topic. Still, it has to be further justified on how it will contribute to the existing theoretical

knowledge in the discipline and how the study's findings will help address social issues and problems.

Whenever a researcher chooses a topic, the chosen topic has to be reformulated in researchable terms in a research proposal. This involves translating the chosen topic into more clearly defined, specific questions or problems amenable to being researched. Both choose a research problem and finalize a research proposal that requires a literature review. By analysing existing material related to the research topic, the researcher may find research gaps and new questions. In the literature review process, the researcher may decide how the research will take, the concretization of a researchable problem and specific questions, the units to be studied, etc.

2.5 SELECTION OF TOPICS AND FORMULATING RESEARCH QUESTIONS

To initiate *exploratory* research, you will just need to identify the subject for investigation. To move beyond exploration to description and explanation, you will need to begin specifying the research problem – the question or questions concerning your topic that you believe are most important to answer. Let us assume that you want to understand the reasons for climate change and its impact on the existing ecosystem, and this problem has to be converted into research questions. To begin to convert this general interest into a design for research, the researcher might formulate questions like the reasons for climate change today? What will happen if we continuously destroy the existing forest in the name of development? Subsequently, the researcher would need to refer to some literature on climate change. Afterwards, the researchable problem has to be converted into a set of research questions: What are the drivers of environmental degradation? If there is a reduction in forest area over time, what are its consequences on society? What happens to the relationships between the environment and human beings?

The formulation of a research problem narrows the topic to manageable proportions. It suggests strategies for the research design, particularly possible variables to be used and the settings for data collection.

Sometimes the purpose of a study is as essential as the topic in determining research design. We may discover the purpose of a piece of research by asking why and to whom it is helpful to answer the questions being asked. Sometimes, there is no particular motive for research other than exploring some phenomenon or adding to human knowledge in a particular area. In this situation, the investigator enjoys a great deal of attitude in defining concepts and operationalizing variables. However, in other cases like deductive inquiry or applied social science research, the purpose of the investigation is much more focused. A specific hypothesis is being tested, or human behaviour is being evaluated according to criteria. In these instances, the purpose of the study has a profound effect on research design. Indeed, we often cannot begin

to choose the most appropriate measuring tools for the variables we are manipulating until we know why the data are being collected in the first phase.

Formulating pertinent research questions from a research problem is a significant step in qualitative and quantitative research. As you learned in the previous units, qualitative research is more open-ended than quantitative research. Research questions help collect the right kind and amount of data to address the research problem. According to Alan Bryman (2008), research questions are essential because they guide:

- your literature search;
- in deciding what data, you need to collect;
- your analysis of the collected data;
- in writing of your research report; and
- prevent you from losing focus of your research.

According to Marx (1997), research questions can be derived from various contexts like personal interests/ experiences, existing theories and available research.

2.6 CRITERIA FOR EVALUATING RESEARCH QUESTIONS

The following points will give you an idea of how could research questions be formulated?

- Research questions should be clearly stated, uncomplicated in form with the capacity to be researchable;
- The researcher should ensure that the research questions are original and the ideas are there;
- Research questions should neither be too narrow nor too broad.
- It should be possible to convert research questions to objectives, and, from the objectives, one should be able to draw hypotheses and develop methodologies to respond to them.
- Research questions should have some connections with already established theory and research. This means that there should be literature from which one can draw. This will facilitate the researcher in formulating research questions. Even if you choose a topic that has been scarcely addressed, it is unlikely that there will be no relevant literature.
- All research questions should be interrelated to develop the overall argument in the final report. Unrelated research questions create confusion.

Professional scientists have long performed scientific research in laboratory settings in different institutions. The trend has been changing, and scientists are trying to cross the institutional settings by involving the general public (the crowd) to carry out the research. The crowd involvement in the scientific research became empirical research. The crowd may or may not be contributing to formulating the research questions. In the earlier centuries, people believed that knowledge believed in drawing on problem-solving and knowledge production theories. The researcher first develops a framework that ties dimensions of research question quality to different experiential and scientific knowledge types. In this Unit, we discuss the potential benefits and challenges of involving the people in Research Question (RQ) formulation and theorize how knowledge interventions affect RQ quality. We then use data and case examples from a field experiment in the environmental sciences to explore features of research questions generated by the crowd and to test the effectiveness of knowledge interventions. Let's look at the recent research related to environmental studies. Our results show crowd members can generate high-quality research questions that differ from those typically produced in scientific research, although most RQ is plain problem restatements. More importantly, recent research shows that the quality of crowd-generated RQ can be improved through simple interventions that provide crowd members with different types of scientific knowledge they otherwise lack. We discuss contributions to the literature on the organization of science and distributed knowledge production and implications for practitioners and policymakers. (https://www.researchgate.net/publication/342322754_What_Is_the_Problem_Crowdsourcing_Research_Questions_in_Science).

2.7 LITERATURE REVIEW

In this section, let us discuss literature review (Reviews, research papers, treatises, monographs, patents, and web sources). Once you identify the research questions, the earliest form of work one has to do is a literature review. Literature review applies to all research questions and all types of studies. To begin the literature review, one must finalize the topic, and research questions, and one must decide how much time one can devote to the chosen topic for research. After the literature review, the researchers are ready to design the study of the chosen topic. For example, suppose you would like to study the topic related to the role of the community in preserving and managing Common Property Resources (CPR). In that case, you need to review the following existing literature related to the role of the community in CPR. You also need to know what CPR is and which resources come under CPR and which institutions are working towards managing CPR (both formal and informal institutions). Suppose you come to know about the current study conducted in this area, based on the existing literature, the researcher must note the current study and she/he must think about how far the present study related to his area of study. The process of literature review facilitates the researchers to formulate research questions. When they do a

literature review, two questions come to their mind. When the literature review progress, the researcher can check whether formulated research questions overlap the existing research. Secondly, they can finalize specific ethical questions and data collection techniques by reviewing the literature. Social and natural science research is conducted through survey research, experiments, field research, historical research, existing documents, content analysis, secondary data analysis, etc. The ethical concerns regarding the research related to a person's privacy, involving an animal in research, involving humans in medical research. The researcher must be aware of the legal issues related to all this research. Through reviewing the existing literature, we will understand the ethical and legal issues. Once you finalize the research topic and research questions, the first and foremost step is to do a literature review. This applies to all research questions and all types of studies. It is good to know what other researchers have done in your study area. First, we must know what is literature? and know how to do a literature review systematically. First of all, the literature review taught us that there is existing knowledge on the chosen topic/field, and we can learn from that and we can build more knowledge of the chosen topic. The review also taught us that the scientific study is a collective process, and we will come to know that already scientist created knowledge on the existing subject, and what we are going to create is a tiny knowledge of the ocean.

Types of Literature Review

We can find six types of literature reviews.

Context Review- It is a common type of literature review in which the researcher tries to link a specific study to the larger body of knowledge. For example, someone has studied the mangrove forest and its usefulness to address disaster management and mitigation. The same mangrove forest or some other shrubs can be grown close to the sea to reduce any kinds of eventualities during heavy rain or sea rising.

Historical Review – The researcher traces an issue over time in this review. A historical review can be conducted to know existing research and build methodology.

Integrative Review- This is a common type of review in which the researcher highlights the present state of research on the chosen topic and highlights agreement and disagreements with it. This can be considered a context review or the researcher may publish this review as an independent research article to benefit other researchers.

Methodological Review – It is a specialized review in which the researcher conducts a review to trace various methodologies used in various studies and tries to conclude how different methodologies bring different results in terms of researcher design measures and sampling techniques.

Self-study Review – In this review, the researcher tries to apply their familiarity with the chosen topic

Theoretical Review- In this review, the researcher tried to find out various theories and concepts related to the chosen topic and chose relevant theories and concepts based on his data to bring assumptions, logical conclusions, consistency and scope of explanation.

Apart from the types mentioned above of literature review, there is meta-analysis. A large number of existing literature related to the topic was collected, synthesized, and the results were brought.

The researcher can find the existing literature through books, scholarly journal articles, dissertations, government documents, and policy reports. The following sub-section broadly explains the various available literature.

1. **Peer-reviewed Scholarly Journal** – Professional researcher publish their research findings in a peer-reviewed scholarly journal. Both natural and social science research related to empirical, experimental, and theoretical research will be published in peer-reviewed journals. It has its strength. Peer-reviewed journals publish high-quality research work. It is verifiable. The weakness of the journal is the use of scientific writings, which are technical, and scholars must know the background in the chosen field to understand the published articles in the peer-reviewed journals.
2. **Semi-scholarly Professional Publication**- Professors and policymakers will publish in semi-scholarly professional publications. They share their new findings and implications with a broader audience. It is accurate and easy to read. The weakness is the lack of complete details, and the authors try to mix up their opinions with results.
3. **News magazine and Newspapers**- Journalists contribute to news magazines and newspapers. We can find the current events in the newspapers. It is easy to read. But it is not entirely accurate, and opinions dominate the facts.
4. **Serious Opinion Magazine**- Academicians, professional policymakers, executives in the government and politicians contribute to such magazines. It is based on values and ideas, and they try to reason the issues through their opinions and ideas. The weakness of the opinion magazine is that it is one-sided.
5. **A popular magazine for the public**- Journalists and others write in this popular magazine. It is entertaining, and it is for the masses. It is easy to read and locate. It is inaccurate and incomplete.

CONDUCTING LITERATURE REVIEW SYSTEMATICALLY

There are various steps to doing a systematic literature review. The researcher first identifies the topic and research question once they begin the research. The literature review can begin after defining the topic and research question(s). The next step is to plan a search strategy. First, one must finalize how much time one can spend on the literature review. Secondly, they must finalize how extensively they would like to review the literature. Researcher(s) may have detailed discussions with their supervisor(s). They must do a careful, systematic and organized literature review. Most of the scholarly research articles will be published in peer-reviewed scholarly journals. As of now, there are hundreds of journals for each subject. For example, the education-related topic, "Educational Resource Information System (ERIC), is helping to identify the journals and research articles. Apart from research articles, the review can conduct in books, dissertations, government documents, policy reports and presented papers. The next step is evaluating the research article. Researchers first need to look into the topic of the article. A good title conveys the nature of the research. After identifying the article through its topic, the researcher has to read the article's abstract. The abstract provides the purpose of the research, methodology, types of research, theoretical understanding and results. Once you identify the article relevant to your topic based on the abstract, you can read the article. If you don't want to read the entire article, you can read the introduction, methodology and conclusion. The conclusion gives you research questions, collected data, interpretation and concluding remarks about the study.

Internet for Review and Scientific research

In the digital era, through the internet, one can access information. The scholar must be cautious in using various sites to review the literature when it comes to research. It is easy, cheap, and widely available now and accessible to all scholars. Once you open the browser, the internet has links, and you need to put the links on the browser. Websites, web sources, libraries, and scientific book publishers have links. The information can be accessed through the link. Some of the sites provide the basic information related to the article. If you need to access the full article, they may ask you to pay specific amounts. Public libraries and libraries in the Universities have subscribed to many journals. The scholar may contact their university libraries to access the entire material. Extensive reviewing of the existing article will lead you to identify the research gap in the chosen area. Based on reviewing the existing literature, scholars may reformulate research questions.

2.8 FORMULATION OF OBJECTIVES AND HYPOTHESIS

As far as natural and physical science research is concerned, the primary objective and hypothesis are closely associated. Researchers should ensure

that the study objectives must define the study's specific aims. The objective of the study should come immediately after the research questions. It must be noted that the study objective is an active statement about how the study will answer the specific research question. The objectives can state their outcome measures. They are essential because they help guide the development of the protocol, and design of the study. The objectives will facilitate the researcher to design the sample size. The objectives demonstrate the power of the study (Farrugia et al. 2010).

The hypothesis needs to be formulated based on the research question. Once the researcher formulated the research questions, they derived objectives and hypotheses from the research questions. When you generate large data from the field or laboratory, you need to test the statistical significance. In that case, the researcher must state the "null hypothesis". The purpose of hypothesis testing is to infer from the experiment carried out in the laboratory. As far as field-based data is concerned, the purpose of the hypothesis is to find the relationship between variables. After forming the null hypothesis, the researchers would form an alternate hypothesis stating the nature of the difference, if it should appear. The alternate hypothesis would help the researcher to anticipate the difference between two or more variables. The null hypothesis is then tested statistically at the end of the study. Suppose the study's findings are not statistically significant, we cannot reject the null hypothesis.

In contrast, if the findings were significant, we can reject the null hypothesis and accept the alternate hypothesis. In other words, hypothesis testing confirms or refutes the statement that the observed findings did not occur by chance alone but instead occurred because there was an actual difference in outcomes between variables.

Designing a research hypothesis is supported by a good research question and will influence the type of research design for the study. Acting on the principles of appropriate hypothesis development, the study can then confidently proceed to develop the research objective.

2.9 UNIT OF ANALYSIS

According to Royce A. Singleton, Jr. and Bruce C. Straits (1999, p.), *"the entities (objects or events) under study are referred to in social research as Units of analysis. Social Scientists study a variety of units (also called elements or cases). These may include individual persons, social roles, positions, relationships, and various social groupings such as family, kinship, organizations, cities, villages, documents, etc. The Unit of analysis is who is analyzed and described and what is analyzed and described".*

As far as environmental studies are concerned, the unit of analysis depends upon the topic. If the researcher chooses a topic that involves human beings to collect data, the Unit of analysis may be persons, location etc.

Defining a unit of analysis is one of the most critical moments in any scientific endeavour, including research on learning and instruction. However, methodology and theoretical assumptions may come later after deciding on the unit of analysis. The Unit of analysis distinctively reflects a study's theoretical premises. Operationalizing theory into observations, units of analysis determine what the objects of study are, the things "you want to be able to say something about at the end of the study" (Patton, 2002, p. 229), the "what or whom can be studied" (Babbie, 2007, p. 94). However, meta-theoretical reflections concerning how chosen units of analysis relate to given theoretical frameworks are in the researcher's hands. It isn't easy to find the existing literature related to the unit of analysis and chosen theory in environmental studies and other fields.

For example, suppose a researcher wants to know the reasons for the high poverty among women. In that case, they could trace the development historically and collect data in the present context. Some research questions could be:

- Is it a fact that historically women are vulnerable in society and facing persistent poverty?
- Is poverty a feminine phenomenon? Or has modernization led them more vulnerable? Here, the study aims to determine the reasons and who is described and what is analyzed.

The unit of analysis for the above said question is famine and women. Famine is an event that happens due to a lack of rain, drought, or any other reason. The researcher might be interested in understanding the causes of famine and why women are more vulnerable to such extreme situations?

The researcher has to get clarified for getting information about the selected sample to decide on the unit of analysis. They must also understand that the selected sample may be individuals or groups (the individuals they belong to). "*Information about one set of units that are statistically combined to describe larger social Unit called aggregate data. Suppose collective information about a particular group is used on a statistical summary basis to describe the makeup of individuals within the group. In that case, the Unit of analysis is the individual. However, if aggregate information is used to compare different groups or collectivities, then the unit of analysis is the group*" (Singleton and Straits 1999).

The following example will give more clarification. Suppose a researcher wants to study a woman in an organization. In that case, a woman is a unit of analysis, provided the objective of the research is to find the characteristics of women. But suppose a researcher's objective is to examine the women members' role in an organization and how an organization responds to women members. In that case, the organization itself is a unit of analysis. The data collected among women in an organization will describe the organization's culture/policy rather than women. So, the unit of analysis is organization.

The researcher's primary objective is to observe the Unit of analysis and the relationship among the characteristics of the unit of analysis. For example, if you take individuals, the characteristics may vary from individual to individual, like age, gender, and marital status, which are called variables. Along with this, a variable may vary from an individual over time, such as age, level of education, and income. The researcher should not confuse variables with attributes. For example, Gender is a variable consisting of male, female and male and female is the category in the Gender. There are different types of variables, like independent variables and dependent variables. Thus, the primary issue involved in formulating a research problem is drawing out units of analysis. Based on the units of analysis, the researcher can collect the data for analysis.

2.10 VARIABLES

When you conceptualize any topic, you need to choose or create categories or characteristics that are relatively straightforward. These important categories or characteristics chosen based on the research question become variables. Each variable should be conceived of to allow for it to be readily and precisely measured. The same principle applies in selecting or constructing theory (the overall blueprint for relating one variable to other variables).

Once the researcher identifies the research problem, they can observe or measure many potentially relevant properties or variables. Those variables selected for analysis are called explanatory variables, and all other variables are called extraneous variables (Kish, 1959).

There are two principal types of explanatory variables: dependent and independent variables. There are antecedent and intervening variables concerning specific independent and dependent variables. An antecedent variable occurs before time to both independent and dependent variables. For example, the national survey in the United States (U.S.) shows that a child's academic achievement depends on the type of schools they attend. The private school students show higher academic achievement than the public school students. Concerning the independent variable – type of school, dependent variable – academic achievement, the antecedent variable would be parents' income. The intervening variables would be the students' attendance, teaching methods, nature of assessment etc.

The control variables are constant, and they won't be any change in the course of observation. Another distinction in variables is quantitative and qualitative variables. If the variables are quantitative, the differences are expressed numerically. But qualitative variables are discrete categories usually designated by words or labels and non-numerical differences between categories.

The prime objective of the research is to find relationships among variables. When we look at research in environmental studies, the focus is on

pinpointing the reasons for the environmental degradation, change in ecosystem and climate vulnerabilities, and their effect on society.

Another critical aspect of research is building a perspective in the minds of researchers. If the issue is environmental degradation, the researchers must build a perspective on the history of environmental degradation in the name of development and theories related to environmental studies. It will give a clear idea about the arguments that the research seeks to advance. Understanding and using appropriate theories in research is vital. Facts alone (whether the researcher collects data through quantitative/qualitative methods) never provide results. Anticipating relationships among variables and using appropriate theories will provide results.

Like individuals in social relationships, different variables are also interrelated in research. Events precede or follow the occurrence of other events. At the same time, pairs or combinations of things occur together or change together. Social scientists are interested in the relationships among variables and the nature and extent of one variable's impact on other variables. This can be studied by using qualitative or quantitative data collection methods.

CHECK YOUR PROGRESS 1

Note: i) Use the space given below for your answers.

ii) Check your answers with those given at the end of the unit.

1. What essential factors need to be kept in mind while choosing the research topic?

……

……

……

……

2. Define variables. Describe the different types of variables.

……

……

……

……

2.11 LET US SUM UP

We have discussed in this unit the significance of formulating research questions, objectives and hypotheses. Further, we have discussed the factors affecting the research topic in research.

2.12 Key Words

Hypothesis : An informed speculation, set up to be tested, about the possible relationships between two or more variables.

2.13 SUGGESTED FURTHER READING/ REFERENCES

Bryman, Alan. (2008). *Social Research Methods*. Oxford: Oxford University Press

Farrugia, Patricia, Bradley A. Petrisor, Forough Farrokhyar and Mohit Bhandari (2010) research questions, hypotheses and objectives Can J Surg. 2010 Aug; 53(4): 278–281.

Kish, L. (1965). *Survey Sampling*, New York: Wiley.

Kothari, C.R. (2004). Research methodology: Methods and Techniques. New Age International (P) Ltd. Publishers.

Royce A., Singleton, Jr. and Bruce C. Straits. (1999). *Approaches to Social Research*, Oxford: Oxford University Press.

2.14 ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress 1

1. Please refer to section 2.4
2. Please refer to section 2.10

UNIT 3 RESEARCH DESIGN

Structure

3.1 INTRODUCTION

The Unit 'Research Design' brings forth various phases of research that could be carried out in a planned and phased manner by developing a research design. Once the researcher finalizes the research design, the entire research process will be under their control. The example below will make learners realize the significance of developing a research design. The architect prepares the design, keeping in mind that he needs to construct a building. The plan will contain the structure of the building, number of rooms, utilization of rooms, size of open space, size of garden space, building material, and length and breadth of the building in square feet. The architect will decide and prepare a blueprint or plan before starting the building. I believe the above example will help you know the research design's significance.

Once the design is in the hands of the researcher, they have the freedom to make necessary changes whenever the need arises. Designing also helps the researcher reduce wasteful expenditure on finance, time and energy. The process of preparing a research design anticipates various difficulties, and the same difficulties will be addressed in the research design through appropriate strategies. Preparing the research design also helps the researcher to control

the unexpected situation rationally. It also facilitates the researcher to articulate the research procedure in a better manner during the academic presentation. It helps them to prevent the possibility of failure. With the above introduction, the present unit facilitates you to learn the definition and need for research design, principles of design research design, and types of research designs. Finally, we discuss sampling techniques.

3.2 OBJECTIVES

After studying this unit, you should be able to

- define research design;
- discuss the need for the research design;
- explain various research designs;
- define sampling;
- discuss the need for sampling; and
- describe various sampling techniques.

3.3 NEED FOR RESEARCH DESIGN

Let us start with defining "what is Research Design". We define the research design as "such design as a symbolic construction or model". "The research design is the arrangement of conditions for data collection and analysis in a manner that aims to combine relevance to the research purpose with the economy in procedure" (Selltiz et al. 1964). If we look at the above definition, we can see that the design talks explicitly about the research objectives, the rationale for doing specific research, and a methodology which includes methods and theory, sampling, data and data organization. Besides the core procedures mentioned above, scientific research design must explicitly describe the accepted methodology. The theory must be a core component of the social science research design. The research design should have the following aspects.

1. The details of the study
2. The rationale for choosing the study
3. Reasons for carrying out the study
4. Type of data required for the chosen study
5. Techniques of data collection
6. Area of Study
7. The period of study
8. Duration of the study
9. Requirements of different types of material for the research study
10. Tools and techniques required for the study
11. Selection of cases, number of cases required for the study
12. Methods of data analysis

The above-said points need to be addressed in a structured manner with clarity in the research design. Once the researcher addresses the above points in the research design, they could achieve the research objectives with minimum expenditure.

1. Let us discuss the need for methodologically designed research in the following paragraph. We will draw the need for research design through an example. Once the researcher formulates research questions and objectives, the researcher has no idea how accurate the results of his study are in many cases. Of course, the researchers may have many questions in their minds and try to inquire. One takes up research to make a valuable contribution to the community and further scientific inquiry. In such a situation, the researcher has to find out how much percentage of inaccuracy can be accepted. Secondly, researchers need to know how much percentage inaccuracy will be produced by/her methods or instruments. In both situations, if a researcher gets clarity, there is no need to trouble themselves by wasting time and energy to get more incredible accuracy.

2. In every research, the collected data must be in a tabular format that needs to be analysed. The collected data should be meaningfully presented to interpret and draw conclusions. The researchers may not get good results if they take lots of time to collect more unwanted data. Most of the time, the researcher intends to collect new data. If researchers have lots of data without understanding how they will give meaning to that data after spending so much time collecting it, the data does not give any meaning to their research. It is too late to give meaning to them at the final stage of the research. The above-mentioned hypothetical situation can be avoided by taking the time to prepare the research design. In laboratory research, the researcher may wish to do impressive research. At the same time, if they develop inferior quality instruments to experiment, they may get inaccurate results. At the same, if the researcher devotes his energy and time to developing quality instruments to do testing, he may get accurate results.

3. As a scientist, it is their responsibility to build scientific institutions with their capability for a better way of inquiry. They may apply various methodological inquiries to build theories to solve societal problems and inquire about social relations. A scientist cannot afford to satisfy with his methods. As a scientist, it is their responsibility to question every stage of their research by questioning their methods with an open mind. This paves the way for improving their methods continuously while doing the research. Once the researcher decides on the research problem, they must develop an appropriate methodology to solve the problem. In this process, developing a research design is very important. According to Ackoff, “the idealized research design is concerned with specifying the optimum research procedure that could be followed where there are no practical restrictions”.

If you look at the above definition of research design, it states that there is no need to develop an idealized research design. One can give a choice to improve the research design in the process of conducting the research. Once the researcher finalized the research design, it must be converted into the working procedure. Before starting the research, the researcher must consider various factors, including time, money and energy.

4. If research is part of the master's or pre-PhD programme, the researcher may face time constraints. In such a situation, the researcher may limit to observing one or two variables rather than finalizing multiple variables to observe. The observation method may bring subjective error in both science and social science research. In such a situation, the researcher may consider using triangulation as a method where the same phenomena can be tested using more than one method. The researcher needs to collect data using more than one method as this may also, in some situation, helps in avoiding errors in collecting the data. They may draw a sampling population that they need to observe multiple times. Sometimes this may take time and energy, which is not practical. Thus, the research design helps the researcher to organize his ideas in a form whereby it will be possible for them to look for flaws and inadequacies. The research design also allows researchers to present their study to the experts for critical comments and evaluation. Without such a course of action, it will be difficult for the critic to provide a comprehensive review of the proposed study.

3.4 PRINCIPLES OF RESEARCH DESIGN

The following principles must be kept in mind while designing the research—the existing literature mentioned the following six principles for research design.

1. Research design should be holistic.
2. It should be agnostic.
3. It should be prepared with a purpose.
4. The research design should be prepared early.
5. It should be flexible.
6. It should be shared with experts and other researchers.

3.5 TYPES OF RESEARCH DESIGNS

According to Manheim, there are three types of research designs.

1. Research design in case of exploratory research studies;
2. Research design in case of descriptive and diagnostic research studies, and

3. Research design in case of hypothesis-testing research studies.

Let us discuss each type of research in detail in this section.

1. Research Design in case of Exploratory Research Studies

It is also called formulative research studies. The study based on exploratory research design is either to formulate a research problem for further precise investigation or to develop a working hypothesis for further research. The following example will help you to know exploratory research with clarity. A person has visited a doctor with a fever. The doctor did not know the reasons for his/her fever. The doctor might treat the patient with the visible symptoms. If the fever went within a few days, the doctor diagnosed it rightly and treated for the disease the doctor diagnosed by giving drugs based on visible symptoms. His exploration of particular patients for visible symptoms might pave the way for knowing symptoms of malaria or dengue, facilitating further research on symptoms and drugs. With the above example, the research design emphasizes discovering ideas and insights. As I mentioned in an example in this section, exploratory research design provides space and flexibility to explore different aspects of a specific research problem. In the initial stage, the research problem will be defined. It will be converted into a specific research problem after exploratory studies. In the exploratory research design, there will be flexibility in changing the research design. In exploratory research design, the following research is mainly carried out.

1. Reviewing existing literature for chosen research problem;
2. The experience survey to document the experiences of individuals on specific issues; and
3. The analysis of 'insight-stimulating' examples.

The survey of an existing literature review may pave the way for formulating particular research problems or developing hypotheses. It is a simple and fruitful method. The researchers need to visit libraries to review the existing literature. The existing studies and the hypotheses stated in the existing studies may be reviewed, and their usefulness is evaluated. Based on that, further research for formulating research problems may be planned. It may also be considered whether the already stated hypotheses suggest a new hypothesis. In this way, the researcher reviews and builds upon their work based on the work done by others. However, in cases where hypotheses have not been formulated, her/his task is to review the available material for deriving the relevant hypotheses. Besides, the bibliographical survey of studies already made in one's area of interest may also facilitate the researcher to formulate the problem precisely. Researchers should also attempt to apply concepts and theories developed in different research contexts to the area in which they are working. Sometimes the works of creative writers also provide a fertile ground for hypothesis formulation.

Experience survey means surveying people with practical experience with a specific problem to be studied. Such a survey aims to obtain insight into the

relationships between variables and new ideas relating to the research problem. For such a survey, competent people can contribute new ideas. The sample population to explore new ideas may be selected carefully. Researchers must ensure that respondents represent different types of experience. The investigator may then interview the selected respondents. The researcher must prepare an interview schedule for the systematic questioning of informants. However, the researcher must ensure flexibility in conducting interviews because the respondents should be allowed to raise issues and questions that the investigator has not previously considered. Generally, collecting information through their experiences in an interview is likely to be long and may last a few hours. Hence, it is often considered desirable to send a copy of the questions to be discussed to the respondents well in advance. This will also allow the respondents to do some advance thinking over the various issues involved so that, at the time of the interview, they may be able to contribute effectively. Thus, an experience survey may enable the researcher to define the problem more precisely and help formulate the research hypothesis. The survey may also provide information about the practical possibilities for doing different types of research.

Analysis of 'insight-stimulating' examples is also a fruitful method for suggesting hypotheses for research. It is particularly suitable in areas with little experience as a guide. This method consists of intensively studying selected instances of the phenomenon in which one is interested. For this purpose, the existing records may be examined, unstructured interviewing may take place, or any other approach may be adopted. The investigator's attitude, the study's intensity and the researcher's ability to draw diverse information into a unified interpretation are the main features that make this method an appropriate procedure for evoking insights.

Now, what sort of examples are to be selected and studied? There is no clear-cut answer to it. Experience indicates that certain types of instances are more appropriate for particular problems than others. One can mention a few examples of 'insight-stimulating' cases such as the reactions of strangers, the reactions of marginal individuals, the study of individuals who are in transition from one stage to another, and the reactions of individuals from different social strata and the like. Thus, in an exploratory formulative research study which merely leads to insights or hypotheses, whatever method or research design outlined above is adopted, the only thing essential is that it must continue to remain flexible so that many different facets of a problem may be considered as and when they arise and come to the notice of the researcher.

2. Research Design in case of Descriptive and Diagnostic Research Studies

The researcher will decide to do descriptive research studies to describe the characteristics of a particular individual or a group. Unlike descriptive studies, diagnostic research studies determine the frequency with which something occurs or its association with something else—the studies

concerning whether certain variables are associated are examples of diagnostic research studies. For example, the world has faced the Covid 19 pandemic, which made it standstill. The diagnostic research may determine the frequency and interval of a pandemic from the 19th century. As against this, studies concerned with specific predictions, with the narration of facts and characteristics concerning individuals, groups, or situations are all examples of descriptive research studies. Most of the social research comes under this category. From the point of view of the research design, the descriptive and diagnostic studies share common requirements. We may group these two types of research studies. In descriptive and diagnostic studies, the researcher must clearly define what he wants to measure and find adequate methods for measuring it along with a clear-cut definition of the 'population' he wants to study. Since the aim is to obtain complete and accurate information in the said studies, the procedure must be carefully planned. The research design must protect against bias and maximize reliability, with due concern for the economical completion of the research study. The design in such studies must be rigid and not flexible. It must focus attention on the following: (a) Formulation of the objective of the study, (b) finalization of methods of data collection, (c) Selecting the sample, (d) Collection of data, (e) Processing and analysing the data. (f) Reporting the findings. The first step in a descriptive/diagnostic study is to specify the objectives after stating the research question(s).

The researcher may encourage using "structured instruments" to reduce biases. The sample design is significant in this type of research design. We have discussed different sample designs in this unit. The researcher must ensure that the selection of the sample must be error-free. It is suggested to design sampling through probability or random sampling. To obtain data free from errors introduced by those responsible for collecting them, it is necessary to closely supervise the field workers' staff as they collect and record information. Checks may be set up to ensure that the data collecting staff perform their duty honestly and without prejudice. "As data are collected, they should be examined for completeness, comprehensibility, consistency and reliability. The data collected must be processed and analysed. This includes coding the interview replies and observations, tabulating the data, and performing several statistical computations. To the extent possible, the processing and analysing procedure should be planned in detail before actual work is started. This will prove economical because the researcher may avoid unnecessary labour. Coding should be done carefully to avoid coding errors.

Similarly, the accuracy of tabulation may be checked by having a sample of the tables re-done. In the case of mechanical tabulation, the material (i.e., the collected data or information) must be entered on appropriate cards, which is usually done by punching holes corresponding to a given code. The accuracy of punching is to be checked and ensured. Finally, statistical computations are needed, so averages, percentages, and various coefficients must be worked out. Probability and sampling analysis may as well be used. The

appropriate statistical operations and tests of significance should be carried out to safeguard the drawing of conclusions concerning the study. Lastly, the completed research must be appropriately communicated through well-written reports. The report's structure needs to be well planned so that all things relating to the research study may be well presented in a simple and practical style. Thus, the research design in the case of descriptive/diagnostic studies is a comparative design throwing light on all points narrated above and must be prepared to keep in view the objective(s) of the study and the resources available. However, it must ensure the collected evidence's minimization of bias and reliability. The said design can be appropriately referred to as a survey design since it considers all the steps involved in a survey concerning a phenomenon to be studied.

3. Research Design in case of Hypothesis-testing Research Studies

It is generally called experimental studies. This research study tests the relationship between two or more variables. In this experimental design, the researcher first finalizes the experimental procedure to reduce bias and ensure reliability and validity. After completing the experiment, the researcher could infer the results about causality.

Experimental design is conducting research in an objective and controlled fashion so that precision is maximized and specific conclusions can be drawn regarding a hypothesis statement. Generally, the purpose is to establish a factor or independent variable's effect on a dependent variable. Thus, in an experiment, we observe and measure the effect of treatment given to a few variables by controlling other variables affecting our observations. The term “treatment” refers to a particular experimental condition. The material to which the treatment is applied and on which the variable under study is measured is known as the experimental unit. Since all variables cannot be controlled, it may cause an error in our observations. It is an experimental error. The whole experiment is conducted according to some plan called the experiment or experimental design. Without a design, a research study is like a construction without any plan or map. The design enables us to answer research questions as validly, objectively, precisely and economically as possible.

The principles of experimental design play an essential role in research. Professor R.A. Fisher’s name is associated with experimental designs. He made the beginning of such designs in agricultural research. As such, the study of experimental designs has its origin in agricultural research. Professor Fisher found that by dividing agricultural fields or plots into different blocks and conducting experiments in each block, whatever information is collected and inferences are drawn from them is more reliable. This fact inspired him to develop specific experimental designs for testing hypotheses concerning scientific investigations. Today, experimental designs are being used in research relating to phenomena of several disciplines. Since experimental designs originated in the context of agricultural operations, we still use

several technical terms of agriculture (such as treatment, yield, plot, block) in experimental designs.

Basic Principles of Experimental Designs

Professor Fisher has enumerated three principles of experimental designs:

(1) Principle of Replication;

(2) Principle of Randomization; and

(3) Principle of Local Control.

1. Principle of Replication

The experiment should be repeated more than once to increase the statistical accuracy. Each treatment is applied in many experimental units instead of one. For example, if we need to compare the yield of two varieties of paddy, then each variety is applied to more than one experimental unit. The number of times these are applied to experimental units is called their number of replications.

2. **Principle of Randomization**

The principle of Randomization involves allocating experimental units at random to avoid any bias resulting from the influence of some unknown extraneous factor that may affect the experiment. In the analysis of variance, we assume that the errors are random and independent. In turn, the observations also become random. The principle of randomization ensures this. It eliminates the systematic bias. "Randomization is analogous to insurance in that it is a precaution against disturbances that may or may not occur, and that may or may not be serious.

3. **Principle of Local Control**

The third principle is called local or error control. As already mentioned, replication with local control reduces the experimental error. In the simplest case, experimental units are divided into homogenous groups. The variation among these groups is eliminated from the error, thereby increasing efficiency. The choice of size and shape of experimental units, and environmental conditions, also affect the experiment, causing errors. It may be controlled by using an analysis of co-variance also.

Local control helps in controlling the systematic error or general factors or say "G" error; Randomization controls the sampling error or "S" error and also a little "G" error. Replication mainly controls the variations in treatment effects. Let us call it an "R" error. Measurement error is controlled by replication. Replication with randomization would be able to control all three errors and the "G" error and measurement error with local control. So, replication is a fundamental principle. Experimental design refers to the framework or structure of an experiment, and as such, there are several experimental designs. We can classify experimental designs into two broad

categories: informal experimental and formal experimental designs. Informal experimental designs are those designs that generally use a less sophisticated form of analysis based on differences in magnitudes. In contrast, formal experimental designs offer relatively more control and use precise statistical procedures for analysis. Important experiment designs are as follows:

(a) Informal Experimental Designs:
    (i) Before-and-after without control design
    (ii) After-only with control design
    (iii) Before-and-after with control design

(b) Formal Experimental Designs:
    (i) Completely Randomized Design (CRD)
    (ii) Randomized Block Design (RBD)
    (iii) Latin Square Designs (LSD)
    (iv) Factorial Designs

Before-and-after without control design: In such a design, a single test group or area is selected, and the dependent variable is measured before the introduction of the treatment. The treatment is then introduced, and the dependent variable is measured again. The effect of the treatment would be equal to the level of the phenomenon after the treatment minus the level of the phenomenon before the treatment.

After only with control design: In this design, two groups or areas (test area and control area) are selected, and the treatment is introduced into the test area only. The dependent variable is then measured in both areas at the same time. Treatment impact is assessed by subtracting the value of the dependent variable in the control area from its value in the test area.

Before-and-after with control design: In this design, two areas are selected, and the dependent variable is measured in both areas for an equal period before the treatment. The treatment is then introduced into the test area only, and the dependent variable is measured in both for an identical period after the introduction of the treatment. The treatment effect is determined by subtracting the change in the dependent variable in the control area from the change in the dependent variables in the test area.

Completely Randomized Design (CRD): CRD involves only two principles, viz., the principle of replication and the principle of randomization of experimental designs. It is the most uncomplicated possible design, and its analysis procedure is also more effortless. The essential characteristic of the design is that subjects are randomly assigned to experimental treatments or vice-versa.

Randomized Block Design (RBD) is an improvement over the CRD. In the RBD, the principle of local control can be applied along with the other two principles of experimental designs. The variable selected for grouping the

subjects is believed to be related to the measures obtained in respect of the dependent variable.

Latin Square Design (LSD) is an experimental design very frequently used in agricultural research. The conditions under which agricultural investigations are carried out differ from those in other studies, for nature plays an essential role in agriculture.

Factorial Designs: Factorial designs are used in experiments where the effects of varying more than one factor are to be determined. They are significant in several economic and social phenomena where many factors usually affect a particular problem. Factorial designs can be of two types: (i) simple factorial designs and (ii) complex factorial designs.

3.6 DEVELOPING A RESEARCH PLAN-EXPLORATION, DESCRIPTION, DIAGNOSIS AND EXPERIMENTATION

The entire research process starts with identifying the research problem. Once the researcher identifies the research problem, the researcher must organize their thoughts in a specific order, and he needs to define the terms related to the research. They may use existing definitions for the terms or define them. The researchers thought need to be converted as a 'Research Plan'. Converting the researcher's ideas into a specific research plan will help the researcher

structure in the following manner.

1. Experts, in particular, may provide suggestions to do research after looking at the proposal. Thus, the researcher could be able to rectify flaws in the research design.
2. It facilitates the researcher to focus on a review of the literature.
3. The research plan starts with a short introduction, research question, objectives, definitions for the concepts, methodology, experimental procedure (if it is experimental research), and theory (if it is social science research). The methodology includes sampling methods, data collection tools and technology, statistical procedure to analyse data and the of the research report.
4. The research plan also contains the time and cost of the study.

3.7 SAMPLING TECHNIQUES

As we mentioned earlier, sampling is an effective research technique as part of the research process. There are various terms related to sampling. We will explain those terms in this section, along with types.

First, we will learn the term 'Universe/Population'. All items in any field of inquiry constitute a 'Universe' or 'Population.' A complete enumeration of all items in the 'population' is known as a census inquiry. You all must be

heard about the census survey of India. The government of India conducted a census survey once in 10 years to generate complete data on population and related indicators. The collected data from all populations in India will be tabulated under various heads, and the researcher may find these data useful for their research to bring certain inferences. However, it needs to be emphasized that when the Universe is small, there is no use in adopting a sample survey. At the same time, when field studies are undertaken in practical life, considering time and cost, we have to select respondents, i.e., selecting only a few items. The selected respondents should be as representative of the total population as possible to produce a miniature cross-section. The selected respondents are called a ‘sample', and the selection process is called the 'sampling technique.' The survey so conducted is known as a ‘sample survey’. The researcher must prepare a sample design for his study, i.e., plan how a sample should be selected and what size such a sample would be.

Sample Designs

The researcher needs to finalize the size of the sample for the study. The finalization of several items to be included in the sample, i.e., the sample size. The selection of the size of the sample is called sample design. The researcher needs to finalize the sample size before proceeding with data collection.

There are two ways of selecting the sample: probability and non-probability. The learners need to understand the fundamental difference between probability and non-probability sampling before we proceed further. First, let us learn what probability is. You all must have learned the definition of probability in the mathematics and statistics courses. If one is unsure about something, does not have enough information, and can only guess in the process of guessing, there is uncertainty about the future course of action.

In daily life, we may face lots of uncertain situations. We always try to think that a particular situation may come or may not. In this situation, the concept of probability gives us a hand to answer a question like what is the likelihood that X will win the election or “A” team will win the match? It is illustrative of the concept of probability. If the chance of winning is one in five, the probability is 1/5 =0.2. If the chances are 1 in 100, the probability is 0.01.

3.8 NEED FOR SAMPLING

Due to various reasons (including limited period and limited resources), it may not be possible for the researcher to include the entire population in survey research. Thus, they select a part of the population to understand the characteristics of a population.

The process of systematically selecting cases from the population or Universe is called sampling. Thus, a researcher gets a set of cases (or a sample) that is more manageable and cost-effective to work with those cases to bring scientific inferences.

The next question is, how we can generalize from a handful of cases? Here we need to research logically with statistical reasoning, testing repeatedly with empirical evidence. Moreover, a researcher cannot use just any sample for generalization. Well-laid down sampling procedures require rigorous exercises to increase a study's precision level.

3.9 SIGNIFICANT TERMS IN SAMPLING

Let us learn about essential terms in sampling

1. Sampling Ratio

The ratio of the size of the sample to the size of the target population is the 'sampling ratio'. For example, a college has 2000 students, and a researcher draws a sample of 200 from it. Thus, the sampling ratio is 200/2000 = 0.1, or 10 per cent.

2. Sampling Frame

A population is an abstract concept. Except for specific small populations, one can never indeed freeze a population to measure it. For example, in a city, at any given moment, some are born, some may leave the city, some may join the city as new entrants, and some may lose their life. The researcher must decide exactly whom to count. Should she or he count a city resident on holiday or outside the city when the time is fixed for the study? Therefore, the notion of 'population' is abstract and exists in the mind but is impossible to pinpoint concretely. Since it is an abstract concept, except for small populations, a researcher needs to estimate the population. Thus, it requires an operational definition.

A researcher operationalizes a population by developing a specific list that closely approximates all the elements in the population. This list is a 'sampling frame'. The researcher may choose from many sampling frames: telephone directories, driving licences, ration cards, membership in a club, and students' registration in a university. A reasonable sampling frame is crucial to good sampling. A mismatch between the sampling frame and the conceptually defined population can be a significant source of error. For instance, if you select the telephone directory as a sampling frame, it constitutes only 5-10 per cent of the population in a city, say, Delhi. The directory does not list those who do not have a telephone connection. It also does not update the frequent shifts of residences and changes in telephone numbers in a city quickly.

3. Parameter and Statistic

Any characteristic of a population is a 'population parameter'. For instance, students from the science stream of children aged 6-11 years. It is the true characteristic of the population. Parameters are determined when all elements in a population are measured. The parameter is never known with absolute accuracy for large populations, so researchers must estimate

it based on samples. Researchers use information from the sample, called a 'statistic', to estimate population parameters.

4. Sampling Error

Sampling error is not necessarily the result of mistakes made in the sampling procedure. Instead, variations occur due to the chance selection of different individuals.

3.10 TYPES OF SAMPLING DESIGNS

Sampling designs are of two types. The first is called probability-sampling design, and the second is non-probability sampling design. In this unit, we discuss each type of sampling design in terms of its essential character and procedure.

i) **Probability Sampling Design:** Probability sampling provides a statistical basis for stating that a sample is representative of the 'target population'. In a probability sample, every element in the population has a known chance of being included in the sample. This allows for estimates of the accuracy of sample findings in approximating what we would find out if we had conducted a census of the total population.

ii) Non-probability Sampling Design: In non-probability sampling designs, we do not know whether an element of the population has an equal chance of being selected. Its probability of selection cannot be determined, as with probability sampling, where each element has a 50 per cent chance of being selected and a 50 per cent chance of not being included in the sample. The non-probability samples are drawn based on judgment regarding the characteristics of the target population and the needs of a survey. With non-probability sampling, some members of the eligible target population have a chance of being chosen, and others do not. Thus, the statistical precision estimates cannot be made with this sample. The non-probability sampling designs are preferred when there is no possibility of probability sampling. Whenever feasible, probability-sampling designs are preferred.

3.11 PROBABILITY SAMPLING PROCEDURES

The following are various probability sampling procedures:

i) Simple Random Sampling

In simple random sampling, each member of the population under study has an equal chance of being selected. The method involves selecting at random from a list of the population (a sampling frame). For example, suppose we need to select 300 people from the Universe (village) study to assess their access to common property resources. In that case, we can write each person's name on a separate slip and then put the slip in a container, and we can conduct a lottery to select 300 people to

conduct a study. In the case of an infinite population, the selection of each item in a random sample is controlled by the same probability, and successive selections are independent of each other. In this process, there is an equal chance for everyone to get selected. One essential requisite for this kind of sampling is that a complete list of the population (sampling frame) is needed.

a. There is a chance to get an unbiased sample without much technical difficulty.
b. It is unbiased
c. Selection will be based on a lottery or through a table of random numbers, or now through computer-generated random numbers. The lottery method is adopted for smaller populations or sampling frames. For more oversized sampling frames, the computer-generated numbers are selected.
d. It is not a statistically efficient method.
e. It does not provide fair representation to the sub-group population

ii) Systematic Sampling

It is another method of simple random sampling. In this method, the selection is made from the list. The researcher takes the first unit randomly. After that, he/she chooses from samples from fixed intervals. For example, If the researcher can choose every 15^{th} house on one side of the street or every 10^{th} name from the list, it is called systematic sampling. In this technique, once the first sample unit is identified randomly, the remaining unit is chosen easily.

iii) Stratified Sampling

It is also called proportional random sampling. It is more efficient statistically because it is an improved version of simple and systematic random sampling. In this sampling method, the population is divided into specified strata. In this Stratified Sampling, the population is grouped into homogenous groups (sub-groups or strata) such as age, gender, class, and location. In stratified sampling, the researcher controls the relative size of each stratum rather than letting random processes control it. This guarantees the representation of different strata within a sample. However, one condition is that the stratified sampling procedures produce samples more representative of the population than simple random or systematic samples if the stratum information is accurate.

iv) Cluster Sampling

The most widely employed probability sample design in survey research is cluster sampling. It addresses two problems: the lack of a reasonable sampling frame and the costs of reaching a sampled element or a case. For example, there is no single list of undergraduates in colleges in a city. Even if one gets an accurate sampling frame, it would cost too much to reach many undergraduates as the colleges are spread out geographically in the city. Researchers use a sampling design that involves 'clusters' instead

of a single sampling frame in this case. In this case, the cluster will be the college.

A cluster is a naturally occurring unit (e.g., a school with many classrooms, students, and teachers; a city with zones (East, West, South, Central, North); states. The clusters are selected randomly, and all members of the selected clusters are included in the sample, or simply random, systematic, or stratified samples are taken from each cluster. Cluster sampling is used in extensive surveys. It differs from stratified sampling in that with cluster sampling, one starts with a naturally occurring constituency. The researcher selects from among the clusters and either surveys all members of the selection or randomly selects from among them. The resulting sample may not represent areas not covered by the cluster, nor does one cluster necessarily represent another.

v) Stage Sampling

Stage sampling also known as multi-stage sampling is an extension of cluster sampling. It involves the selection of a sample in several stages. That is, taking samples from samples. Suppose we want to survey children's academic performance in schools in a large city. One type of stage sampling might be to select several schools randomly, and from each of these schools, select several classes and select children from within these classes. Another type of stage sampling could be to select one school in terms of either the geographic region of the school in the community/city or in terms of the type of school (public, private aided, private unaided, etc.) and take their simple random sampling, systematic sampling, or stratified sampling or even mixture of all these.

3.12 NON-PROBABILITY SAMPLING PROCEDURES

The following are the non-probability sampling procedures:

i) **Accidental or Convenience Sampling**

This is also called the 'man-on-the-street' survey. It involves choosing the individuals/cases readily available on the street, marketplace, school, or cinema theatre until the required sample size is obtained. This survey can produce ineffective, highly unrepresentative samples and is not recommended. When a researcher haphazardly selects a convenient sample, he can quickly get a sample that misrepresents the population. Such samples are cheap and quick, although biases and errors are plenty. An example of this kind of survey is the kind of interviews, television programmes conduct on the street.

ii) **Quota Sampling**

Quota sampling has often been described as the non-probability equivalent of stratified sampling. In quota sampling, the researcher divides the population into sub-groups or categories such as men and women, reserved castes

and non-reserved castes, arts and commerce, younger and older, and then decides the proportion of individuals in each category or sub-group. Thus, the number of respondents is fixed in various sample categories.

iii) Purposive or Judgmental Sampling

In purposive sampling, researchers handpick the cases to be included in the sample based on their judgment of their typicality. That means the researcher's judgment is used in selected cases with a specific purpose. Purposive sampling is appropriate in the following three situations. First, a researcher uses it to select unique cases that are exceptionally informative. Second, a researcher may use purposive sampling to select members of a difficult-to-reach, specialized population. Third, purposive sampling is preferred when a researcher wants to identify particular types of cases for in-depth investigation.

iv) Dimensional Sampling

This is a further refinement of quota sampling. It involves identifying various factors of interest in a population and obtaining at least one respondent of every combination of those factors.

v) Snowball Sampling

It is also called a network or chain referral or reputational sampling, and it is a method for identifying and sampling (or selecting) the cases in a network. Snowball sampling is based on an analogy to a snowball which begins small but becomes more extensive as it rolls on wet snow and picks up additional snow. Friendship networks are the most important sources of this kind of sampling. Further, professional associations and chat groups may also provide bases for such sampling.

Sample Size

A question often asked is about the size of the sample. How large should it be? The best answer could be that it depends. That means there is no clearcut answer to this question. However, the survey sampling literature does give prospective survey researchers general advice. For some people, a sample of thirty is the bare minimum if the researcher plans to undertake some form of statistical analysis of the data. However, the sample size depends on the researcher's plans, how accurate the sample has to be for his purposes, and population characteristics. It may be stated here that a large sample alone does not guarantee a representative sample. Further, when we increase the sample size, we increase costs. Larger samples mean increased costs. A researcher may keep in mind all these considerations while judging the size of the sample.

CHECK YOUR PROGRESS 1

Note: i) Use the space given below for your answers.

ii) Check your answers with those given at the end of the unit.

1. Write a short note on the principles of research design.

……

……

……

……

2. Write a short note on sampling techniques.

……

……

……

……

3. Write a short note on types of research design.

……

……

……

……

3.13 LET US SUM UP

The Unit introduced the learners to the significance of developing research design. In this unit, we have discussed the need for research design and principles and various types of research design. We have also discussed the need for sampling, sampling techniques and different types of sampling procedures.

3.14 KEY WORDS

Completely Randomized Design (CRD) : CRD involves only two principles namely the principle of replication and the principle of randomization of experimental designs. The essential characteristic of the design is that subjects are randomly assigned to experimental treatments or vice-versa.

Research Design : The research design is the arrangement of conditions for data collection and analysis in a manner that aims to combine relevance to the research purpose with the economy in procedure.

3.15 SUGGESTED FURTHER READING/ REFERENCES

Aldridge, A. and Levine, K. (2001). *Surveying the Social World - Principles and Practice in Survey Research.* Open University Press: Buckingham.

Bryman, A. (2008). *Social Research Methods*. 3rd Edition, Oxford University Press., New York.

Cohen, L., Manion, L., and Morrison, K. (2007). *Research Methods in Education.* Routledge: London and New York

Kothari, C.R. and Garg. G. (2019). Research Methodology: Methods and Techniques., New Delhi: New age Publishers.

Malik, SM. (2014). Sampling Methods and Estimation of Sample Size (Unit 19) In: MGS 005 Research Methodologies in Gender and Development Studies, IGNOU, New Delhi. Available at https://egyankosh.ac.in/handle/123456789/8711

Moser, C. A. and Kalton, G. (1971). *Survey Methods in Social Investigation.* The English Language Book Society: London

Sarnamohan, V. (2014). Non-Probability Sampling (Unit 2) In: Block 4 Quantitative Methods. MGS 005 Research Methodologies in Gender and Development Studies, IGNOU, New Delhi.

Sarnamohan, V. (2014). Probability Sampling (Unit 1) In: Block 4 Quantitative Methods. MGS 005 Research Methodologies in Gender and Development Studies, IGNOU, New Delhi.

Selltiz, C., Jahoda, M., Deutsch, M. and Cook, S.W. (1964). Research Methods in Social Relations.

Singleton Jr., R.A. and Straits, B.C. (2017). *Approaches to Social Research*, 6th Edition. Oxford University Press, Oxford.

3.16 ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress 1

1. Please refer to section 3.4

2. Please refer to section 3.7

3. Please refer to section 3.5