Introduction to the Scientific Method in Research: A Guide for Student Scientists

Introduction to the Scientific Method in Research: A Guide for Student Scientists

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PUSAT E-PEMBELAJARAN UNIVERSITI MALAYSIA SABAH
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Acknowledgments

First and foremost, I would like to express my sincere gratitude to the Centre for e-Learning at Universiti Malaysia Sabah (UMS) for introducing me to the ideas of open educational resources (OBE) and inclusive open textbooks (iOTB). I extend my heartfelt thanks to the Centre and the Commonwealth of Learning (COL) Canada for organizing the workshop on the development of iOTB. Special appreciation to the workshop speaker, Dr. Indira Koneru, for her guidance on using the UMS Pressbooks platform and making sure that the development of iOTB adheres to inclusive open education best practices. I also like to thank Universiti Malaysia Sabah as this project would not have been achievable without their tremendous support. Not to forget the entire staff at the Center for e-Learning for their continuous oversight as well as their technical assistance. Last but not least, thanks to everyone who has been there for me, my family and friends, for their unwavering support and encouragement during this process.

About the Author

Ts. Dr. Soo Chen Lin is a senior lecturer at the Institute for Tropical Biology and Conservation (ITBC), Universiti Malaysia Sabah. She holds a Ph.D. in Aquatic Science from Universiti Malaysia Sarawak and a master's degree in Aquaculture from Universiti Malaysia Terengganu. As an experienced researcher with a wealth of experience in aquatic science and conservation biology, she brings a unique perspective and practical experience to the topics covered in this textbook.

Dr. Soo's extensive expertise in aquatic pollution and ecology is reflected in her successful track record of securing national and university grants for projects related to microplastic pollution, fish biodiversity, DNA barcoding, and environmental DNA. She has published over 30 scientific papers, with a Scopus H-index of 12. Dr. Soo has also been involved in consultation projects that have had a tangible impact on environmental management and biodiversity conservation, further underscoring her commitment to translating research into real-world applications.

As an educator, Dr. Soo has taught various postgraduate and undergraduate courses, covering research methodology, ecology, aquatic ecology, and meiobenthology. Her dedication to mentoring is apparent in the extensive number of undergraduate and postgraduate students she has supervised in their research endeavors. Dr. Soo currently holds the postgraduate program (research) coordinator position at ITBC. In addition, she held other

administrative positions within her institution, such as Deputy Coordinator of Academic Program Quality and Acting Head of Program. These experiences have provided her with a profound comprehension of the difficulties that students have while embarking on a new research project, as well as the best practices in academic program management, quality assurance, and curriculum development.

Dr. Soo's extensive research experience and dedication to teaching and mentoring make her highly prepared to offer readers a comprehensive and authoritative overview of the scientific research process. Her profound insights and exceptional skills will be of immense value to readers as they embark on their research journeys, enabling them to make substantial contributions to the advancement of scientific knowledge in their respective areas of study.

Preface

Hi there, and welcome to the UMS Pressbooks. “Introduction to the Scientific Method in Research: A Guide for Student Scientists” is a book that I hope you can benefit from it! This textbook has been put together to be your go-to resource as you embark on your research journey. Whether you’re an undergraduate or a postgraduate student, working on science-related research projects or thesis work, this book will provide you with the necessary information and skills to do research. While the primary target readers for this textbook are science students, early-career researchers and academic supervisors can find value in this textbook. Early-career researchers can use the book as a reference to hone their research skills while the supervisors can use it as a structured guide to supervise students throughout their research process.

The main goal of this book is to give you a fundamental understanding of the iterative research process. By integrating the scientific method, this book provides you with a structured and comprehensive approach to research projects. The scientific method is a systematic process and set of procedures that help us engage in research. It is the roadmap that guides us through every step of the research process, which includes making observations and asking questions, constructing hypotheses and defining specific research objectives, the intricate process of designing studies, collecting and analyzing data, coming to reliable conclusions, and disseminating the findings. Understanding and applying scientific method in research are crucial for ensuring the reliability and validity of your research. Throughout each chapter, you’ll find clear explanations, practical examples, and thought-provoking exercises to enhance your understanding and application of scientific method in research.

Research is fun and amazing! It’s the backbone of all discoveries and knowledge. My final-year thesis was my very first research

project, as I recall. The thrill of planning the research, collecting data, and arranging it to look for trends was unforgettable. Even though there weren't any courses teaching students how to conduct research at that time, I am grateful to my supervisor who guided me through the research process and sparked my interest in research, an interest that I still have today. Now, let us embark on this exciting journey through this textbook together. May this book be your guiding light as you navigate the intricate path of research, enabling you to contribute to the advancement of scientific knowledge in your respective fields.

Soo Chen Lin (Institute for the Tropical Biology and Conservation, Universiti Malaysia Sabah)

PART I

INTRODUCTION TO SCIENTIFIC METHOD IN RESEARCH

"Science is much more than a body of knowledge" – Carl Sagan

Science is more than just facts or knowledge; it is a way of understanding the world. Every day, new evidence and insights emerge from undertaking **research**. The **scientific method** is a systematic process and set of procedures that help us do research. The general steps of the scientific method in research are usually established in six or seven steps, as shown below:

1. observing a phenomenon or a problem that you wish to investigate,
2. formulating a **research question** based on existing knowledge,
3. developing a **hypothesis** which is an educated guess or tentative explanation for the question,
4. designing a study and collecting relevant **data**,
5. analyzing data using appropriate **statistical analysis**,
6. interpreting the results and critically evaluating the findings,
7. concluding and sharing the findings.

It should be noted that the exact steps and order of the scientific method may differ based on the research topic or field of study. For example, a hypothesis is generally linked with hypothesis-driven

research, it may or may not be required in descriptive or exploratory research. Research is an iterative process as illustrated in Figure 1.1; steps may overlap or be revisited as new information and insights emerge. Flexibility and adaptation are essential throughout the research journey.

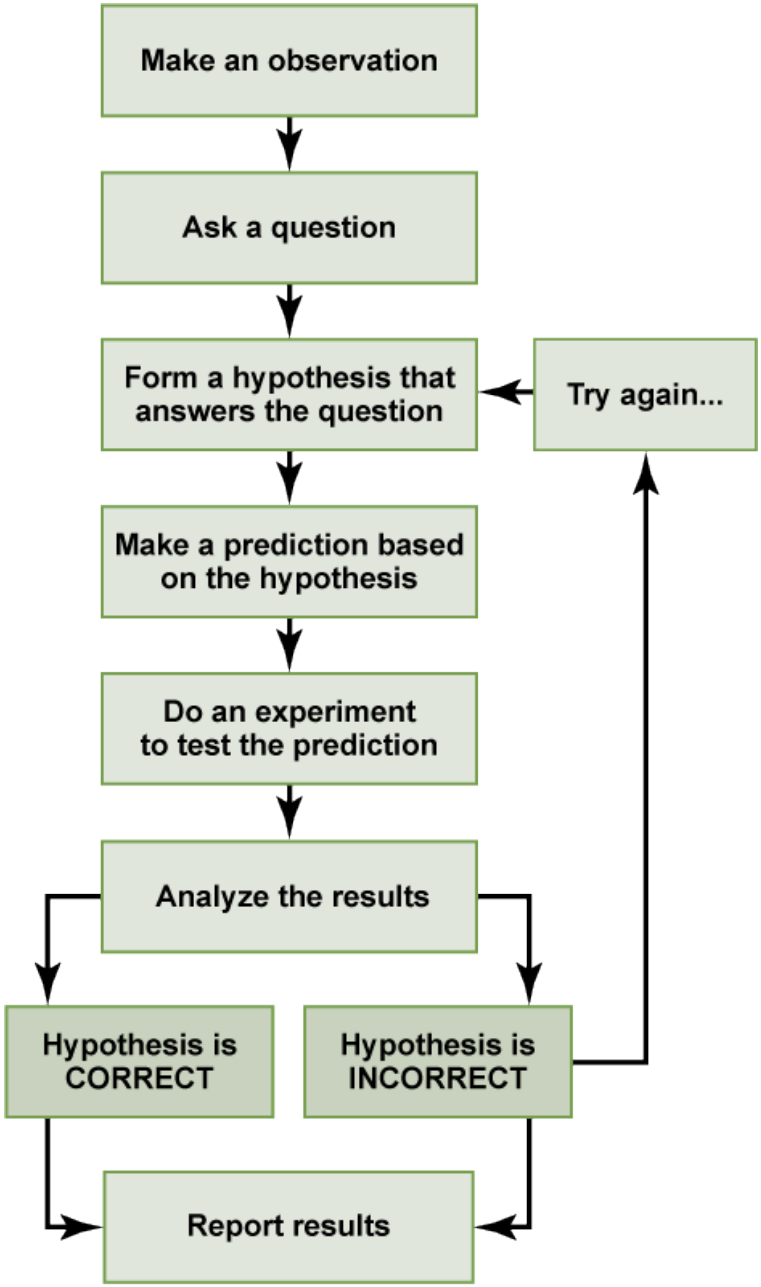
Make an observation
Ask a question
Form a hypothesis that answers the question
Try again...
Make a prediction based on the hypothesis
Do an experiment to test the prediction
Analyze the results
Hypothesis is CORRECT
Hypothesis is INCORRECT
Report results

Figure 1.1: The scientific method is an ongoing process with well-defined steps to standardize how scientific knowledge is gathered through a logical, rational problem-solving method. Source: "1.2 The Process of Science" by OpenStax is licensed under CC BY 4.0

The scientific method emphasizes critical thinking and evidence-based reasoning. It can be used not only in research but also in everyday decision-making and problem-solving. Let's look at the various circumstances in which scientific method is employed in everyday life. These scenarios illustrate that we indeed apply the scientific method in our daily lives without noticing it (Figure 1.2).

Figure 1.2: A broken car and a failed baking attempt illustrate the use of the scientific method to solve problems in our daily lives.

In other words, we are all researchers! Research is neither limited to academic, scientific, or industrial research, nor is it restricted to

any formal institution. We conduct research in our everyday lives. We generate new ideas, gather information to solve problems, and make informed decisions everyday. Furthermore, open educational resources (OER) enable us to learn freely and the internet has made it easier than ever to acquire large volumes of information and do independent study.

Watch this video to learn about the term "research" and the variety of ways in which we engage with research on a daily basis [3 mins, 42 sec]

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By the end of this textbook, you will have a clear understanding of the scientific method and its application in conducting research. The following chapters are covered in this textbook:

1. Make Observations and Ask Questions

2. Construct Hypotheses and Define Objectives

3. Design the Study and Develop a Data Collection Plan

4. Data Analysis and Interpret the Findings

5. Draw a Conclusion and Share the Discoveries

You will recognize the importance of making **observations**, and know how to formulate **research question**s, testable hypotheses, and specific **objective**s for your study. Furthermore, you will know how to design and implement a study to collect relevant **data**, analyze and interpret findings, and draw valid **conclusion**s. Finally, you will understand how to share your research discoveries with the scientific community and the general public. This crucial knowledge will serve as a strong foundation for you to kick-start your research. Still, this textbook is intended as an introduction to student scientists who are new to research. There are a myriad of resources available for more in-depth information about conducting research in your particular field of study.

1. Make Observations and Ask Questions

The scientific method begins with observation. You observe and identify a phenomenon or problem that you wish to investigate, and subsequently formulate a research question. As an illustration, one may inquire, "What is the total number of plant species that can be observed within the confines of my backyard?"

Learning Objectives

After completing this topic, you will be able to:

- explore how observations lead to the formulation of research questions.
- formulate clear and focused research questions that address the identified research problem and guide the research process.

Careful **observation** and curiosity are both integral to the process of scientific inquiry. They play significant roles in shaping scientific investigations, generating **research question**s, and advancing our understanding of the natural world. There are many examples of how careful observation and curiosity have led to a scientific

breakthrough. For instance, Fleming's discovery of penicillin[1] (See Box 1.1) stands as a testament to the power of careful observation and the importance of curiosity in scientific breakthroughs. Video 1.1 shows another example of Charles Darwin's careful observation and curiosity, which led to the development of the theory of evolution[2]. These examples highlights how a scientist's ability to notice and question can lead to significant advancements in science.

BOX 1.1: *Discovery of penicillin by Sir Alexander Fleming*

In 1928, Fleming, a Scottish bacteriologist, was conducting research on *Staphylococcus* bacteria at St. Mary's Hospital in London. He had left a petri dish containing *Staphylococcus* bacteria uncovered on his laboratory bench while he was on vacation. Upon returning, he noticed that mold had grown on the dish, and to his surprise, he observed that the bacterial colonies around the mold appeared to be dying. Fleming's careful observation and curiosity prompted him to investigate further. He noticed that the mold belonged to the *Penicillium* genus and hypothesized that the mold was producing a substance that inhibited the growth of bacteria. He conducted a series of experiments to isolate and purify this substance, which he named penicillin. This accidental discovery, resulting from Fleming's keen

1. Fleming, Alexander. "On the antibacterial action of cultures of a Penicillium, with special reference to their use in the isolation of B. influenzae." British Journal of Experimental Pathology, vol. 10, no. 3, 1929, pp. 226-236.
2. Darwin, C. (1859). On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life. John Murray.

observation and curiosity, laid the foundation for the development of the first widely-used antibiotic. Fleming's subsequent research and the work of other scientists led to the mass production of penicillin, which revolutionized medicine by providing an effective treatment for bacterial infections and saving countless lives.

VIDEO 1.1: *Development of the Theory of Evolution by Charles Darwin [3 mins, 18 sec]*

Charles Darwin's theory of evolution is another example of a scientific breakthrough influenced by careful observation and curiosity. During his voyage on the HMS Beagle, Darwin made numerous observations of diverse species and their adaptations to different environments. He was curious about the patterns he observed, such as the variations among finches on the Galapagos Islands. These observations and his curiosity led him to develop the theory of evolution through natural selection, which revolutionized our understanding of the origin and diversification of species.

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So then, what are the key characteristics that contribute to the formulation of a high-quality research question? First of all, let us shift our attention towards some practical considerations. A good research question is one that:

1. you are interested in
    - When you are enthusiastic about the topic in question, you are more likely to stay motivated, focused, and engaged throughout the research process. Know yourself. For instance, if you have weak microscopy skills and have headaches whenever you look through a microscope, you may not want to pursue a meiofauna study.
2. you have the resources to answer
    - It is critical to assess whether you have the resources you need (financial, technological, facilities, assistance, etc.) to effectively respond to the research question. What is your plan if you do not have the necessary resources at that point in time? Are you going to apply for a research grant to cover the sampling or experiment costs? Have you located any institutions that have the facilities you require for your experiment?
3. you have access to the data you require

- It is essential to consider if you have access to the required data or samples to address your research question. Limited access or limited sample size can impact the scope and feasibility of the study. For instance, research on an endangered species can be critical for developing a conservation strategy and making informed decisions. However, if you have difficulties locating the species or obtaining enough samples for hypothesis testing, your efforts may be in vain because there is not enough evidence to draw a meaningful conclusion.

4. can be implemented properly

    - A good research question should be realistic and can be implemented within the constraints of the research context. Consider factors such as time, logistical considerations, ethical considerations, and any other practical limitations. It is important to formulate research questions that are realistic and achievable within the limitations of available resources and current scientific understanding.

5. has a specific objective

    - It should state what you aim to achieve, what aspect you want to investigate, or what **knowledge gap** you want to address. A specific objective helps guide your research process, focuses your efforts, and facilitates the evaluation of research outcomes.

Consider these criteria for a good research question when formulating one. This will allow you to set realistic goals, plan properly, and increase your chances of successfully answering your research questions within the available resources and limitations. Furthermore, a good research question often seeks to close significant knowledge gaps, contribute to current theories, or have

practical implications in various fields of study or real-world settings. Consider whether your research question covers vital topics and advances knowledge about your field of study. BOX 1.2 and BOX 1.3 provides some examples of practical and impractical research questions. Check each out to see why they are practical or impractical!

BOX 1.2: *Examples of practical research questions*

These examples illustrates research questions that address important topics and can be practically implemented with the necessary resources and data accessibility. Click on the drop-downs to read more.

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https://openbook.ums.edu.my/researchmethodology/?p=34#h5p-1

BOX 1.3: *Examples of impractical research questions*

These examples illustrate research questions that are impractical due

to their scale, feasibility, resource requirements, or the complexity of the ecological systems involved. The research question may be overly specific, lack broader relevance, requires long-term efforts, or involve impractical measurements or data collection methods. Click on the drop-downs to read more.

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Check Point 1.1

Check out the clip below and answer the questions to learn what makes a good research question.

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Problem Statement

In many cases, people tend to start asking questions when encountering a problematic situation. A problem statement serves as the foundation for every research project. It clarifies why the research is important given our limited time and resources. A problem statement should not be too broad or ambiguous as it will be difficult to set an exact goal and complete the tasks in the period allocated for the study. This is especially crucial for student scientists who are also limited by study period.

The problem statement should do three things:

1. Describe the problem in detail.
2. Identify the knowledge gap about the problem and its solutions.
3. Explain the repercussions of failing to find a solution to justify the significance of your research.

Exercises 1.1

Imagine that you are going to start a research-based postgraduate study. Pick a topic that interests you. Identify the phenomenon or problem you wish to investigate. Formulate a good research question that is realistic and achievable within the available resources and current scientific understanding.

2. Construct Hypotheses and Define Objectives

*The next step involved in the **scientific method** is to formulate a **hypothesis** based on the **observation**. How can you do it? Try answering your problem or your **research question**.*

Learning Objectives

After completing this chapter, you will be able to:

- construct a testable hypothesis that is specific, falsifiable, and supported by existing knowledge
- formulate research objectives that are specific, measurable, achievable, relevant, and time-bound (SMART)

In its simplest form, a hypothesis is an educated guess. It is a tentative statement that suggests a potential answer to a research question. It could be a possible explanation for an observed phenomenon, a proposed solution to a problem, or a potential correlation between variables. However, there are several conditions to meet for a well-formulated hypothesis. Among others, it should be:

- testable through experimentation and data analysis,

- falsifiable[1],
- clear and specific,
- logically consistent with existing knowledge,
- including an **independent variable** and a **dependent variable**.

Let's explore the characteristics of a well-formulated hypothesis one by one.

Testability

The hypothesis should be formulated in a way that it can be empirically tested through data collection and analysis. You should be able to design experiments, conduct observations, or analyze existing data to empirically test the hypothesis and generate evidence for or against it.

> "Increasing levels of noise pollution negatively impact bird species richness."

This hypothesis is testable by conducting field surveys in areas with varying levels of noise pollution and analyzing the relationship between noise levels and bird species richness.

Falsifiability

A good hypothesis is falsifiable, which means it can be potentially proven wrong or falsified using empirical data. In other words, there

1. Popper, K. (1959). The Logic of Scientific Discovery. Routledge.

must be a way to test the hypothesis and find evidence that refutes it.

> "Increasing levels of pesticide exposure have no effect on honeybee colony health."

This hypothesis is falsifiable because it is possible to conduct experiments or collect data that could show a detrimental effect of pesticide exposure on honeybee colonies and refute the hypothesis.

Clarity and specificity

A well-formulated hypothesis is clear and precisely states the relationship or phenomenon being investigated. This clarity and specificity help in designing appropriate research methods, collecting relevant data, and subsequent analysis.

> "Increased levels of habitat fragmentation are negatively correlated with plant species diversity in a forest ecosystem."

This hypothesis guides researchers to investigate the impact of habitat fragmentation on plant species diversity. It clearly states the relationship between habitat fragmentation and plant species diversity. The hypothesis statement directs the researchers how the research could be conducted by selecting multiple forest sites with varying degree of habitat fragmentation and collecting plant diversity such as species richness and abundance data within each sample area. The relationship between the two variables can then

be evaluated by applying statistical methods like regression analysis or correlation analysis.

Logical consistency

A well-formulated hypothesis should be logically consistent with existing knowledge, theories, or observations in the field. It should build upon existing evidence and be grounded in a sound theoretical framework.

> "Increased temperature leads to changes in the breeding behavior of reptiles."

This hypothesis is consistent with the known physiological responses of reptiles to temperature changes, such as influencing their reproductive behavior and nesting patterns.

Independent and dependent variables

In most cases, hypothesis statement should include clearly defined independent and dependent variables. The researcher manipulates or changes the independent variable that is believed to affect the dependent variable. The dependent variable will be measured or observed and it is expected to be influenced by the independent variable.

> "Increased total suspended solids levels negatively impact

fish growth."

In this case, fish growth is the dependent variable being tracked, and it is believed to be affected by the independent variable, total suspended solids levels. The researcher manipulates different levels of total suspended solids to see how they affect fish growth.

It's important to note that in some cases, there may not be a clear independent variable if the research is focus on describing a specific phenomenon or characteristic.

"There is a new species of orchid in Borneo rainforest region."

This hypothesis focuses on describing the presence or absence of the new species rather than examining a relationship between variables. The researchers conduct field surveys and collect plant specimens from the Borneo rainforest region. They compare the collected specimens with known orchid species and conduct morphological and genetic analyses. If the specimens exhibit distinct characteristics that differentiate them from known species, the researchers may conclude that they have discovered a new orchid species.

Check Point 2.1

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After constructing your hypothesis, you should define a set of research **objectives** that can be achieved for you to answer your research question. Research objectives are specific goals that outline the tasks or outcomes that a researcher aims to attain through their study. The SMART framework, which stands for Specific, Measurable, Achievable, Relevant, and Time-bound, can help you define research objectives. Here's a breakdown of each component:

Specific

Research objectives should address specific aspects of the research topic. Clearly state what you intend to investigate in your objective. It should be precise and focused, and avoid vague or overly broad objectives.

TRY IT!

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Measurable

Identify key variables or indicators that can be quantified or observed for your objectives. This is important because progress and achievement can be assessed through the output. It also facilitates data collection and subsequent statistical analysis.

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Achievable

Research objectives should be realistic and attainable within the available resources, time frame, and constraints of the study. It's important to set objectives that can be accomplished given the available means and limitations.

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online here:
https://openbook.ums.edu.my/researchmethodology/?p=36#h5p-7

Relevant

The research objective should be relevant to your research topic. Aligned your research objectives with the research questions and hypotheses being investigated. It should be able to provide specific information that directly addresses the research question or problem at hand.

TRY IT!

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Time-bound

Research objectives should have a specific time frame or timeline for completion. This helps to plan and manage the research process effectively. Most of the time, the objective itself may not provide a specific timeline. Various factors, such as the complexity of the experiment and laboratory procedures, or the nature of the data collection and analysis, can be used to estimate the timeframe for the objective.

TRY IT!

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online here:
https://openbook.ums.edu.my/researchmethodology/?p=36#h5p-9

When defining your research objective, always check if it fit to the SMART criteria (see BOX 2.1) to ensure that your objective is clear, measurable, attainable, relevant, and time-bound. This approach enhances the focus and effectiveness of the research study, leading to meaningful outcomes and contributions to the field.

BOX 2.1: *Example of research objective fits the SMART criteria*

"To determine the relationship between habitat heterogeneity and amphibian species richness in wetland ecosystems by conducting surveys over a 1-year period."

SMART criteria	Check	Remarks
Specific	✔	clearly states the focus on determining the relationship between habitat heterogeneity and amphibian species richness.
Measurable	✔	the variable, amphibian species richness is measurable.
Achievable	✔	it is feasible to conduct field surveys and analyze the correlation between habitat heterogeneity and species richness.
Relevant	✔	the objective is relevant to understanding the factors influencing amphibian biodiversity in wetland ecosystems.
Time-bound	✔	the objective specify a duration for data collection by conducting surveys over a 1-year period.

Always check if your research objective fit the SMART criteria!

Research Aim

The research aim is the overarching goal of a research study. It is broader in scope and provides the general direction for the study, whereas the research objective is a specific, measurable step or sub-goal

that contributes to the achievement of the research aim. Like the research objective, it should also be in line with the research question and hypothesis, and it should be realistic and attainable given the limitations of the study, such as the time, resources, and expertise that are available.

Research Aim: To evaluate the long-term effectiveness of a newly gazette marine protected areas (MPAs) in promoting the recovery of coral reefs.

Research Objective: To measure the changes in coral cover within and outside of the protected areas every six months after the gazette of the marine protected areas for three years.

As shown in the example above, the research aim states a broader goal without going into detail about methodology, whereas the research objective provides a specific task that is measurable, achievable, relevant, and time-bound.

Exercises 2.1

Carefully review the research question in Exercise 1.1 and identify the variables involved. Construct a hypothesis that

is specific, testable, falsifiable, and logically consistent with existing knowledge. Subsequently, formulate a research objective using the SMART framework.

3. Design the Study and Develop a Data Collection Plan

At this stage, relevant data is collected to test the hypothesis and answer your research question. There are many ways to do it. Plan and decide how you will collect your data.

Learning Objectives

After completing this chapter, you will be able to:

- explore different types of research studies and their key features, advantages, and limitations
- develop a comprehensive data collection plan by applying the 5W1H approach (Why, Who, What, When, Where, and How)

There are various types of research that you can conduct according to the sources of information, type of data used, and research purposes. It's important to note that a research project will not be limited to one type of research, but will likely use several. Understanding the types of research and what each of them focuses on will allow you to better plan your project and utilizes the most appropriate methodologies and techniques. It is also important to

know the advantages and limitations of each type of research to avoid misinterpretation of the research output and better communicate your findings to other researchers.

Sources of Information: Primary vs Secondary Research

Research can be divided into two groups based on how the data is collected: primary and secondary. **Primary research** is when you collect the data yourself while **secondary research** is when you use existing data to do your research. Primary research can be executed through observations, experiments, surveys, interviews, and other approaches. The main advantage of primary research is that you may set up and use a data collection strategy that is tailored to your study objectives. On the other hand, you can retrieve and synthesize secondary data from a variety of sources, such as scholarly journals, databases, and even museum collections. However, you have no control over how the data was collected firsthand.

Check Point 3.1

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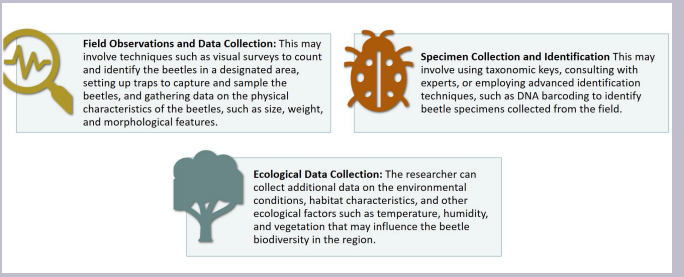
https://openbook.ums.edu.my/researchmethodology/?p=46#h5p-10

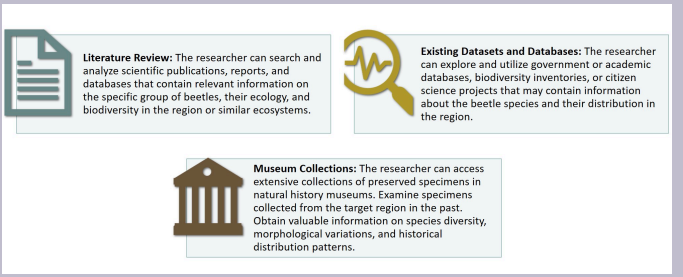
BOX 3.1: *Examples of primary and secondary research*

Lets explore how a researcher can study the biodiversity of a specific group of beetles in a particular region using primary and secondary research.

Primary research provides first-hand and customized data that can be conducted by the following approaches:



Secondary research leverages existing information and can include the following approaches:



By combining the primary research approach, which involves direct field observations and data collection, with the secondary research approach, which utilizes existing literature and data sources, the researcher can gain a more comprehensive understanding of the biodiversity of the specific group of beetles in the particular region. The integration of these two approaches can lead to more robust and reliable research findings.

Type of Data Used: Qualitative vs Quantitative

Qualitative and quantitative research uses different types of data for research purposes. **Qualitative research** gathers non-numerical data to investigate subjective experiences, perceptions, and behaviors, whereas **quantitative research** collects numerical data to quantify and measure specific aspects of the research topic.

Watch this video to learn about qualitative and quantitative research [1 min, 08 sec]

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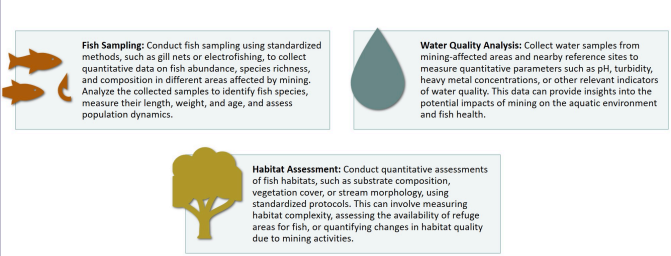
BOX 3.2: *Examples of qualitative and quantitative research*

Lets explore how a researcher can study the impact of mining activity on fish biodiversity via qualitative and quantitative approach.

Qualitative research can include the following approaches:

Quantitative research can include the following approaches:



By combining qualitative and quantitative research methods, researchers can gain a comprehensive understanding of the impact of mining activity on fish biodiversity. Qualitative data provide insights into local knowledge, perceptions, and the human dimension of the issue, while quantitative data provide objective measurements and statistical evidence of changes in fish populations, habitats, or water quality. The integration of both types of research supports a more holistic understanding of the complex relationships between mining activity and fish biodiversity, guiding conservation efforts and informing sustainable resource management practices.

Research Purposes: Exploratory, Descriptive, Correlational, and Explanatory Research

Exploratory research is conducted when a topic was previously unexplored or poorly understood, and the purpose is to explore the nature of the phenomenon. This type of research is often initiated

to obtain preliminary insights. Sometimes referred to as hypothesis-free research, exploratory research involves developing hypotheses and identifying key variables. After basic insights and concepts have been obtained, **descriptive research** is useful to provide a more detailed understanding. The focus is on documenting and describing the characteristics, patterns, and interactions of the variables.

Compared to exploratory and descriptive research, correlational and explanatory research typically require a more substantial foundation of prior research. While **correlational research** investigates relationships between variables without necessarily showing causality, **explanatory research** looks at the underlying mechanisms and causal links. A correlational research measures the variables exactly as they are, and examines the direction and strength of correlations between variables. On the other hand, explanatory research uses controlled experiments, manipulation studies, or longitudinal investigations to figure out why and how certain phenomena happen.

BOX 3.3: Examples of exploratory, descriptive, correlational, and explanatory research

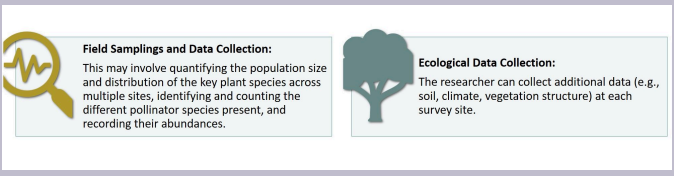
Let us focus on the study of the plant-pollinator system in the grassland ecosystem, and explore how to conduct the study with different research purposes.

Exploratory Research:

The goal of exploratory research is usually to identify relevant variables, generate initial hypotheses, and refine the research question for the next stage of the study.

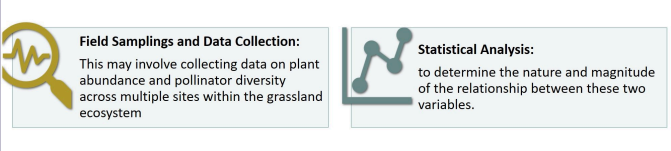
Descriptive Research:

The goal of descriptive research is to provide a comprehensive and accurate description of the current state of the plant-pollinator system in the study area. This could involve the following approach:



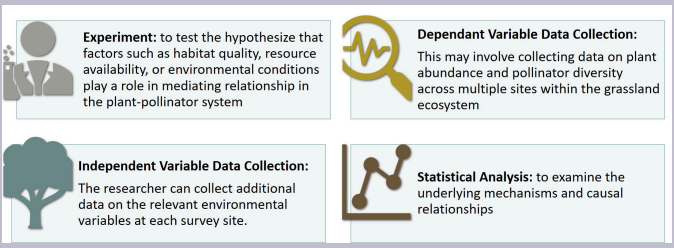
Correlational Research:

The goal of correlational research is to understand the degree to which changes in plant abundance are associated with changes in pollinator diversity, without necessarily establishing causality.



Explanatory Research:

The goal of explanatory research is to find and explain the primary causes of the observed patterns in the plant-pollinator system.



Through a combination of exploratory, descriptive, correlational, and explanatory studies, the researcher can develop a thorough understanding of the plant-pollinator system in the grassland ecosystem. The process begins with an exploratory phase that helps to refine the research question, continues with the collection of baseline data to uncover patterns, and ends with discovering significant relationships, and underlying mechanisms between the key variables of interest.

Keep in mind that the type of study design you choose will rely on your specific research goals and study objectives, the resources you

have at your disposal, the nature of the research question, and the current state of knowledge in the field. You are free to use more than one of these research designs in a single study to develop a deeper comprehension of the research problem. Click on the drop-downs to read more on the summary of key features, advantages, and limitations of different research types, and select the most suitable one for your research.

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Data collection is one of the most resource-intensive tasks in the research process, where time, money, and labor are invested. Thus, developing a thorough data collection plan is critical to ensure the process is smooth and maximizes the quality and reliability of the collected data. You can improve your data collection strategy by taking into account the essential elements of the 5W1H approach, which are the Why, Who, What, When, Where, and How. Here's a step-by-step guide for each component:

Why?

When designing a data collection plan, you should be clear about

the aim of your data collection. Determine why you require this data and why you are collecting it in this way. It allows you to collect the right sample in the right way. Justify the acceptability of your selected methods with a detailed explanation. The most common practice is to use prior studies that have successfully employed a similar method to collect relevant data or to adhere to established protocols and standard methods. The ultimate goal of data collection is to gather evidence to test hypotheses and answer research questions. Make sure the method you have chosen will provide valid and reliable data that aligns with the research questions, hypotheses, and objectives.

BOX 3.4: Examples of WHY component in the data collection plan

You should provide a justification for your choice when defending the use of a selected method for data collection. Let us use the example of qualitative and quantitative research in BOX 3.2 to explore some points to help justify the acceptability of a data collection method:

WHY component	Things to be considered
Testing hypotheses or research questions	Clearly explain whether the data obtained is relevant and can be used to address the particular goals or research questions. For example, information directly collected from individuals affected by mining activities through surveys and interviews allows us to gather their perceptions and knowledge regarding the impact of mining on fish biodiversity which aids in answering research questions concerning the specific consequences on fish biodiversity and related factors.
	Quantitative methods, such as fish sampling combined with water quality analysis and habitat assessment, can provide data to test the hypothesis that there are significant relationships between mining activities, water quality parameters like pH, dissolved oxygen, turbidity, and nutrient levels, and their effects on fish populations.
Validity and Reliability	Justify your selected method by demonstrating its validity and dependability. For instance, validated survey instruments and rigorous interviewing techniques are used to increase the credibility of the acquired data.
	Standardized protocols and established standard methods for fish sampling, water quality analysis, and habitat assessment can justify the acceptability of the chosen methods.
Ethical considerations	Informed consent from participants is obtained before conducting surveys, interviews, or focus group discussions to address ethical considerations associated with the data collection.
	Field observations and sample collection are conducted in a way to minimize disturbance to the environment and adhering to relevant regulations and permits. For example, fish sampling and handling are conducted in a way to minimize stress and ensure the well-being of captured individuals.

Eventually, choose a strategy that is practical given the available resources, including time, budget, personnel, and equipment. Explain why

the method is the most practical and efficient way to collect the necessary data within the given limits.

Who?

Conducting research, particularly postgraduate studies, is a solitary endeavor. You will need a lot of self-commitment and self-discipline to continue and succeed on this journey. However, research is not a one-man show either. Throughout the research process particularly during data collection phase, you will interact with lots of people either directly or indirectly, regardless of whether you are working on surveys, questionnaires, field samplings, or lab experiments. It could involve the research participants, field assistants, institutional staff, ethical review board, and government agencies. Identifying the WHO involved in your data collection plan is critical for you to successfully conduct your research.

BOX 3.5: *Examples of WHO component in the data collection plan*

Let us use the example of qualitative and quantitative research in BOX 3.2 to explore who you'll be dealing with during the data collection process, assuming you are the one who plans to study the impact of mining activity on fish biodiversity.

The list below are points that you might take into considerations for the qualitative research.

WHO component	Things to be considered
Government agency / Ethical review board	Obtaining research permission is a prerequisite for sample collection. Identify which agency grants permission for the research.
	Identify the ethical review board or committee that is responsible for reviewing and approving the ethical aspects of qualitative research.
Research participants	Identify the right participants, such as local community, fisherman, environmental organization, and scientists that are familiar with the area. Ensure their cooperation and consider the ethical aspects, such as obtaining informed consent, ensuring participant confidentiality, and complying with relevant regulations.
Field researcher/ Field assistant	Sometimes language could be an issue when conducting qualitative research, like an interview. Is a translator required to assist you during the interview session with the local communities?

On the other hand, the list below illustrates the WHO component when you are conducting quantitative research.

WHO component	Things to be considered
Government agency / Ethical review board	Obtaining research permission is a prerequisite for sample collection. Identify which agency grants permission for the research.
	Identify the ethical review board or committee that is responsible for reviewing and approving the animal ethics since fish is the study subject.
Field researcher/ Field assistant	Some sampling procedures may be conducted by a single person, while others may necessitate additional personnel. Do you need field assistant(s) to help you with the habitat assessment, fish sample collection, and water sample collection? Is a porter required to assist in carrying the heavy apparatus to the sampling site?
	Some sampling sites may be difficult or inaccessible. Is a local guide required to bring you to the remote sampling area?
Institutional staff	Some laboratory procedures might require specialized instruments. Do you need a lab assistant to operate the instruments? Do you know who is the staff handling the reservation of the lab that you are working at? Have you check who to call in case of an emergency in the lab?
	Laboratory analysis requires chemicals, tools, and consumables. Who is the staff or supplier that can provide the materials that you need for the lab analysis?

The checklist above illustrates the persons that might be involved directly or indirectly during the data collection. Identify each of them along with their contact information, such as phone number or email address, when you develop your data collection plan to ensure smooth operation.

What?

Conducting research requires a bunch of tools and materials. The tools and materials required for research vary depending on the nature of the study, the research field, and specific research objectives. List out as much detail as possible of what you need for your research, including consumables, field equipment, laboratory equipment, specialized instruments, and even software for subsequent data analysis. In addition, safety equipment such as additional personal protective equipment (PPE) depending on the specific sampling activities, lab work, and potential hazards should not be overlooked as well.

BOX 3.6: Examples of WHAT component in the data collection plan

These are a few examples of the tools and materials you will need for your research. The list of items is not yet exhaustive.

WHAT component	Things to be considered
Consumables	Notebooks, pens, and markers for taking observation notes, recording data, and labeling collected samples.
	Paper, printing supplies, and stationery for printing questionnaires, consent forms, or other documents.
	Storage containers or plastic bags for fish and water sample collection or storage.
	Disposable gloves, masks, wipes, and other cleaning supplies for maintaining hygiene during fieldwork and lab work.
Field equipment	GPS devices for recording locations.
	Surveys, questionnaires, or interview guides for collecting data from participants. Digital voice recorders or video cameras for recording interviews or observations.
	Sampling equipment such as fish nets or electrofishing device to catch fish samples, a pail to collect water samples, a multiparameter water quality sonde to record *in-situ* water quality parameters
Laboratory equipment	Microscopes, centrifuges, autoclave, water bath, oven, spectrophotometers, pipettes, test tubes, beakers, flasks, petri dishes, and so on for sample processing and analysis.
Specialized instruments	Atomic absorption spectroscopy (AAS) or inductively coupled plasma mass spectrometry (ICP-MS) for determination of heavy metals.
Software and computing	Statistical analysis software such as SPSS for data processing and analysis.
	Spreadsheet software such as Microsoft Excel for organizing and managing data.
	Qualitative data analysis software such as NVivo for coding and analyzing qualitative data

Safety equipment	First aid kit and additional personal protective equipment (PPE) depending on the specific sampling activities, lab works, and potential hazards.
	Determine the suitable attire such as wading boots or water shoes during water and fish samplings in streams; or safety goggles, lab coats or protective clothing for lab work.

Try to be as thorough as you can when listing the things you require. Checks inventories regularly during the data collection process. This is to ensure that you have an adequate supply of the necessary consumables and essential instruments for your research to avoid disruptions or delays in work.

When?

Conducting research requires good time-management skills. Planning ahead and keep organized for your research activities. It's also crucial to be proactive and flexible in how you manage your research schedule. Always have a plan B that accounts for potential contingencies, delays, or unforeseen circumstances. A detailed list of research activities, milestones, and a Gantt chart are important for developing a data collection plan and for subsequent progress monitoring.

BOX 3.7: Examples of WHEN component in the data collection plan

Here are some key aspects to consider when planning your research activities.

WHEN component	Things to be considered
Fieldwork	Identify the optimal sampling times and conditions for your fieldwork. Plan ahead for the appropriate season, weather conditions, or ecological phenomena that address to your research question and hypotheses.
	Plan ahead for scheduling participant appointments, taking into account their availability and any specific requirements for data collection.
	Develop a detailed timeline for your sampling activities, estimate the duration required for each task or appointment. Conduct a recce or a pilot study for a better estimation.
Lab or Facility Bookings	Determine the availability of lab, facility or any resources you may need. Booking in advance and ensure they are available during your scheduled time slots.
Administrative Tasks	Allocate time for administrative tasks such as preparing consent forms, ethics and research permit applications, or processing reimbursement for the expenses spend during research.
	Initiate the application process early, check any deadlines for submission, and ensure you have sufficient time to complete these tasks.

Ensure prompt and transparent communication with the individuals you identified in the WHO component. Send reminders closer to the appointment dates to confirm appointments and ensure everyone is aware of the scheduled dates to minimize no-shows or scheduling issues.

Where?

Identify the physical or virtual locations where data collection will

take place. This could include study area, specific sites, institutions, or online platforms. The study area, which can be a particular habitat, region, or community, is the geographic area on which the research is largely focused. It could be a forest, a marine reserve, an urban neighborhood, and so on. Your research may cover a small or large geographic area, depending on whether the issue is being posed on a local, regional, or global scale. Field sites refer to locations within the study area where data collection activities are carried out. For instance, a researcher studying tropical biodiversity would collect data from multiple field sites within a tropical country's national park. Your data collection plan should include not just the study area and field sites where sampling will take place, but also where you will stay if you are doing overnight fieldwork, the location for lab analysis, sample storage, and other activities. Find out where all of the materials and equipment are kept after you've made a list of what you'll need for your research.

BOX 3.8: Examples of WHERE component in the data collection plan

Here are some key aspects to consider when developing the data collection plan for the study of the impacts of mining activities on fish biodiversity.

WHERE component	Things to be considered
Study area	The study area would be the specific geographical region where the mining activity and fish biodiversity are of interest. This could be a particular watershed, river system, or a defined area impacted by mining activities.
Field site	Identify the field sites within the study area for surveys and interviews, such as villages located in the vicinity of the mining activities.
	Determine appropriate locations for conducting focus group discussions. These can be community centers or meeting rooms where participants can gather and engage in group discussions about the impacts of mining on fish biodiversity.
	Select the specific sites within the study area where fish sampling, water sample collection, and habitat assessment will take place. These sites should cover a range of habitats, proximity to mining sites, upstream and downstream locations, and areas affected by runoff or discharge to represent different levels of exposure to mining activities. Selecting field sites for sample collection should also take accessibility and safety into mind.
Facilities / Resources whereabouts	Locate any facilities or resources you will need for your research, such as the lab you may use for water quality analysis and fish sample processing, and make sure you have access to them. The instruments you require for the analysis could be located in a different lab or building. Sometimes, the facilities can be located outside your research institution, for example, those that provide specific analytical services.
Online platform	Data collection can also take place in virtual spaces through web-based surveys, online interviews, or online focus groups. This allow researchers to collect data remotely and reach a broader audience.

The selection of study areas and specific sites should be based on a combination of scientific considerations, logistical feasibility, and relevance to the research questions and objectives. Additionally, ensure that all

necessary permissions and permits are obtained before conducting data collection activities in the selected sites.

How?

Before initiating data collection, get proper training and acquaint yourself with the procedures, instruments, and techniques. This includes interview tactics, sampling procedures, laboratory analyses, and so forth. Make sure you understand how to use the equipment or tools safely. If you are working with a team, make sure that everyone understands their roles and responsibilities during the data collection process. Creating flow charts or step-by-step procedures will help to ensure that data is collected efficiently and accurately.

BOX 3.9: *Examples of HOW component in the data collection plan*

Here are some important points to keep in mind:

HOW component	Things to be considered
Fieldwork	How are the fieldwork preparations made? Have you planned transportation to the study area or accommodations if the fieldwork is overnight? Have you packed all of the necessary equipment and tools for the field? Have you confirmed that all of the tools and equipment are in good working condition prior to departure?
	For qualitative research, determine how you will conduct focus group discussions, surveys and interviews. Ensure you understand the principles of effective interviewing, active listening, and non-verbal communication.
	For research involves sampling, determine the appropriate sampling strategy (probability or non-probability sampling) and clearly define the target population and sample size.
	If your data collection requires specific equipment or tools, ensure that you are familiar with their operation. Have you read the instruction manuals and practice using the equipment? .
Lab analysis	If laboratory analysis is involved, familiarize yourself with the specific protocols and equipment required. Prepare a step-by step protocol for analytical procedures such as for water quality analysis.
	Unused samples or samples that cannot be processed in time should be properly preserved, labeled, and stored for future use or reference. Determine the proper preservation and storage guidelines according to the sample type. This could include refrigeration, freezing, or employing specific preservation procedures. For example, acidification, or lowering the water pH to less than 2, is often used to preserve water samples for nutrient analysis, whereas fish samples can be preserved through formalin fixation and ethanol preservation.

	Dispose of any unused or remaining chemicals and reagents properly after analysis is critical for safety and environmental compliance. Follow local legislation, guidelines, and best practices when disposing of chemicals. Throughout the handling, storage, and disposal processes, prioritize safety measures to protect yourself, others, and the environment.
Data management and analysis	Define how the collected data will be managed, stored, and analyzed. Establish protocols for data entry, quality control, and data security.

Before you initiate full-scale data collection, run a pilot test to validate your data collection strategy. Test the tools, procedures, and logistics on a smaller sample size to discover potential issues or possibilities for improvement.

Exercises 3.1

Decide the type of research you plan to conduct and develop your data collection plan with the 5W1H component.

4. Data Analysis and Interpret the Findings

Now, turn your raw data into meaningful insights. How? Compile and analyze your data, talk about what you have found and what it means, tie everything back to your research questions, and don't forget to acknowledge the limitations and implications for future research.

Learning Objectives

After completing this chapter, you will be able to:

- explore different data analysis techniques and their applicability to different types of study
- interpret and critically evaluate the results in the context of the research questions and objectives.

Recall that we can conduct research in many different ways to answer the research question. Thus, the subsequent data analysis varied depending on your research design, the type of data collected, and your research objectives. Suppose you are collecting qualitative data (words, graphics, recording, etc.) to investigate subjective experiences, perceptions, and behaviors; proceed with qualitative analysis such as thematic analysis, content analysis, or grounded theory. If quantitative data (counting, measuring, rating, etc.) is the type of data you collected, you can use descriptive and

inferential statistics based on your research design and objectives. Descriptive statistics summarize and describe your data whereas inferential statistics use your sample data to infer or draw conclusions on a larger population.

Qualitative Data Analysis

Qualitative data analysis focuses on non-numerical data such as text, images, or audio recordings. Qualitative analysis aims to uncover patterns, themes, and meanings within the data to develop rich descriptions and understandings of the research topic. Rather than relying on statistical tests, it interprets and makes sense of the data through techniques such as coding [1]. Box 4.1 lists a few examples of approaches and methods used in qualitative data analysis.

BOX 4.1 *Examples of qualitative data analysis*

Qualitative data analysis allows researchers to gain deep insights and understanding of experiences and perspectives. Below are a few examples of approaches and methods used in qualitative data analysis. Click on the drop-downs to read more.

1. Saldana, J. M. (2015). The coding manual for qualitative researchers (3rd ed.). SAGE Publications.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://openbook.ums.edu.my/researchmethodology/?p=48#h5p-12

Check out the video to learn about qualitative data analysis [11 min, 17 sec]

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Descriptive Statistics

Descriptive statistics summarize and describe data. It helps us to understand the main characteristics of the data, identify patterns,

detect outliers, and make data-driven decisions. Descriptive statistics can be categorized into three types:

- measures of central tendency (e.g. mean, median, and mode), which describe the center of a dataset,
- measures of dispersion (e.g. standard deviation and range), which indicate how dispersed the values are in a dataset,
- measures of shape (e.g. kurtosis, and skewness), which provide information about the distribution's shape or symmetry.

Descriptive statistics often utilize graphical tools like bar charts, box plots, histograms, and scatter plots to illustrate the data. Tables such as frequency tables can assist us in understanding how data is distributed. BOX 4.2 illustrates a scenario on how descriptive statistic was applied in a descriptive research.

BOX 4.2: Examples of descriptive statistics in research

The following example illustrates how we might use descriptive statistics in research.

Suppose a research study aims to assess the species richness (number of different species) in different forest patches of a nature reserve. Researchers visit multiple forest patches within the nature reserve and conduct biodiversity surveys to document the species present in each patch. They compile a list of observed species for each site. Here's what the raw data looks like:

Forest Patch	A	B	C	D
Species Richness	10	8	12	9

The study wants to provide a descriptive summary of the species richness data collected from multiple sites. The following descriptive measures can be calculated:

Mean = 9.8; Median = 9.5; Range = 4; Standard deviation = 1.7; 25th percentile = 8; 75th percentile = 12

These calculations provide a descriptive summary of the species richness data for the forest patches within the nature reserve. The mean, median, range, standard deviation, and percentiles offer insights into the central tendency, variability, and distribution of species richness, helping to understand the biodiversity patterns in the different forest patches.

Check out the video to learn how to generate descriptive statistics in Excel [3 mins, 16 sec]

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Inferential Statistics

Inferential statistics are used to make inferences and draw conclusions about a population based on a sample of data. These techniques include hypothesis testing, confidence intervals, and regression analysis. Inferential statistics help researchers determine if the observed patterns in the sample are likely to be representative of the larger population. It allows researchers to make informed decisions, generalize findings to larger populations, test hypotheses, and draw meaningful conclusions based on sample data (see BOX 4.3).

BOX 4.3: Example of Inferential Statistics – Independent t-test used in a research

Let's consider a research study investigating the impact of a conservation intervention on the population size of a bird species in different habitat types. The study aims to determine whether there is a significant difference in the bird population sizes between the intervention and control habitats. Inferential statistics can be used to make inferences about the broader population based on the data collected. Here's how it may unfold:

Data collection: Population size data for the bird species are collected from multiple sites, including intervention and control habitats. The data include the number of observed individuals or an estimate of population density.

Descriptive statistics: Descriptive statistics are used to summarize and describe the data collected. For each habitat type (intervention and

control), the mean, standard deviation, minimum, and maximum values of bird population sizes are calculated.

Assumptions check: Before proceeding with inferential statistics, assumptions of the selected test need to be checked. For example, the data should meet assumptions such as normality and independence.

Inferential Statistics – Independent t-test: The independent t-test can be used to determine whether there is a significant difference in bird population sizes between the intervention and control habitats. This test compares the means of the two groups while taking into account the variability within each group. The null hypothesis would state that there is no difference in bird population sizes between the two habitat types.

Statistical analysis: The data from the intervention and control habitats are inputted into the independent t-test. The test calculates a t-value and associated p-value. The t-value indicates the magnitude of the difference between the means, while the p-value represents the probability of observing such a difference by chance.

Interpretation: If the p-value is below a predetermined significance level (e.g., $p < 0.05$), the null hypothesis is rejected, suggesting a significant difference in bird population sizes between the intervention and control habitats. This would indicate that the conservation intervention may have had an impact on the bird population.

There are many other statistical tests available. Click on the drop-downs to read more.

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https://openbook.ums.edu.my/researchmethodology/?p=48#h5p-13

Check out this video to learn how to run an independent t-test in SPSS [1 min, 39 sec]

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Check out this video to learn how to interpret SPSS output for an independent t-test [4 mins, 16 sec]

One or more interactive elements has been excluded from this version of the text. You can view them online

here: https://openbook.ums.edu.my/researchmethodology/?p=48#oembed-4

Selecting the best data analysis techniques requires careful consideration of the research problem, the type of data collected, and the specific goals and objectives of your study. Researchers often employ a combination of statistical techniques to acquire a thorough grasp of their data and draw key conclusions. There are a variety of software tools and programming languages available to help with your data analysis, ranging from user-friendly interfaces like Microsoft Excel, SPSS [2], and PAST to R [3] or Python, which demand certain programming skills. Qualitative researchers may also organize, classify, and analyze vast volumes of qualitative data with tools like NVivo [4] and Atlasti [5]. Make sure you are conversant with at least one type of statistical or analytical tool for your study.

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2. "SPSS tutorials" by Kent State University Libraries. (2024, May 15)
3. "R for Data Science (2e) " by Hadley Wickham, Mine Çetinkaya-Rundel, and Garrett Grolemund is licensed under CC BY-NC-ND 3.0
4. Software solutions for Data Analysis & Management (2023) Lumivero. Available at: https://lumivero.com/ (Accessed: 14 May 2024).
5. The #1 software for qualitative data analysis (2024) ATLAS.ti. Available at: https://atlasti.com/ (Accessed: 14 May 2024).

After you have finished gathering and analyzing data, it is common to feel overwhelmed by the amount of information, and making sense of it and extracting genuine knowledge may appear unattainable. Yet, the data-to-insight path, which entails extracting meaning from information, is critical in research because by connecting raw data to meaningful insights, it can help with the interpretation and decision-making. Critical thinking, analysis, and information synthesis are required to get a cohesive and meaningful grasp of your research findings. You must be able to distinguish between useful and insignificant data, identify patterns and relationships, and extract ideas. All of which will lead to a better understanding of your research and answering your research questions.

First thing first, before you interpret your findings, it is important to revisit your research questions, hypothesis, and objectives. Afterall, the purpose of a research is to answer the research question. Thus, establish a clear connection between the findings and the original purpose of the research is essential. The interpretation should address the specific goals of the study by assessing how the results align with them. Then, a few key elements should be include when you interpret your findings, which are contextualizing the findings, seeking explanations from various perspectives, evaluating methodological **limitations**, assessing **implications** and significance, and identifying future research directions. Let us explore each key element one by one.

Contextualizing the Findings

The most common practice of interpreting your research findings is to contextualize them. Simply put, compare your findings to existing literature and past research in the field to determine whether they are similar, different, or whether there are any gaps between your

results and prior study. This allows you to determine whether your findings support or challenge current theories, models, or explanations. This contextualization helps to place your findings within the larger knowledge base and demonstrate how they contribute to or build on current knowledge in the field of study.

Seek Explanations and Causal Inferences

Regardless of whether your findings are consistent or contradictory with previous research, explain the apparent patterns found in the data. It involves looking into the underlying mechanisms or processes that may explain the findings. You can explore several plausible interpretations or factors that might influence the observed results to propose the most possible explanations or causal linkages. The most important thing is that you must discuss the feasibility of these interpretations critically based on current research and knowledge. By delving into the mechanisms, you can gain a better understanding of why particular outcomes occurred, resulting in a more robust interpretation of the findings.

Assess the Implications and Significance

When interpreting your findings, you should assess the implications and significance of the findings within your research context. Evaluate whether the research findings have theoretical, practical, stakeholder, or policy implications. For example, you may highlight how your discoveries expand knowledge and add to existing theories or models in the related discipline. If your findings have practical implications, explain how they might be utilized in real-world settings or decision-making processes. Highlight **stakeholders** or important domains that may be impacted by your

findings, whether positively or negatively. Finally, consider whether your findings are consistent with any current related policies and whether changes to policies or mitigation are warranted.

Acknowledge the Limitations

No research is flawless. You should reflect on the methodological limitations of your study and how they may influence the outcomes to ensure a realistic interpretation. Limitations to consider include sample size, data collection methods, tools and equipment used, or any other potential biases. It is also advisable to assess the generalizability of the results by determining if they can be applied to different populations, contexts, or locations. For example, if your study was conducted in a specific place, at a specific time, or with a specific group, you should highlight the limitations and potential differences that may exist when applying the findings to other circumstances. Lastly, suggestions for future research that address these limitations should be provided.

Identify Future Research Directions

Finally, identify areas for further research based on your findings. This step involves discussing any unanswered questions, unresolved issues, or emerging areas of interest that arise from the study. By suggesting potential avenues for future research, you can contribute to the ongoing development of knowledge in your field and encourage further exploration of the topic.

Check Point 4.1

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https://openbook.ums.edu.my/researchmethodology/?p=48#h5p-14

Interpreting research findings effectively requires a systematic and comprehensive approach that considers various aspects of the study. Simply put, you interpret your results by looking at the key findings of your research, and discussing how or why they are the way they are, in terms of your research questions or hypotheses. Tie them back to previous studies and literature by discussing if the results fit in with previous research or if the results are unexpected. Provide a reasonable interpretation of why they may have appeared.

Exercises 4.1:

Identify the type of data you will collect and explain how you intend to analyze it.

5. Draw a Conclusion and Share the Discoveries

The scientific method's final step is to draw a conclusion and disseminate your findings. You can share your findings with diverse communities either the scientific community or the general public.

Learning Objectives

After completing this chapter, you will be able to:

- create clear and concise conclusion of research findings.
- explore different methods of research communication for different audiences.

As the name implies, the **conclusion** is where your study is wrapped up. It is also your last chance to emphasize the significance of your research and the contribution it has made. The fundamental rules to follow while drawing your conclusion are that there should be no new points, information, or arguments to be added, and the conclusion should be concise and clear. All you have to do is underline and summarize what has already been stated and discussed. There are a few key elements you should include in the conclusion. First, reintroduce the research question and study goal to remind people of the purpose of your research. Next, summarize

the **key findings** that capture the essence of your work. Highlight the **novelty** of your research and explain how it fills knowledge gaps or expands existing understanding. You should also add the work's broader relevance, potential impact, and **implications**. Finally, acknowledge any **limitations** and suggest areas for further investigation. Table 5.1 highlights the dos and don'ts of drawing conclusions.

Table 5.1: Dos and don'ts when drawing conclusions

	Do	Don't
1	Reinstate the research question and the study goal	Provide a detailed description of methodology
2	Summarize the key findings	Use the exact same sentences or lengthy explanations
3	Emphasize the significance and contribution	Make unsupported or speculative claims
4	Discuss the broader relevance and implications	Go off-topic or include irrelevant details
5	Acknowledge limitations	Apologize for limitations or undermine the value of your research
6	Suggest areas for further investigation	Include personal opinions or subjective statements

Check Point 5.1

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Watch the video to learn what are the differences between discussion and conclusion [1 min, 43 sec]

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At this point, you have completed your thesis or report. You probably thought your task was finished. However, your research should not end with the submission of a thesis, dissertation, or

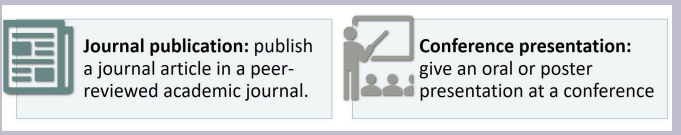
report that is then archived forever. A scientific process is not complete until its findings are effectively disseminated to others (not just to your supervisor or examination panels). Why is it crucial to disseminate our findings to different audiences? The primary reason is that disseminating research findings is the only way for the progress of science, the growth of knowledge, and the betterment of society. When research findings are disseminated to the scientific community, they can inspire others, generate new ideas, and act as a basis for additional study and collaboration. Your findings may one day become secondary data or sources of reference for someone's research only if you have shared them. On the other hand, when you communicate your findings with policymakers and the broader public, they can help inform decisions, shape policies, and contribute to societal improvement.

What are some effective ways of conveying research to a wide range of audiences, including the scientific community and the general public? One thing is certain: the approaches must be different. In general, researchers can interact with others in their field in two ways: by giving an oral or poster presentation at a conference and by publishing a journal article in a peer-reviewed academic journal. However, the language used in presentations and journal papers is highly technical, with a lot of scientific jargon. Therefore, the general public, which includes children, college students, stakeholders, policymakers, and so on will have difficulty understanding the significance of such presentations and journal articles. Therefore, you can convey your findings to non-experts using alternative channels such as press release and media coverage, public lecture, social media engagement, outreach program, and so on. Box 5.1 illustrates how we can share research findings to different audiences.

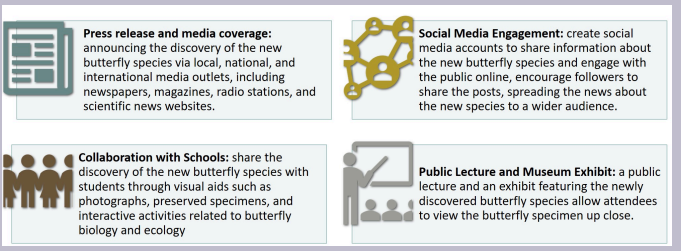
BOX 5.1: *Example of research communication for different audiences*

Suppose you are a researcher that recently discover a new species of butterfly in a remote rainforest. Lets explore how you could share your discovery of a new species to different audiences.

Journal publication and presentation at conference are the common practices to share the discovery with the scientific community.



Here is how you could share your discovery of a new species with the general public:



By employing these strategies, a researcher can effectively shares their discovery of the new butterfly species among peers and with the general public. The combination of various approaches ensures that the news

reaches a diverse audience, fostering appreciation for biodiversity and promoting the importance of conservation efforts.

Sharing Discovery with Scientific Community

The two typical approaches we use to communicate our findings to the scientific world are conference presentation and journal publication. A conference is a broad term for an organized event where individuals with a common interest or field of expertise gather to exchange knowledge, present research findings, discuss current topics, and network with fellow professionals. In addition to conferences, you may have heard of other terms like congress, symposium, colloquium, seminar, and so on. These terms refer to various kinds of events that facilitate the exchange of knowledge and ideas within specific fields (see Box 5.2).

BOX 5.2: Examples of different types of events for knowledge exchange and professional development

There are various types of events that facilitate the exchange of knowledge and ideas within specific fields. While there may be some overlap in their formats and purposes, there are also distinct differences between them. Click on the drop-downs to read more.

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https://openbook.ums.edu.my/researchmethodology/?p=52#h5p-16

Oral and poster presentations are two common formats for presenting research or findings at conferences. Both oral and poster presentations have their advantages and can be effective ways to share research at conferences. Oral presentations offer the opportunity to deliver a structured talk, highlight key points, and engage the audience through verbal communication. On the other hand, poster presentations allow for visual representation, direct interaction with attendees, and the flexibility to discuss research in a more casual and interactive setting. The choice between oral and poster presentations often depends on factors such as the conference guidelines, the nature of the research, personal preferences, and the desired level of engagement with the audience. Table 5.2 summarize an overview of each format.

Table 5.2: Oral and poster presentations at a conference

Presentation	Oral	Poster
Purpose	to share work and findings with a conference audience and provide opportunities for networking	
Difference	delivering a spoken presentation using slides	involves a visual display on a large poster board or display panel
	Typically, oral presentations are allocated a specific time slot, often ranging from 10 to 20 minutes	Poster sessions are usually scheduled at specific times during the conference, where presenters stand next to their poster and engage with attendees who visit their display
Pro	Allows for a more detailed and structured presentation of research findings.	Provides a visual representation that can attract attention and facilitate understanding.
	Provides an opportunity to emphasize key points, data, or findings through verbal communication.	Allows for more informal and interactive discussions with attendees throughout the poster session.
	Allows for immediate interaction and feedback from the audience during the Q&A session.	Offers flexibility in discussing research with interested individuals at their own pace.
	Can be more effective for conveying complex concepts or research methodologies	Provides an opportunity for networking and establishing connections with other researchers.
Con	Limited time allocation may restrict the depth of discussion or presentation of complex research.	Requires concise summarization of research findings due to limited space.
	Requires effective public speaking skills to engage and captivate the audience.	May not allow for in-depth or detailed explanations compared to oral presentations.
	Less visual representation compared to poster presentations.	Less structured format may require effective communication skills to engage the audience.
	Limited opportunity for extended one-on-one discussions with attendees.	May have less visibility compared to oral presentations, as attendees may prioritize attending oral sessions.

In the context of academic and scientific research, a journal refers

to a periodical publication that focuses on a specific field of study. Journals play a crucial role in facilitating the dissemination, evaluation, and advancement of scientific knowledge by providing a platform for researchers to publish their work and contribute to their respective fields. Disseminating research findings through journal publication usually will go through a process called **peer review**, wherein submitted research manuscripts are evaluated by experts in the field before publication. This process helps ensure the quality, validity, and significance of the research. Peer review involves critical assessment of the research methodology, data analysis, interpretation of results, and overall contribution to the existing body of knowledge.

Watch this video to learn about the peer-review process [3 mins, 18 sec]

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In recent years, there has been increasing interest in preprints, which are preliminary versions of research articles that are shared openly prior to formal peer review. Preprints allow researchers to disseminate their findings quickly and receive early feedback from the scientific community. Many journals are accepting manuscripts that have been previously shared as preprints, and some even actively encourage preprint sharing. However, you should always

take precautious and review the policies of specific journals and communicate with editors to clarify any potential conflicts between preprints and journal publication.

Watch this video to learn about the preprint [6 mins, 22 sec]

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://openbook.ums.edu.my/researchmethodology/?p=52#oembed-3

Journal publication is not a simple task. It is a challenging process and possess many obstacles that can hinder you from publishing your findings. Fear of rejection or criticism is the most common reason why researchers are hesitant to submit their work for publication. A piece of advise to overcome this is to take any rejection and criticism positively as an opportunity to improve the manuscript. Regardless of the decision, appreciate the editor and reviewer for their time and efforts, as these are typically volunteer positions for academic journals. If you ever felt lost of confidence due to the rejection or harsh comments from reviewers, always seek support from mentors and colleagues to boost your confidence.

The majority of journals are in English, with the exception of few local journals in their home country. As a result, if you are non-native English speakers, you may struggle to write and communicate effectively. Even worse, you may feel driven to publish in selective journals with high-impact factors to improve your academic reputation and career prospects. Most of the time, **publication bias**, where positive or statistically significant results

are more likely to be published, can pose challenges if your studies yield negative or inconclusive findings. To overcome the language barrier, there are numerous language editing services and experienced editors available for a cost. You can also ask friends or colleagues who are fluent in English for assistance with proofreading and editing. You should also avoid selecting a journal based on its high **impact factor** or classification as a Q1 or Q2 journal. Choose a journal that corresponds to the scope and relevance of your research. You can also consider publishing negative or inconclusive findings in specialized journals or platforms that value rigorous methodology and complete reporting.

Lastly, the peer review process itself can present challenges. Reviewers may provide critical feedback that requires extensive revisions or additional experiments, which can prolong the publication timeline. Addressing reviewer comments can be time-consuming and you may often face time constraints due to other more pressing commitments and lost tract during the process. Prioritize tasks and delegate responsibilities as appropriate. Participate in writing workshops or join a writing group to gain insights into the publication process and respond to feedback effectively.

Watch this video to learn how to become a better academic writer [6 mins, 22 sec]

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://openbook.ums.edu.my/researchmethodology/?p=52#oembed-4

Predatory Journal

A predatory journal is a publication that uses unethical practices in the academic publishing industry. These publications prioritize profits over academic integrity and do not adhere to the rigorous standards of peer review and editorial quality that reputable journals do. How do you determine if it is a predatory journal? Here are the three main characteristics of predatory journals:

1. **Lack of rigorous peer review:** Predatory journals frequently accept manuscripts without a proper peer-review process, resulting in low-quality publications.
2. **Deceptive Practices:** Predatory journals may employ deceptive strategies to tempt you to publish with them, such as sending invitation emails with promises of publication within seven days or less. They may even establish websites that appear to be reputable journals in order to mislead authors.
3. **Exorbitant Article Processing Charges (APCs):** Predatory journals often require you to pay exorbitant article processing charges (APCs) in

exchange for publication. In other words, as long as you pay, they will publish.

Protect yourself, your reputation, and your scientific integrity from predatory journals by making informed decisions about where to submit your manuscript for publication. Check the reputation and credibility of journals before submitting the manuscript. Beall's List is a well-known list of predatory open-access publishers, which many people use to identify exploitative publishers and detect publisher spam. Click the link below to see if the journal where you intend to submit a manuscript is on the list!

https://beallslist.net/

Sharing Discovery with the General Public

Sharing discovery with a broader audience may be more challenging than you realize. The term "general public" encompasses people of diverse ages, educational levels, and special interests. As a result, tailoring study findings to different audiences is essential for effective communication. So first things first. Who is your target audience? Are they children, college students, policymakers, or potential grant funders? After you have identified your target audience, consider a few aspects to make sure that the sharing is relevant, interesting, and beneficial to them. First, different audiences have varying levels of technical understanding and experience with the topic. As a result, you should adjust the findings

to an acceptable level of detail and complexity dependent on the audience's understanding. You should also translate technical jargon into common words or provide clear definitions for easier understanding. This allows your audience to engage with the information and understand the main results and implications. Furthermore, different audiences have unique agendas and areas of interest. By personalizing the information to their interests and concerns, you can effectively catch and engage their attention. For example, when engaging with the general public or policymakers, it may be important to emphasize the research's practical implications and societal influence. There are numerous alternative channels to share discovery with the general public such as press release and media coverage, public lecture, social media engagement, outreach program and so on. Among other, social media have emerged as one of the popular alternative [1]. Select the platform which is most suit to your audience. Finally, while adjusting the findings and conveying through different platforms, make sure the facts are correct and clear to avoid misinterpretation or misunderstandings.

Check Point 5.2

1. Britton, B., Jackson, C. & Wade, J. The reward and risk of social media for academics. Nat Rev Chem 3, 459–461 (2019). https://doi.org/10.1038/s41570-019-0121-3

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://openbook.ums.edu.my/researchmethodology/?p=52#h5p-17

Watch this video to learn about research communication and social media [3 mins, 09 sec]

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://openbook.ums.edu.my/researchmethodology/?p=52#oembed-5

Exercises

Identify three possible journals for publishing your research. Determine which groups of the general public you can share your study with and how you can do so.

Glossary

Conclusion

A summary or final statement that is drawn from the evidence, analysis, and findings presented in a research study or argument.

Correlational research

Research that examines the relationship or association between two or more variables without establishing causality. Correlational research assesses the degree and direction of the relationship using statistical techniques, such as correlation coefficients.

Data

Information collected through observation, measurement, or experimentation.

Dependent Variable

The variable that is measured or observed in response to changes in the independent variable. It is expected to be influenced by the independent variable.

Descriptive research

Research that aims to describe or depict a phenomenon, event, group, or situation as it naturally occurs. Descriptive research focuses on providing an accurate and detailed portrayal of the subject under investigation, often using qualitative or quantitative methods.

Experiments

A controlled procedure performed to gather data and test a hypothesis.

Explanatory research

Research that seeks to establish causal relationships, understand cause-and-effect dynamics, and provide explanations for observed phenomena. Explanatory research often involves quantitative methods and statistical analysis to identify relationships and test hypotheses.

Exploratory research

A type of research conducted at the initial stage of a study or investigation to explore and gain a better understanding of a topic, phenomenon, or problem. Exploratory research aims to generate ideas, hypotheses, or initial insights and often involves qualitative methods like interviews or focus groups.

Falsifiability

The principle that a scientific hypothesis or theory must be capable of being proven false.

Hypothesis

An assumption based on sound evidence (educated guess) assumed for the sake of testing its soundness.

Impact factor

A measure used to assess the relative importance or influence of a scholarly journal within its field. It is often calculated and published by citation analysis organizations such as Clarivate Analytics (formerly Thomson Reuters) using a formula based on the number of citations received by articles published in the journal over a specific period.

Implications

The practical or theoretical consequences, effects, or significance of the findings. Implications explore the broader impact or relevance of the results and may suggest future actions or directions.

Independent Variable

The variable that is intentionally manipulated or changed by the researcher in an experiment. It is hypothesized to have an effect on the dependent variable.

Key findings

The most important or significant results or outcomes of the research study.

Knowledge gap

The specific area or aspect where existing knowledge, research, or understanding falls short or is incomplete.

Limitations

The shortcomings, constraints, or restrictions of the research study that may have influenced the results or conclusions.

Novelty

The originality or uniqueness of the research study in terms of its approach, methodology, findings, or contributions.

Objective

A specific and measurable goal or outcome that the problem statement seeks to achieve. Objective provide a clear direction for the research or problem-solving process.

Observation

The active acquisition of information from a primary source, either through our senses, or data recorded during an experiment using scientific tools and instruments

Peer review

The evaluation of scientific work by experts in the same field to assess its quality, validity, and significance. Peer review helps maintain scientific integrity and ensures rigorous standards.

Primary research

Original research conducted by the researcher or research team to gather new data or information firsthand. It involves collecting data directly from sources such as surveys, interviews, experiments, or observations.

Problem statement

A concise and clear description of an issue or challenge that needs to be addressed or solved through research or problem-solving efforts.

Publication bias

The tendency for scientific journals to publish studies with positive or significant results, while disregarding studies with neutral or negative findings.

Qualitative research

Research that focuses on exploring and understanding phenomena through non-numerical data, such as interviews, observations, or case studies.

Quantitative research

Research that focuses on collecting and analyzing numerical data to draw conclusions and make predictions.

Research

Systematic investigation and study of a particular topic or issue to discover new knowledge, validate existing knowledge, or solve problems.

Research question

A clear, concise, and specific question that guides the research process and defines the focus of the study.

Scientific method

A systematic and iterative approach used by scientists to investigate and understand the natural world. It involves making observations, formulating hypotheses, conducting experiments, analyzing data, and drawing conclusions.

Secondary research

Research based on existing data or information that has been collected and published by others. It involves analyzing and synthesizing data from sources such as books, articles, reports, databases, or previously conducted studies.

Stakeholders

Individuals, groups, or organizations that have a vested interest or are affected by the problem being addressed. They can include individuals directly impacted by the problem, policymakers, industry representatives, or community members.

Statistical analysis

The use of statistical methods to analyze and interpret data collected from experiments or studies.

Bibliography

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