Research Design

Course Curriculum and Instructor Manual

FAST
DISCOVERING THE FUTURE

BRITISH COUNCIL

Creative Spark

SciNova

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FAST DISCOVERING THE FUTURE

Aston University BIRMINGHAM UK

This book consists of two sections. The first section is the course curriculum, and the second section is the instructor manual.

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Topic 1. What is Science/Research?

Learning Objectives

At the end of this session, the students will be able to:

1. Define science
2. Define basic science/research. Give examples of basic research
3. Define applied science/research. Give examples of applied research
4. Describe the relationship between basic research and applied research

What is science?

Science is any system of knowledge that is concerned with the physical world and its phenomena and entails unbiased observations and systematic experimentation. In general, science involves the pursuit, extension, or revision of knowledge covering general truths or the operations of fundamental laws. It is the discovery of new knowledge by reading and analyzing information, identifying gaps in knowledge, suggesting hypotheses, and designing experiments to prove or disprove current hypotheses.

Characteristics of science:

- **Innovative**
  Just imagine you, and only you, can uncover new knowledge that has never been described before.
- **Essential**
  Everything you see, touch, use in your life is, or was, a new scientific discovery at one time. It begins in the form of new knowledge that can be developed into new technologies and therapeutics to help advance our ability to thrive in our environment.

- **Continuous systematic exploration**
  We continually refine and expand our knowledge of the universe, leading to sub sequent questions that in turn need to be answered. As such, science will never be "finished."
  For example, the smallest component of life: It was first described as an atom, then further discovery showed neutrons, protons, electrons, and quarks and will most likely see continued discovery.
- **A global human effort**
  Science aims to make this world better, safer, healthier, for example by investigating solutions to climate change, creating new and improved medical technology and therapeutics, sustainable agriculture, engineering safer materials for use in our homes and lives, designing more efficient and accessible water treatment systems. We are all contributors of science in our environments.

Key scientific concepts:

1. Science studies the natural world.
2. Science aims to produce a more accurate explanation of how the natural world works, what its components are, and why the world is as it is now.
3. Testable scientific ideas are within the purview of science.
   A testable idea will generate observations that will ultimately lead to a conclusion.
4. Scientific ideas must be tested with an approach that will provide evidence to support or reject a hypothesis. This characteristic is at the heart of all science. Scientists actively seek evidence to test their ideas and are exposed to a rigorous peer-review process to ensure authenticity and reproducibility of their data. As a result, it is common for scientists to spend years testing a single scientific question until adequate evidence is collected to accept or reject the hypothesis.
5. The progress of science depends on interactions within the scientific community, which is referred to as the peer-review process (mentioned above). Independent scientists and corporations generate scientific ideas, test those ideas, publish in scientific journals, organize conferences, train scientists, and

distribute research funds based on the review of scientific evidence among peers in the scientific community.
6. Most typically in science, answering one question inspires deeper and more detailed questions for further research. Similarly, a fruitful idea to explain a previously anomalous observation frequently leads to new expectations and areas of research.

Types of research

Scientific discovery becomes a part of everyday routine. Usually, we do not recognize the science behind everyday objects in daily use. Nonetheless, there is a long road from scientific discovery to a ready-to- use product. According to its purpose, the science is divided into two categories:

1. Basic (Fundamental) science
2. Applied science

Basic science is defined as the work of scientists and others who pursue their investigations without conscious goals, other than the desire to unravel the secrets of nature.[1] Basic science seeks to answer the question "How does it work?" and describes ongoing processes in nature.

Applied science develops the findings of basic research in a way to solve a specific problem or area of unmet need. In Europe, the United States, and Japan, the unified concept of research and development has been an integral part of economic planning, both by government and by private industry. In other words, applied research takes the knowledge from basic research and uses it to find ways to modulate natural processes.

In summary, fundamental research is pioneering, and applied research is a mix of science and engineering, because having knowledge is not enough to make it a necessary and useful thing.

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[1] Holstein K. W., "Research and Development, Encyclopedia Britannica": https://www.britannica.com/topic/research-and-development#ref210517

Both fundamental and basic science are performed in academia as well as in private companies to solve problems and make an impact on the world.

The same approaches and scientific methods accepted by the scientific community are used in both types of research.

According to the type of the data used, research is classified into:[2]

- **Quantitative research** involves studies that make use of statistical analyses to obtain their findings. Quantitative variables are measured and represent amounts. Key features include formal and systematic measurement and the use of statistics.

- **Qualitative research** involves studies that do not attempt to quantify their results through statistical summary or analysis. Qualitative studies typically involve interviews and observations without standardized measurement. A case study, which is an in-depth examination of one person, is a form of qualitative research. Qualitative research is used as a source of hypotheses for later testing in quantitative research. Qualitative variables do not arise by counting or measuring, instead, data is separated by groups or categories. For examples, rating something as “attractive” or “not attractive,” “helpful” or “not helpful,” or “consistent” or “not consistent” are examples of qualitative variables.

[2] Christensen, 2001

Topic 2. Scientific Method

2a. Introduction to the Scientific Method

Learning Objectives

At the end of the session, the students will be able to:

1. Define the stages of the Scientific Method
2. Define the key components of each stage of the Scientific Method
3. Explain the relationship between the stages of Scientific Method

The Scientific method is a mathematical and experimental technique employed in the sciences. More specifically, it is the technique used in the construction and testing of a scientific hypothesis[3].

The scientific method consists of the following key stages:

1. Make an observation and ask a question
2. Background research
3. Formulate a hypothesis
4. Experimental design
5. Data collection and analysis
6. Communicate the results

One way the scientific method/process is often represented is a cycle. But it does not accurately capture the complexity of the actual process. The scientific method was first outlined by Sir Francis Bacon (1561–1626) and allows for logical, rational problem solving across many scientific fields. Across all scientific disciplines, the major precepts of the scientific method are verifiability, predictability, falsifiability, and fairness. Thus, **science is not linear; rather it is ever-changing, and cyclical (see Figure 1 below).** Looking at this fluid model of the nature of science, you can find many entry points into the process. Perhaps there is a new technology to be tested, a practical problem to solve, or a surprising observation that inspires you to learn more. Within the scientific process there is a continuous exploration and discovery phase. A researcher finds out what other scientists have learned by exploring previous research, sharing data and ideas with other researchers, asking

[3] Encyclopedia Britannica, "Scientific Method": https://www.britannica.com/science/scientific-method

questions, making more observations, and refining or expanding the scope of what is investigated based on what is learned. Researchers often revisit phases during a study, as there are many routes through the scientific process.

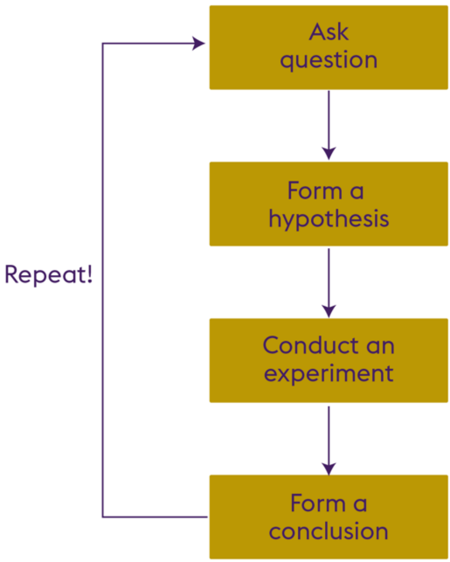

Figure 1: The scientific method is not linear. It requires constant reevaluation.

1. Make an observation and ask a question

The first step in the scientific method is asking questions about what you observe: How, What, When, Who, Why, or Where?

This is the most important part of the research, as it entails a large amount of thought and effort. Moreover, it is important not to rush this stage to ensure that the question(s) you are proposing has not been previously investigated.

In science, the art of making accurate observations has three purposes. First, observation enables the ability to identify and focus on the relevant facts about the phenomena under investigation. Second, what we observe can provide clues as to what might explain the phenomena. Finally, observational data can provide the evidence by which we can determine whether various explanations succeed or fail.

In general, the process of making a set of observations must consider the following concepts:

1. Do we have a clear sense of the relevant phenomena?
2. Have we overlooked anything in the process of making our observations?

These two questions can usually be addressed in a fairly straightforward way. To answer the first question, one must carefully consider the application of key terms. Specifying how observational terms are used in science is of the utmost importance. Recent scientific studies have reported findings about smokers, left- and right-handed people, and people who attend church. Do cigarette smokers have higher rates of cardiovascular disease than nonsmokers? Do right- handed people live longer than left-handed people? Do people who attend church have a better quality of life than those who do not? Data relevant to these questions cannot be obtained properly without clearly defined variables and outcomes of interest. What exactly constitutes a cigarette smoker? Anyone who has ever smoked a cigarette? And what of people who have recently stopped smoking? Would they be characterized as a smoker or nonsmoker? Likewise, is someone who writes with the right hand but throws with the left to be classified as right-handed or left-handed? What about older people who were taught to be right-handed even if their natural tendency was to be left - handed? Just how often must one attend church to be considered a church attendee? Without a clear sense of how these key terms will be defined, an adequate research study cannot occur.

Dedicating sufficient time to this first stage of the Scientific Method will ensure you are asking a novel and relevant scientific question.

2. Background research

A good place to start is to conduct a thorough search of the literature surrounding your research topic. In this day in age, the majority of peer-reviewed and indexed scientific journals have online sources with open access to the public. The most commonly used scientific search on life sciences and biomedical topics is PubMed. Below are some important tips on setting yourself up for a successful search of the literature using PubMed: Asking the right questions is half of successful research. Keywords, which represent the main concepts of the research topic, are helpful for searching.

In this part, you need to pay attention to the source of information:

- **Peer reviewed journal**
  An impact factor is used as an indicator of journal quality within a particular field of study. Journals with a higher impact factor are typically considered of higher scientific quality. An impact factor is calculated after a period of three years of publication and thus, newer journals will not have one for at least this time period.
- **Date of publication**
  Typically, the most recent publication date will provide the most up-to-date information on a topic.
- **Scientific rigor**
  This is defined as the strict application of the scientific method to ensure well-controlled experimental design for the unbiased collect and interpretation of results.

A high quality manuscript is well-organized and clearly written.

Once you have found an adequate amount of data on the topic you are investigating, you will be able to draw unbiased and informed conclusions on the current state of your topic of interest. More often than not, your conclusion will lead to new questions of scientific interest.

For example, medical researchers at a large University were studying the effect of calcium on pregnancy-related high blood pressure. Though they observed no significant reductions in the blood pressure (primary outcome) of the women who took calcium, their research yielded an interesting and unexpected result. The women in their study who took calcium during pregnancy had lower rates of depression than those who were given placebo. As a result, the researchers designed the subsequent study to determine the effect of calcium supplementation on depression in pregnant women. Thus, it is important not to become too attached to a fixed notion of what may constitute relevant observational data. Otherwise, we run the risk of missing something that may turn out to be significant.

Trick from a scientist: Review papers are often a great way to understand the basic foundation of knowledge on a topic that is new to you.

Upon completion of observation and questioning, you will be able to generate a **hypothesis**, the building block of the scientific method.

3. Formulate a hypothesis

A **scientific hypothesis** is an idea that proposes a tentative explanation about a phenomenon or a narrow set of phenomena observed in the natural world[4]. It is an idea or explanation of something based on a collection of facts that is not yet proven. The two primary features of a scientific hypothesis are falsifiability and testability, which are reflected in an "If…then" statement summarizing the idea and in the ability to be supported or refuted through observation and experimentation. The notion of the scientific hypothesis as both falsifiable and testable was advanced in the mid-20th century by Austrian-born British philosopher Karl Popper.
In this step of the scientific method, scientists derive predictions from the hypotheses about the results of future experiments, and then design experiments to test whether their predictions are correct. In short, they are investigating possible answers to their questions.

The key requirement to hypothesis is that it must be **testable**. Therefore, your hypothesis must highlight two or more variables that affect the object you are observing.

How are hypotheses written?

1. Salt in soil may affect plant growth.
2. Plant growth may be affected by the color of light.
3. Bacterial growth may be affected by temperature.
4. Ultraviolet light may cause skin cancer.

[4] Rogers K., "Scientific Hypothesis", Encyclopedia Britannica: https://www.britannica.com/science/scientific-hypothesis

5. Temperature may cause leaves to change color.

All of these are examples of hypotheses because they use the tentative word "may”. However, their form is not particularly useful. Using the word “may” does not suggest how you would go about providing supporting evidence for the hypothesis. If these statements had not been written carefully, they may not have even been hypotheses at all. For example, if we state, "Trees will change color when it gets cold." we are making a prediction. If we write, "Ultraviolet light causes skin cancer." we are stating a conclusion. One way to prevent making such easy mistakes is to formalize the form of the hypothesis.[5]

Examples of a formalized hypothesis:

- **If** skin cancer is **related** to ultraviolet light, **then** people with a high exposure to UV light will have a higher frequency of skin cancer.
- **If** leaf color change is **related** to temperature, **then** exposing plants to low temperatures will result in changes in leaf color.

Notice that these statements contain the words, **if** and **then**. They are necessary in a formalized hypothesis.
Two types of hypotheses with which you should be familiar are the null hypothesis and the alternate (or experimental) hypothesis. The null hypothesis always predicts that there will be no differences between the study groups. By contrast, the alternate hypothesis predicts that there will be a difference between the groups.

4. Experimental design

A well-designed experiment will prove or reject the hypothesis.

An experiment is a research method in which you manipulate one or more independent variables and measure their effect on one or more dependent variables. Experimental design means creating a **set of procedures to test a hypothesis.** A good experimental design requires a strong understanding of the system you are studying.

[5] California State University, Bakersfield, “Formatting a Testable Hypothesis”: https://www.csub.edu/~ddodenhoff/Bio100/Bio100sp04/formattingahypothesis.htm

The level of detail and the external validity of your results will be determined by the extent to which your independent variables are broad or narrow. Internal validity will depend on randomization, experimental controls, and design of experiment.
During the experiment you always need to have a control group. This is an object of experiment, which is not affected by variables, or is affected only by one variable in case of multiple variables. It is the zero point, and you will compare all data you gained from the experiment with control group data.

It is important that experiments are designed for accuracy and reliability.

- **Accuracy** refers to whether the measurement is correct
- **Reliability** refers to whether the measurement is consistent.

For example, when throwing darts at a dart board, "accuracy" refers to whether the darts are hitting the bull's eye (an accurate dart thrower will throw darts that hit the bull's eye). "Reliability," on the other hand, refers to whether the darts are hitting the same spot (a reliable dart thrower will throw darts that hit the same spot). Therefore, an accurate and reliable dart thrower will consistently throw the darts in the bull's eye. As may be evident, however, it is possible for the dart thrower to be reliable, but not accurate. For example, the dart thrower may throw all of the darts in the same spot (which demonstrates high reliability), but that spot may not be the bull's eye (which demonstrates low accuracy). In the context of measurement, both accuracy and reliability are equally important.

All experiments should be repeated at least in triplicate (three times), to ensure that data is reliable and reproducible. In addition, when possible, samples should be run in duplicate or triplicate to eliminate the variability of measurements and ensure consistency with experimental technique. As such, meticulous records of each experiment should be kept, to ensure results are reproducible by other scientists.
We will discuss the importance of team members and the responsibility of being part of a scientific team when we discuss Project Management in a later lecture.

5. Data collection and analysis

The strength of any scientific research depends on the ability to **gather and analyze empirical data** in an unbiased and controlled manner. Once experiments are completed and data collected, scientists begin the analysis phase. This step requires careful consideration of the statistical approach, which is determined by your experimental design and outcome variables of interest.

A key decision that researchers must make with the assistance of statistics is whether the null hypothesis should be rejected. Remember that the null hypothesis always predicts that there will be no difference between the groups. Therefore, rejecting the null hypothesis means that there is a difference between the groups. In general, most researchers seek to reject the null hypothesis because rejection means the phenomenon being studied (e.g., exercise, medication) had some effect.

6. Communicate the results

It is important that researchers make only those conclusions that can be supported by reliable and unbiased data collection and proper statistical analyses. Stating conclusions that your data does not support must be avoided. For example, if a researcher conducted a correlational study and the results indicated that the two things being studied were strongly related, the researcher could not conclude that one thing caused the other. As explained in later chapters, correlation (i.e., a relationship between two things) does not equal causation. As such, just because two things are related does not mean that one caused the other.

Finally, communication of final conclusions, or the accurate dissemination of results, in a highly respected peer-reviewed journal is an important last step in the scientific method. Remember, rejection of the hypothesis based on results from well-designed experiments can still provide useful information to propel the field of study further.

Learning Objectives

At the end of the session, the students will be able to:

1. Understand the process of making observations
2. Distinguish between three types of investigative questions
3. Create detailed observations of the natural environment

In this section we will discuss how to effectively conduct the first stage of the Scientific Method: Make an observation and ask a question.

Observations can be qualitative or quantitative. Qualitative observations describe properties or occurrences in ways that do not rely on numbers. Examples of qualitative observations include the following: the outside air temperature is cooler during the winter season, table salt is a crystalline solid, sulfur crystals are yellow, and dissolving a penny in dilute nitric acid forms a blue solution and a brown gas. Quantitative observations are measurements, which consist of both a number and a unit. Examples of quantitative observations include the following: the melting point of crystalline sulfur is 115.21° Celsius, and 35.9 grams of table salt—whose chemical name is sodium chloride-dissolved in 100 grams of water at 20° Celsius. For the question of the dinosaurs' extinction, the initial observation was quantitative: iridium concentrations in sediments dating to 66 million years ago were 20–160 times higher than normal.

It is important to highlight that questions that are not scientific may still be very meaningful and valuable. The differences and similarities between scientific and non-scientific questions are reflected in the following Venn diagram (Figure 2).

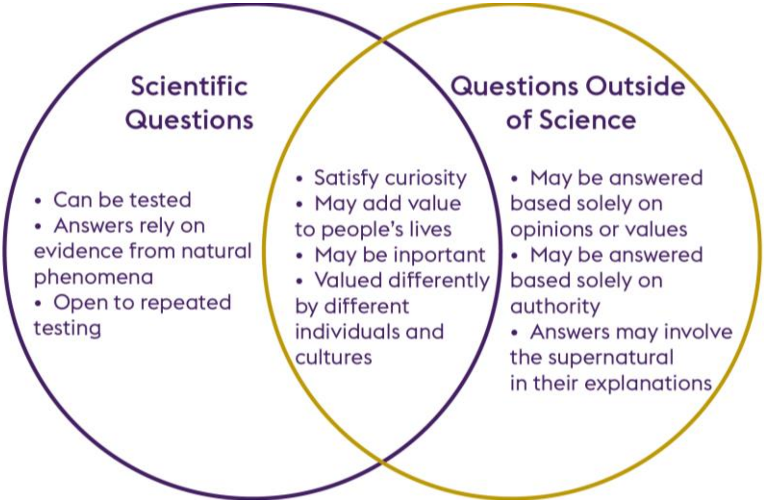

Figure 2: Venn diagram depicting the differences and commonality between scientific and non-scientific questions.

There are three types of investigative questions:

1. **Descriptive** – Questions involving descriptions of a natural system. They focus on measurable or observable variables that can be represented spatially in maps or as written descriptions, estimations, averages, medians, or ranges (How many tree species are there in Armenia? When did Armenian language split as a separate branch in Indo-European language tree?).
2. **Comparative** – Questions focus on one measured variable in at least two different (manipulated variable) locations, times, organisms, or populations (Is there a difference in Covid susceptibility between male and female? Who is at risk for developing the disease - young or older adults?).
3. **Correlative** – Questions focus on two variables to be measured and tested for a relationship or pattern (How does a spider's reproduction rate change with a change in season? What is the relationship between length of the tail and age in whales?).

Learning Objectives

At the end of the session, the students will be able to:

1. State the aim of conducting background research
2. Describe key components of quality background research
3. Define criteria for assessing scientific publications
4. Effectively read and analyze scientific literature

Reading academic papers

The next step after defining the research question, is to conduct a thorough review of the literature. A visit to the library and an extensive online search will uncover existing research surrounding the topic of study. This step helps researchers gain a broad understanding of work previously conducted on the topic at hand and enables them to position their own research to build on prior knowledge. Researchers—including student researchers—are responsible for correctly citing existing sources they use in a study or that inform their work and never plagiarize.

While many find reading through scientific literature to be difficult in the early stages of their scientific training, the good news is that it gets easier as you move along in your career. The Figure 3 below shows that the more you advance as a scientist and knowledge you gain of a particular area of study, the less important the introduction and methods sections become and the more likely you will move directly to the heart of the data, the results and discussion section. Early-stage PhD students find the methods, results, and figures the easiest to understand since the early years of the PhD focuses on methodology and producing results, while the discussion is the most difficult since that is the section of a paper that requires the most scientific critique, a skill that is learned over time. You are likely to have a similar experience.

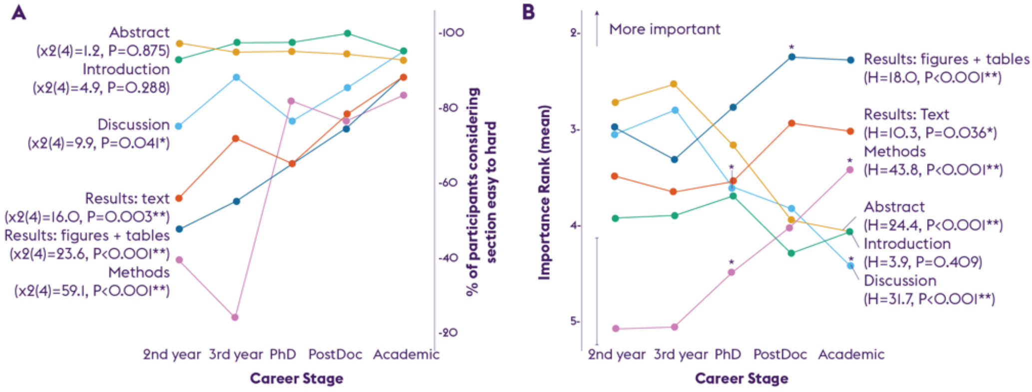

Figure 3
A: The proportion of participants considering a section easy to read (presented as 'Somewhat easy', 'easy' 'very easy' combined) as a function of career stage.
B: The mean importance rank of sections as a function of career stage.[6]

What is it exactly that makes going through this process so difficult and time consuming?

- Authors tend to assume that readers already have significant background knowledge
- Academic syntax is dense and thus difficult for readers to parse
- Mathematical expressions are typically condensed and equations reordered to be concise, often skipping steps in derivations
- Substantial knowledge gaps are filled if a reader has read cited papers (sort of like — you need experience to get a job, but need a job to get experience!)
- Not all conclusions drawn are correct. Small sample size and power, poor study design, researcher bias, and selective reporting ensures that you must be a critical reader!

[6] Hubbard KE, Dunbar SD (2017) Perceptions of scientific research literature and strategies for reading papers depend on academic career stage. PLoS ONE 12(12): e0189753. https://doi.org/10.1371/journal.pone.0189753

Think about this, the more papers you read, the more you will learn and the faster this process of reading becomes.

How Papers are organized

The overwhelming majority of papers follow, more or less, the same convention of organization.
The order will depend on journal specifications, but is typically the following:

- **Title:** Hopefully catchy, includes additional info about the authors and their institutions
- **Abstract:** High level summary
- **Introduction:** Background info on the field and related research leading up to this paper
- **Methods:** Highly detailed section on the study that was conducted, how it was set up, any instruments used, and the process and workflow
- **Results:** Report data that was created or collected, it should read as an unbiased account of what occurred. Only the facts are presented.
- **Discussions:** Interpretation of results
- **References:** Any work that was cited in the body of the text
- **Appendix:** More figures, additional treatments on related math, or extra items of interest can find their way in an appendix

Recommendation

Before you begin reading, take note of the authors and their institutional affiliations. Some institutions (e.g. University of Texas) are well-respected; others (e.g. the Discovery Institute) may appear to be legitimate research institutions but are actually agenda-driven.

Tip: Google "Discovery Institute" to see why you do not want to use it as a scientific authority on evolutionary theory.

Also take note of the journal. Check out Web of Science for a more complete index of science journals. Beware of questionable journals, often termed ‘predatory’ as they may not be indexed on well-respected platforms, do a very loose peer-review, and charge large amounts of money to publish.

Start by reading the title and abstract. Aiming to gain a high-level overview of the paper. What are the main goal(s) of the author(s) and the summary of the results? The abstract typically provides some clues into the purpose of the paper. Think of the abstract as an advertisement. Spend about 15- minutes skimming the paper. Take a quick look at the figures and note any keywords relevant to your topic of interest when reading the text. Try to get a sense for the layout of the paper and where things are located. You will be referencing back and forth between the different sections as you read more thoroughly, thus, it helps knowing where stuff is located. Begin by turning your attention to the introduction. The more unfamiliar with the paper/field, the longer time should be spent in the introduction to gain a better understanding of the topic. A well-written introduction will do a good job of consolidating background information and provide most up-to-date references. This section is usually the easiest to read and it almost feels like you are reading from a textbook. Here, take notes of other references and background information you want to investigate further.

Overall, plan to spend anywhere from 3–6 hours to really digest a paper, remember they are very dense! Be ready and willing to make several passes through the paper, each time looking to extract different information and understanding. And please, do yourself a favor and do not read the paper front to end on your first pass.

Once you have a solid understanding of the paper, you will be able to communicate intelligently about it to others (in group meetings or at journal clubs). The following questions can help you ascertain your level of understanding:

1. What previous research and ideas were cited and provide the foundation for this paper? (introduction)
2. Was there reasoning for performing this research, if so, what was it? (introduction)
3. Clearly list out the objectives of the study.
4. Was any equipment/software used? (methods)
5. What variables were measured during experimentation? (methods)
6. Were any statistical tests used? What were their results? (methods/results)
7. What are the main findings? (results)
8. How do these results fit into the context of other research and their field? (discussion)
9. Explain each figure and discuss their significance.
10. Can the results be reproduced and is there any code available?
11. What key terms and concepts do I not know and need to look up in a dictionary, textbook, or ask someone?
12. What are your thoughts on the results? Were the proper controls used and results validated?

Literature survey and review

What is a literature review? It is a comprehensive digest at what has been done in the field to date.

Where you identify:

- Your research focus
- Your critical review of the relevant literature
- What is the gap within that literature that your research will attempt to address

Explain how your work will add what is already known:

- Overcoming these deficiencies
- Bringing together different fields
- Creating new theory
- Looking at existing theory in a new way

Bring an example of a literature review marking scheme for a dissertation work.

1. **Core texts, journal, and industry publications**
    - both depth and breadth of coverage.
2. **Evidence of substantial wider reading (citations)**
    - has to be relevant
    - up to date and
    - clearly linked to the objectives of the dissertation.
3. **Consistent and correct referencing using the Harvard system**

Learning Objectives

At the end of the session, the students will be able to:

1. Define a scientific hypothesis
2. Understand how a hypothesis is used in the scientific method
3. Differentiate between hypothesis and theory
4. Describe the main types of scientific hypotheses
5. Formulate scientific hypotheses

Introduction

A scientific hypothesis is an assumption, a tentative statement proposing an explanation about a scientific question, a phenomenon observed in the world. The scientific hypothesis should have two features: falsifiability and testability. Testing the hypothesis is the key to discovering and moving the knowledge about a phenomenon from unknown to known. Forming hypotheses and testing them as part of a scientific method gives directions for the researchers and paves a path for new discoveries[7].

Generating a hypothesis can be considered a creative process built on scientific evidence, knowledge, and experience. Thus, despite hypotheses being "educated guesses," they can be regarded as informed assumptions with a scientific basis.

The hypothesis should have the following characteristics:

1. Simplicity and clarity
2. Testability
3. Based on the existing scientific theory and impact
4. Comprehensiveness
5. Falsifiability
6. Operationalizability[8]

After a thorough review of the existing body of scientific literature, the researcher forms a scientific hypothesis and moves to testing it. Once

[7] Berche, P. (2012). Louis Pasteur, from crystals of life to vaccination. Clinical Microbiology and Infection, 18, 1–6. doi:10.1111/j.1469-0691.2012.03945.x

[8] Encyclopedia Britannica, Scientific Hypothesis: scientific hypothesis | Definition, Formulation, & Example | Britannica

the researcher applies specific statistical analysis to the data, the hypothesis can be either accepted or rejected. The researchers can do multiple replications of the same study for the accepted hypothesis to verify the results. In the rejected hypothesis, the researcher should modify or improve the experimental design[9].

It is essential to have a hypothesis defined clearly to give the research experiment a narrow focus for the data collection, data analysis, and interpretation of the research findings[10].

Although the hypothesis is inherently falsifiable, and even the accepted hypothesis can be later proven wrong by another scientific experiment, it is crucial to refine the existing knowledge and build new information based on it. Depending on the outcome, a hypothesis can never be conclusively correct; instead, it can be stated as incomplete[11].
Investigating scientific hypotheses plays an important role in scientific theory development, and it is essential to differentiate between the two concepts of hypothesis and theory.

A **hypothesis** serves as a primary means to gather data to provide evidence for the scientific explanation.
A **theory** gives a broad answer based on sources of different hypothesis testing results[12].

An example of hypothesis testing is the one conducted by the physician Francesco Redi (1668) and chemist and microbiologist Louis Pasteur (1859) to investigate whether the origins of living organisms come from nonliving matter. The hypothesis was later disproved. Another concept was later suggested in the 19th century claiming certain diseases are caused by microorganisms, which is now well known as "germ theory".

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[9] Gasparyan et al. “Scientific Hypotheses: Writing, Promoting, and Predicting Implications”. J Korean Med Sci. 2019 Nov 25; 34(45): e300
[10] Berche, P. (2012). Louis Pasteur, from crystals of life to vaccination. Clinical Microbiology and Infection, 18, 1–6. doi:10.1111/j.1469-0691.2012.03945.x
[11] Gasparyan et al. “Scientific Hypotheses: Writing, Promoting, and Predicting Implications”. J Korean Med Sci. 2019 Nov 25; 34(45): e300
[12] Ibid

Sources for hypotheses

Defining the research hypothesis comes before initiating the data collection. A researcher with good experience can generate a reasonable hypothesis. However, having data in advance, conducting a thorough literature review, or having a pilot study on the topic can help create and refine the existing hypothesis.

A researcher can use the following idea sources to come up with a good hypothesis:

- Literature review
- Discussing the topic with the experts in the field to understand the validity and feasibility of the research interest.
- Using a researcher's intuition may help to form a good hypothesis.
- Reviewing previous empirical studies on the topic[13].

Challenges of defining a good scientific hypothesis:

- Lack of knowledge on theoretical frameworks used in scientific research is a significant challenge in developing a reasonable hypothesis.
- Lack of theoretical evidence or the lack of knowledge on the academic evidence.
- Lack of awareness on scientific research techniques to be able to develop research hypotheses.

Despite all the challenges or barriers to forming reasonable research hypotheses, the researchers attempt to generate a hypothesis to develop search experiments. Hypothesis generation is a creative process of thinking, analysis, imagining, and innovating. The generation process starts from deriving the problem statement before initiating the data collection process. Sometimes, an additional hypothesis can be developed after collecting the data. Still, the newly developed hypothesis testing should be tested on the recently collected data rather than the same old set of data.

The following points should be considered for hypothesis generation:

- Expected correlation between the study variables

[13] Porto et al. "A Scientific Hypothesis Conceptual Mode". ER 2012: Advances in Conceptual Modeling pp 101-110

- Variable definition
- Generating the hypothesis based on the existing literature

For scientific research, there are two categories of the hypothesis:

- Null hypothesis (Ho)
- Alternative hypothesis (Ha or H1)

Null Hypothesis (Ho)

A null hypothesis is used to assess the significance of differences between the two variables. In its simplest form, Ho is the "no difference" between the variables being compared. When the statistical analysis shows no significant difference between the compared samples' means, the researcher can accept the null hypothesis. In contrast, when the statistical analysis shows a substantial difference between the compared samples, the null hypothesis can be rejected. The null hypothesis must always be clear, specific, and not approximate[14].

Alternative hypothesis (Ha or H1)

The Ha indicates the hypothesis that the researcher believes in holding true. The Ha can be any other possibility contradictory to the null hypothesis[15].

Errors in testing a hypothesis

As previously stated, hypotheses are assumptions that can be proven true or false. On the way of testing the hypothesis, it is possible to come up with incorrect assumptions if:

- Errors occurred during the data collection process
- The methodology selected for the data collection was inappropriate
- The methods selected for hypothesis testing was inappropriate
- The statistical chosen methods for hypothesis testing was inappropriate

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[14] Banerjee A, Chitnis UB, Jadhav SL, Bhawalkar JS, Chaudhury S. Hypothesis testing, type I and type II errors. Ind Psychiatry J. 2009;18(2):127-131. doi:10.4103/0972-6748.62274

[15] Banerjee A, Chitnis UB, Jadhav SL, Bhawalkar JS, Chaudhury S. Hypothesis testing, type I and type II errors. *Ind Psychiatry J.* 2009;18(2):127-131. doi:10.4103/0972-6748.62274

- The interpretation of the study results are wrong

Two common errors in hypothesis testing:
Type I error – rejection of a null hypothesis when it is true.
Type II error - acceptance of a null hypothesis when it is false[16].

	Null hypothesis is true	Null hypothesis is false
Reject null hypothesis	Type I Error False Positive	Correct Outcome True Positive
Fail to reject the null hypothesis	Correct outcome True Negative	Type II Error False Negative

Example:

Null hypothesis	**Type I Error / False Positive**	**Type II Error / False Negative**
The person is not guilty of the crime	The person is guilty when the person did not commit the crime (convicting an innocent person)	The person is not guilty when they did commit the crime (letting a guilty person go free)

[16] Hypothesis Formulation and Sampling: http://egyankosh.ac.in/bitstream/123456789/20897/1/Unit-4.pdf

Learning Objectives

At the end of the session, the students will be able to:

1. Define an experiment
2. Describe experimental controls
3. State the relationship between experiment and hypothesis
4. Define types of experiments
5. Conduct high-quality experiments

Introduction

An experiment is a scientific method to test an existing or new hypothesis, with the objective to approve or disprove. It is a systematic means to gain insight into cause and effect relationships by measuring the effect of a particular factor on the outcome. Although different experiments have different goals and objectives, they always rely on repeatable testing and logical analysis[17].

Experimental studies vary by its nature depending on a particular research question and study design. For example, John Snow conducted a natural experiment showing the likelihood of cholera symptoms in comparative households. As a results of this, controlled experiments have been more emphasized in science as a preferable approach in assessing scientific hypotheses. Thus, appropriate controls should be implemented in an experimental study to ensure the results are due to the effect of the variable being tested (dependent variable)[18]. Use of controls will minimize the effects of variables other than the primary independent variable, sometimes referred to as confounding variables (factors that mar the accuracy of the experiment or distort the interpretation of the results), which enhances the reliability and the validity of the study results.

[17] Voit EO. Perspective: Dimensions of the scientific method. PLoS Comput Biol. 2019;15(9):e1007279. Published 2019 Sep 12. doi:10.1371/journal.pcbi.1007279

[18] Ibid

Randomization

Randomization is the process by which participants in a study are assigned by chance to separate groups that are given different treatments/interventions. This is often done using a computer software system, neither the researcher nor the participant chooses which treatment or intervention the participant will receive. By randomization, the researcher minimizes interference by irrelevant factors on the investigation, i.e., neutralizes research biases and, by controlling for the identified confounding variables, gives an unbiased assessment of the experiment. Randomization is not a haphazard process; instead, it follows probability distributions, meaning the outcome is not predetermined[19].

There are various randomization methods, such as using random number generation devices, tables of random numbers, etc.

Experiments in the engineering and physical sciences rarely use randomization. In this case, experiments are mainly used to test how some physical processes work under particular conditions (e.g., obtaining a desired chemical compound through a specific engineering process under special conditions). Mainly, experiments in these fields do multiple test replications (triplicates) to produce identical results in each replication to prove the validity of the results.

In health and social sciences, experiments are typically in the form of a clinical trial. The experimental units are the human subjects randomly assigned to either experimental (treatment) or control groups to assess the effect of a particular treatment on the disease or health outcome. Contrary to physical sciences, the measure is typically the average treatment effect (the significance of the difference between the treatment and the control groups). In a clinical trial, replication is not a part of the experiment, though the results of multiple separate studies can be aggregated and analyzed through systematic reviews or meta-analysis.

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[19] Suresh K. An overview of randomization techniques: An unbiased assessment of outcome in clinical research. J Hum Reprod Sci. 2011;4(1):8-11. doi:10.4103/0974-1208.82352

In agricultural experiments, randomization is commonly used for assessing the effectiveness of different fertilizers. At the same time, experimental economics does not rely on random sample assignment to treatment and control groups as it often utilizes theorized human behaviors of individuals[20].

Types of experiment

There are three types of experiments:

1. Natural or quasi-experiments
2. Field experiments
3. Controlled experiments

1. Natural or quasi experiments

There are cases when controlled experiments are impossible or prohibitively hard to conduct, such as experiments in economics, sociology, archeology, astronomy, geography, etc. In this case, researchers do natural experiments, also called quasi-experiments. In natural/quasi-experimental studies, the researchers collect data solely from observations of the study variables. In contrast to controlled experiments, variables are not controlled in natural experiments. Researchers attempt to assess the contribution from all variables in the system on the dependent variable to receive reliable results on the experiment. When the correlations are weak or are not observed, hypotheses can be tested via controlled experiments[21].

The disadvantage of natural experiments is that there may be factors in the environment affecting the experiments that cannot be detected, measured, and reported. This reduces the power of the experiment and hinders correct analysis and interpretation of the findings. For instance, in astronomy, it is impossible to test the hypothesis "Stars are collapsed clouds of hydrogen." It is impracticable to take a cloud of hydrogen and observe billions of years until it forms a star. Instead, one can observe different states of hydrogen clouds in various states of

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[20] Suresh K. An overview of randomization techniques: An unbiased assessment of outcome in clinical research. J Hum Reprod Sci. 2011;4(1):8-11. doi:10.4103/0974-1208.82352

[21] Curtis MJ, Bond RA, Spina D, et al. Experimental design and analysis and their reporting: new guidance for publication in BJP [published correction appears in Br J Pharmacol. 2015 Sep;172(18):4600]. Br J Pharmacol. 2015;172(14):3461-3471. doi:10.1111/bph.12856

collapse or assess a star's light spectral emissions. This kind of experiment was conducted in the 17th century proving that light has a measurable sleep and it does not simply travel from one place to another. Jupiter moons appeared later when it was farther from Earth, which proved that the moons' appearance was consistent with a measurable speed [22].

2. Field experiments

Fields experiments are differentiated since they are not performed in a controlled laboratory environment. These experiments are applied in disciplines like social sciences. The advantage is that the experiment outcomes can be assessed in a natural setting, which gives the experiment finding higher external validity. Despite that, field experiments have a higher risk of external contamination as there can be many factors that may be hard or impossible to control in the natural environment [23].

3. Controlled experiments

In a controlled experiment, the scientist tests the effect of one or more factors by comparing experimental samples to a control, which should be identical except for the tested factors, also called independent variables. Pharmaceutical drug trials are an example of such an experiment. To test the effectiveness of a drug, the researcher collects data from two groups: experimental/treatment group (individuals that received the new drug) and control group (individuals receiving either placebo or regular treatment drug). In a laboratory experiment, it is always advantageous to replicate samples. The results can be averaged, or, in case of an inconsistency between the samples, it can be regarded as an experimental error. Besides, it is a good practice to have positive and negative controls. Positive controls are known to elicit a response based on the previous testing. In contrast, negative controls create the baseline to

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[22] Angus Dawson and Julius Sim (2015). The nature and ethics of natural experiments. JMedEthics.

[23] Glenn W. Harrison and John A. List (2004). Field Experiments. Journal Of Economic Literature.

assess the experiment outcome compared to positive results (difference between the groups)[24].

When humans are the experimental units, the investigator deals with outside variables such as the placebo effect. The study can be double-blinded (the experiment group distribution is unknown to both the study volunteers nor the researcher until the end of the survey), eliminating experiment outcomes due to the placebo effect. More than one treatment group can be applied in the experiment to assess differences between the mean values for the treatment response[25].

Ethics

Every study involving humans is subject to ethical considerations, i.e., protecting human rights and keeping integrity in science, balancing study risks and benefits, assuring fair distribution of the intervention, obtaining informed consent from every study participant is imperative. For instance, it is unethical to provide substandard treatment in studies with healthcare interventions, meaning it is not allowed to experiment with lower effectiveness than the current best practice. It is also unethical to conduct randomized experiments on harmful treatments (e.g., impact ingesting arsenic on health). To investigate the latter, scientists can use observational studies as an alternative. Ethical concerns can also be present in experiments without human subject involvement, such as nuclear bomb experiments (the Manhattan Project)[26].

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[24] Dennis W. Lendrem et al (2015). Lost in space: design of experiments and scientific exploration in a Hogarth Universe. Drug Discovery Today.
[25] Dennis W. Lendrem et al (2015). Lost in space: design of experiments and scientific exploration in a Hogarth Universe. Drug Discovery Today
[26] Marcello Menapace (2019). Scientific Ethics: A New Approach. SciEngEthics.

Learning Objectives

At the end of the session, the students will be able to:

1. Understand the difference between qualitative and quantitative research
2. Make simple data tables
3. Present data using graphs and tables
4. Write a conclusion statement

Data analysis plays a central role in any research as it includes summarizing the collected data and interpreting the analyzed results. Data analysis is conducted using specific statistical or logical techniques to reveal trends, patterns, relationships within the data[27].

Making simple data tables and graphs

The format of simple data should be based on variables used in the research. The table includes several columns where the researcher lists observed values for independent and dependent variables. For example, when reporting the same outcome from multiple trials, results from each trial are reported in a separate column, and the last column is dedicated to the average value from all the trials. The average value, the mean, median, the mode can be used depending on the variable type (categorical or continuous) and whether it is normally distributed. In all instances, it is essential to note the measuring units for each variable and give a title for each table presented[28].

There are various ways to present or illustrate experiment results that allow a clear understanding of the results. The simplest form of presenting data is using descriptive qualitative wording of the concept. A more advanced approach, when quantitative data is available, includes the use of graphs or mathematical equations. The

[27] Ali Z, Bhaskar SB. Basic statistical tools in research and data analysis [published correction appears in Indian J Anaesth. 2016 Oct;60(10):790]. Indian J Anaesth. 2016;60(9):662-669. doi:10.4103/0019-5049.190623

[28] Introductory Science Skills. Gabel, D. (1993). Prospect Heights, IL: Waveland Press, Inc.

selection of the methods depends on the nature of the experiment, research question, and the independent and dependent variables of the experiment[29]. Graphs are helpful tools to visually present data in a more explicit format than tables[30]. There are also tons of other ways of representation (box plot, scatter plot, charts) that depends on the type of data.

Deciding what type of graph to use

Various types of graphs can be used depending on the information being presented. **Line graphs** are used to track changes over time and are more advantageous than bar graphs when changes are smaller. The line includes data points connected with a straight line where each point infers a value of the dependent variable corresponding to given values of the independent variable. When the independent variable is a discrete variable (i.e., finite, countable values) and the intervals between the points have no significance, a **bar graph** is a more appropriate choice.

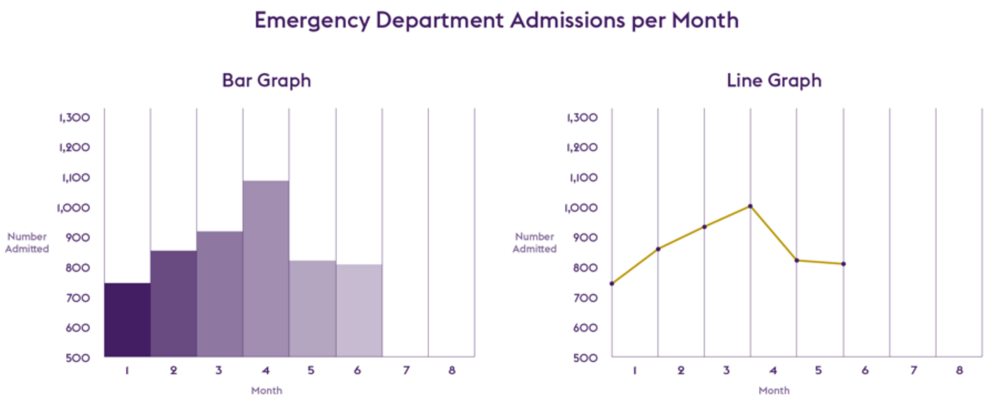

Figure 4: Emergency Department Admissions per Month

Another type of bar graph is the frequency distribution graph, where there are bars for every value of the independent variable. Each bar represents counts for each category of the dependent variable.

[29] Exploring Data. Landwehr, J. M., & Watkins, A. E. (1994). Palo Alto, CA: Dale Seymour Publications.
[30] Introductory Science Skills. Gabel, D. (1993). Prospect Heights, IL: Waveland Press, Inc.

For example, in an experiment assessing the leaf quality of the grown plants using different fertilizers using a rating scale of 1-4 there would be four bars for each level of fertilizer, and the bars would present the number of plants with each leaf quality rating.

There are specific rules to follow when drawing a graph. The horizontal x-axis should present values for the independent variable, while the vertical y-axis should present values for the dependent variable. When setting up a graph with two numerical scales, scales of both axes should start from (0,0) data point, which is the starting point for a line-of-best-fit. For instance, to demonstrate how the bounce height is affected by the height the ball is dropped, one would be sure that dropping the ball from zero height would result in zero bounce. That is point zero, where the line graph should start. All graphs must have a title, clearly labeled x- and y-axis with units of measure and a legend[31].

Summarizing experimental data: descriptive statistics

Making summary data tables & displaying data trends

Upon completing the experiment, the researcher creates a simple data table presenting all of the study measurements. The data in the summary data table is raw and summarized, which is done using measures of central tendency (mean, median, mode) and variation (range, frequency, standard deviation)[32]. It is preferable to display the data in a simple format and insert only the most critical information in the summary table, especially if there is a considerable amount of data in the experiment.

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[31] Learning from Data: An Introduction to Statistical Reasoning. Glenberg, A. (2nd Ed.). (1996). Mahwah, NJ: Lawrence Erlbaum Associates.

[32] Students and research: Practical strategies for science classrooms and competitions. Cothron, J. H., Giese, R. N., & Rezba, R. J. (3rd Ed.). (2000). Dubuque, IA: Kendall/Hunt Publishing Company. This book provides all the information you will need about teaching K – 12 students to analyze data.

Writing a conclusion

The conclusion statement should include answers to six critical questions:

1. What was the purpose of the experiment?
2. What were the significant findings of the research?
3. Did the study support the original hypothesis?
4. How do the findings from this research compare with other experiments?
5. What are the logical explanations for the findings?
6. What are the future directions of the research?

By answering all these six questions, the conclusion statement will be comprehensive and transparent. This framework of six questions helps the writer to summarize the experiment [33].

[33] Longwood University, "Analyzing Experimental Data": http://www.longwood.edu/cleanva/images/sec6.analyzedata.pdf

Learning Objectives

At the end of the session, the students will be able to:

1. Understand the purpose of scientific conferences
2. How to prepare for conferences
3. Create a scientific conference/academic poster
4. Give an effective oral presentation

An academic conference is an assembly of scientists and researchers where they present their research findings and discuss the most important topics and issues surrounding the specific topic of the conference. There are many types of conferences such as symposiums, research conferences, academic meetings, academic conferences, etc. Academic conferences are usually organized by a group of scientists under the supervision of a technical committee which ensures the scientific quality of the event.

Conferences can also vary in size, from a small local conference organized by a small group of junior scientists at a university or company, to global conferences where thousands of eminent scientists from all over the world come together. The conferences can also differ by their scope. Some of the conferences focus on narrow topics that only highly specialized scientists attend. Still, there are also interdisciplinary conferences that bring together a wide variety of specialists from different fields of science and industry. Attending academic conferences is one of the essential tools of scientific communication. It will often offer unique networking opportunities with prominent scientists worldwide and enables researchers to get acquainted with the latest research in the field[34].

[34] McCurry D., "Your complete guide to academic conferences", 19 February 2019: https://www.exordo.com/blog/guide-to-academic-conferences/

Posters and Oral Presentations

Posters

Poster presentations are one of the most effective ways to communicate in scientific conferences for junior researchers. It is sometimes the only standard format in academic meetings. The posters usually have the same formats as short scientific reports. In particular, posters should have a title, introduction, materials and methods, results, and conclusion. In addition, posters should be visually appealing and convey the information to the viewers in a short amount of time[35].

One interesting idea is to encourage students to use recycled materials when setting up their posters. On the poster board, the title may state the independent and dependent variables or, alternatively, maybe creatively worded to catch the reader's interest. The statement of the problem should clearly communicate the essentials of the experiment. Typically, this will include the purpose of the investigate ion and the original hypothesis. Because of limited space, the procedure must be stated concisely. It can be either in list or paragraph form. The results of the experiment w are presented as data tables and graphs, followed by a short-written summary. Whenever possible, photographs or diagrams can be included to emphasize or make the message as clear as possible and will often make the poster more attractive. A digital camera is useful for taking photos of experiments. The conclusion should summarize the major findings and the extent to which the results support the original hypotheses, as well as an explanation of the findings. Recommendations for future research and study limitations can be included if space permits[36] [37].

Oral presentations

In addition to posters, oral presentations give students and junior researchers crucial skills in many aspects of scholarly communication. Scientists at the more advanced levels of their careers could deliver

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[35] Larkin M., "How to give a dynamic scientific presentation", Elsevier, 4 August 2015: https://www.elsevier.com/connect/how-to-give-a-dynamic-scientific-presentation

[36] Wood C., "What is a scientific conference?", Catalyst, December 2013: https://www.stem.org.uk/system/files/elibrary-resources/legacy_files_migrated/31076-Catalyst%2024%202%20570.pdf

[37] New York University, How to create a Research Poster: https://guides.nyu.edu/posters

presentations in global interdisciplinary conferences[38]. Classroom presentations usually are concise. However, oral presentations in competitive events can last up to 15-minutes. To train for oral presentations, students can practice 1-minute talk sessions with their peers to discuss their latest research results or scientific papers. This is more convenient for students than lengthy presentations, and the practice helps students prepare for the more difficult oral presentations.

When making oral presentations for more extended experiments, students are advised to adhere to the following steps[39]:

- Provide background information about the research topic and yourself.
- Describe the significance of the problem and why it is vital to be solved.
- Articulate the scientific hypothesis.
- Describe the experimental procedures that have been used to solve the problem.
- Present results in visually appealing formats such as graphs and tables.
- State the summary of conclusion points and specify whether they correspond to the original hypothesis or not.
- Describe the prospects of future research and how the described experiments can be improved.

Students need moral support to overcome nervousness when speaking in front of an audience until they become more experienced. Encouragement of taking every opportunity to present their data by the oral presentation is critical. Through practice, students will feel confident to make presentations in front of various audiences, including largely attended scientific conferences[40].

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[38] Udovicich et al. Journal of Clinical Urology 2017, Vol. 10(4) 396–399
[39] Scitable, "Oral Presentations Structure": https://www.nature.com/scitable/topicpage/oral-presentation-structure-13900387/
[40] Gundogan et al. Annals of Medicine and Surgery Volume 11, November 2016, Pages 69-71

Topic 3. Writing: Manuscript/Thesis

<u>Learning Objectives</u>

At the end of the session the students will be able to:

1. Arrange data from the project into proper structure for a manuscript/thesis formatted according to requirements.
2. Write a manuscript/thesis using correct technical and scientific language.
3. Understand the steps of manuscript/thesis writing and submission.

Imagining design of your thesis/paper

Let's imagine that you have done a 3-year research project. Whether the results are as expected or not, what is your next step? Since the goal of research is to generate new knowledge, you need to share it with others, at relevant scientific society conferences or by publication in a field-related, peer-reviewed journal. Publishing also improves the potential for you (scientists) to obtain funding for further research either from the government or private enterprises, or achieve professional advancement at universities or academic institutions.

The best way to begin, is to compile your data and present them in a logical and simple way in a paper. Below are the steps to writing a paper. Most steps are also relevant to the development of your thesis, and any differences are noted in boxes within the section.

What is a paper?

A paper is written to communicate new knowledge to the reader and is published in scientific journals. Most journals publish a very narrow range of topics. For example, the Journal of Molecular Veterinary Research will publish papers that describe findings at the molecular level using molecular methods and approaches.

Before determining a target journal, study its latest issues and see if your contribution will fit the general concept and policy. Study the guidelines for the authors and decide what type of publication will best suit your purpose. In other words, "**Begin with the end in mind**".

Every scientific journal has specific manuscript types that may be published (for example, original research, brief report, review article, case report/series, etc.).

The first step to writing a manuscript is to compose an outline that complies with the formatting requirements of the target journal. Careful attention must be taken to report content within the proper section of the manuscript (e.g., discussion points should not be included in the results section). Poor placement of content can confuse the reader (reviewer) and may cause misinterpretation of content.

Criteria to assist with journal selection:

- Impact Factor or Impact index
- Quartile position of the journal

Information about these criteria can be easily found online at: Journal Citation Reports (JCR), which is a paid service; or Scientific Journal Rankings (SJR), which is free of charge.

By analyzing the citations received by the articles published within a journal, impact indicators measure the impact that a journal has had on scientific literature and the importance of a publication within a specific subject area. This enables the ability to compare journals impact and rank, while also measuring the relevance of each title in a particular subject area.

One way of determining the IMPACT FACTOR of a journal is by looking at the average number of times, in one year, that articles published in the previous two years have been cited.

A simple formula is used to calculate the Impact Factor (IF) a criteria used by JCR:

$$\frac{\text{the total number of citations received in the previous two years}}{\text{the total number of articles published in those previous two years}}$$

The SJR IMPACT INDEX was developed based on an algorithm conceived by Google to organize its search results (Google PageRank). This means that not all citations carry the same value: rather, their value depends on the position of the journal cited. For example, a citation from a journal with a high SJR index will have a greater value than a citation from a journal with a lower SJR index.

SJR details the number of links that a journal receives based on the weighted citation of its documents relative to the number of documents published in that year by each publication. The weighting of the citations is based on those received by the citing publication. The calculation disregards citations to documents published within the journal itself.

The citation period is three years - one year longer than JCR - and has been calculated on a yearly basis since 1999, although data from Scopus publications have been compiled since 1996.
In addition to Impact Factor or Impact Index, rankings of journals in each subject category are divided into quartiles by both JCR and SJR.

These quartiles (Q1, Q2, Q3 and Q4) rank the journals from highest to lowest based on their impact factor or impact index:

- Q1 - top 25%
- Q2 - 25 to 50%
- Q3 - 50 to 75%
- Q4 - bottom 25%.

The H-Index was created by Jorge E. It measures the impact of a particular scientist rather than a journal. The h-index takes into account the number of papers published and the citations to those papers in a balanced way, and thus is useful to make comparison between scientists.

What is a thesis?

Thesis is also text written to communicate new knowledge to the reader, however, there are differences and nuances that we will discuss in parallel with paper writing below.

For Masters thesis preparation, each university and institution has its own requirements, which usually are available on their websites. Depending on the field of study, the structure of the master thesis may vary.

By the requirements of the Supreme Certifying Committee (bok.am), PhD students are allowed to use Armenian, English, and Russian languages for the body of their thesis. All details for thesis preparation are found here.[41]

Writing style requirements

Choose words with care and precision: Words that enhance the quality of writing are characterized by clarity, accuracy, and consistency. Clarity implies using the simplest and most accurate word to express each idea, giving an understanding of what information is relevant and irrelevant. Accuracy entails using the correct words to express exactly what you mean.
For scientific articles aimed at peer-reviewed journals, it is important to write objectively and based only on observations. It is important to continually improve the clarity of your writing, refine the accuracy of the words you use, and maintain consistency by using the same word for the same idea in all your writing.

Consider the following recommendations as you write:

- State the facts only
- Avoid using unfamiliar words
- Do not use colloquial speech or slang
- Do not use contractions (e.g., "don't" should be "do not")
- Be consistent: never use different words for the same scientific term.

[41] Բարձրագույն որակավորման կոմիտե, Ցուցումներ և հղումներ, https://bok.am/templates

Avoid long sentences: Shorter sentences have greater impact. Unnecessarily long, rambling sentences are difficult to read. Sentences should be short or medium in length (typically 15–20 words) and include only one or two subordinate clauses.

The use of numbers: When a number starts a sentence, that number should be presented in words. Numbers under 10 should also be spelled out, whereas numbers over 10 can be presented in figures.

Let your colleagues help: When you have finished writing, let your colleagues help you with constructive criticism. Allow them to keep your manuscript for 1–2 weeks to read, check, and ensure that your article is conclusive and understandable.

After choosing the journal it is helpful to follow the IMRaD format for writing scientific manuscripts:

- Introduction
- Methods
- Results
- Discussion.

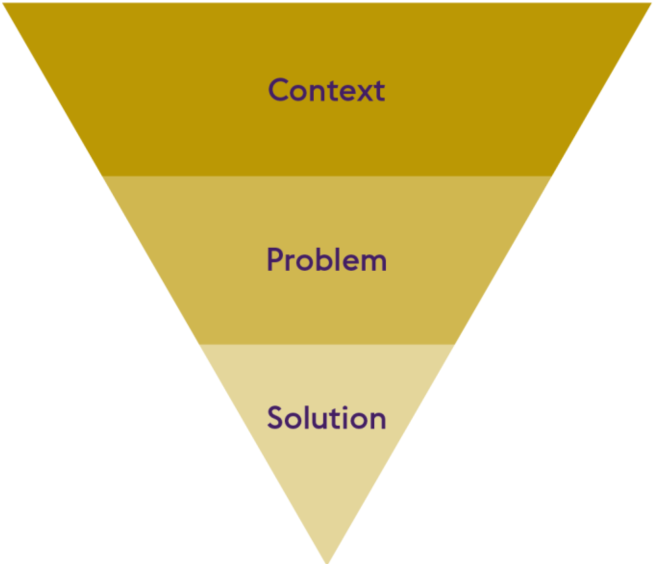
Introduction

- **For paper**
  Past studies are used to set the stage or provide the reader with information regarding the necessity of the represented project. For an introduction to work properly, the reader must feel that the research question is clear, concise, and worthy of study.

  A competent introduction should include at least four key concepts: 1) significance of the topic, 2) the information gap in the available literature associated with the topic, 3) a literature review in support of the key questions, 4) subsequently developed purposes/objectives and hypotheses.
  In order to develop a proper introduction, conduct an accurate and adequate literature review: Incomplete, inaccurate, and outdated background information and references can be reasons for a paper not to be accepted for publication. An adequate and up-to-date introduction informs the author of the strengths and weaknesses of his or her study and whether it is worth writing, given the existing literature. The search may be performed using the Internet or by screening the latest issues of scientific journals and the proceedings of recent conferences. Common searches include electronic databases (MEDLINE, EMBASE, and the Cochrane Library).

  When constructing a review of the literature to develop your introduction, stay focused on your topic at hand. Do not reach beyond the specific topic or let the search get too broad. For example, do not include extraneous information about performance or prevention unless your research specifically relates to that.

  The introduction of a scientific paper is not an exhaustive review of all available knowledge in a given field of study. That type of thorough review should be left to review articles or textbook chapters. The format of an introduction can be thought of as an inverted triangle: broadly introduce and describe the main topic, critically discuss current knowledge on the topic; identify the gaps in knowledge; and finally, state the objectives of the current paper.



Throughout the introduction, (and later in the discussion!) remind yourself that a paper, existing evidence, or results of a paper cannot draw conclusions, demonstrate, describe, or make judgments, only PEOPLE (authors) can. For example, it is correct to write:

- "Petrosian and Karapetyan, demonstrated that...."
- "Previous work revealed that..."
- "Several studies have reported..."
- "It has been shown that..."

Conclude your introduction with a solid statement of your purpose(s) and your hypothesis(es), as appropriate. The style of some journals is such that you may end with a brief summary of your methodology and main findings.

The purpose and objectives should clearly relate to the information gap associated with the given manuscript topic discussed earlier in the introduction section. This may seem repetitive, but it is helpful to ensure the reader clearly sees the evolution, importance, and critical aspects of the study at hand.

Once you have a full draft of the introduction, it may need to be further edited as you develop the other sections of the manuscript in order to align with the main points of the content overall.

- For thesis
  - The content of the chapter should be broader than what would be written for the introduction of a manuscript, which should focus on the main topic. In the literature review, the author must show his expertise in the field, dive deep, and include all aspects of the problem. The supervisor usually guides PhD students and helps not to over- or under-write.
  - It is acceptable to refer to older data and show what was discovered with the new research.

Methods

- For paper

  The methods section should clearly describe the specific design of the study and provide a clear and concise description of the procedures that were performed. **The purpose of sufficient detail in the methods section is to enable an appropriately trained person to replicate your experiments.** There should be complete transparency when describing the study. In some cases, preparation instructions on a target journal website may provide guidelines for details to include in the methods.

  A clear methods section should contain sub-headers that cover the following information:
  - Study design - the population and equipment used in the study

Most scientific journals support the need for all projects involving humans or animals to have up-to-date documentation of ethical approval, including a clear statement that the researchers have obtained approval from an appropriate institutional review board.

- Details on how the population and equipment were prepared and what was done during the study. Sub-headers could include:
  - **Protocols** - specific details on experimental procedures/methods
  - **Assessments** - the outcomes and how they were measured
  - **Study population** - If the project is related to human clinical studies for example, this first paragraph will generally contain a description of inclusion and exclusion criteria, or treatment regimens, which help the reader understand the population used.

- Statistics - the methods used for data analysis; the actual results should be discussed in the results section, as they have an entire section of their own!

Although it is a good idea for the authors to have justification and a rationale for their procedures, these should be saved for the discussion section. Occasionally, studies supporting components of the methods section such as reliability of tests, or validation of outcome measures may be included in the methods section.

- **For thesis**

The purpose of providing sufficient detail in the methods section is to enable an appropriately trained person to replicate your experiments.

Even if the thesis topic is a development of a new method, the author should include only details of methods that were used to design the new one. For example, in some cases it is acceptable to include phrases such as “As previously described” or “As previously published", and provide the appropriate reference for a common method.

Results

The Results section is the core of both the paper and thesis. Results should include only the essential points and report the facts of the experiment.

It is important that you clearly distinguish your results. Do not include opinions of the findings, the methods used for data analyses, or references; this section should consist only of data. During the outline process, it is essential that the author identifies which results require interpretation in support of the goals of the study and which can be excluded or put into supplemental material for the manuscript. Careful organization of the data presentation (tables and figures) is crucial for enabling the sequence to tell a story.

Report your results neutrally, as they occurred. Use separate paragraphs or sub-headers within the results section to report on different types of experiments.

To supplement the text, data may be presented in tables or figures (photographs, drawings, graphs, or flow charts) for clarity if verbal descriptions are too long or complicated. Results should be described and then the table or figure should referenced within the text. For example, "X was significantly higher than Y (**Table 2**)" and include a reference to the table or figure. All tables and figures should be easy to understand and with sufficient resolution (for figures). Each should be numbered sequentially so that readers do not need to refer to the text to understand them. The titles of tables and figure legends should be succinct.

The statistical significance of any differences should be always reported. Similarly, it is important to note if certain expected results are not significant. Statistical tests to evaluate the significance should be defined in the methods section.

If your manuscript includes a table or figure that has already been published, permission should be obtained from the copyright owner (usually the publisher; not the corresponding author).

Discussion

The purpose of the Discussion section is to explain the meaning of the results to the readers. Indeed, many papers are rejected despite interesting data due to imperfect interpretations or explanations of the results. The Discussion section should (1) state and explain the major findings of the study, (2) compare and contrast your findings with those found by similar studies, (3) address the study's limitations and strengths, (4) discuss the importance and clinical relevance of your findings, and (5) offer suggestions for further research. Your findings should be neither overemphasized nor inflated, nor should you criticize or attack other studies in the Discussion section. In general, the first paragraph should discuss the major findings and state whether the hypotheses were supported or rejected. Subsequent paragraphs should compare and contrast the findings of your study with those of similar research. You can also discuss alternative hypotheses and why these were inconsistent with your data as well as to mention the future studies needed to test such alternative hypotheses. The last paragraph of the Discussion section should contain a concise summary, regardless of statistical significance, and offer recommendations for further research. Do not repeat detailed descriptions of the data and results in the Discussion section.

References

- **For paper**
  Journals vary in their reference formats. Before submitting your article, make sure that you have followed the format of your target journal. Referees will often check the references or know them because they are experts in the field, so any errors in this section reflect badly on the paper as a whole.

- **For thesis**
  - Requirements for Master's thesis is up to university and institution.
  - Acceptable format has been developed by the Supreme Certifying Committee (bok.am)[42]

NOTE - UPON COMPLETION OF A FULL MANUSCRIPT DRAFT AND BEFORE SUBMISSION:

Ask co-authors, peers, and mentors to review and approve your draft. This is a critical step (and a type of pre-peer review) that will provide important contributions that may strengthen the paper.

[42] Supreme Certifying Committee, https://bok.am/templates

Submission and review process

When you write an excellent (as you may think) manuscript, the next step is to submit to the journal. An overview of what happens next is shown in the figure and explained in detail below.

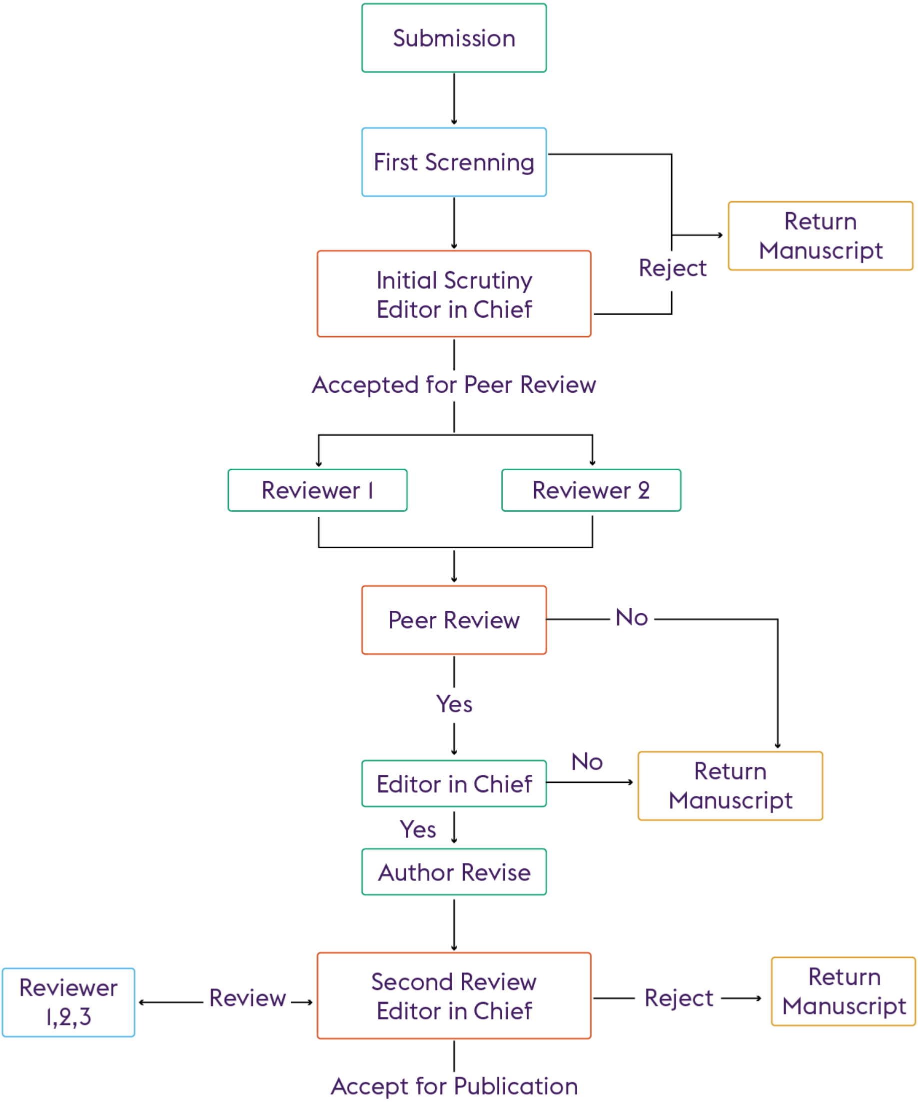


Figure 5: What happens after you submit your paper?

Submit manuscript

Submit your manuscript online through the targeted journal's homepage after completing required details in the online submission system. The manuscript should not be submitted to more than one journal at the same time (follow submission policy).

In some instances, the editor may decide that the rigor or scope is not appropriate for the journal and not send for peer-review, in which case, turnaround is usually within a week if not a few days.

Peer-review

After the editorial screening to ensure that the manuscript is formatted correctly and within the scope of the journal, the peer-reviewing process will be initiated. Review time varies from journal to journal, you may visit a section of an individual journal to find the approximate required reviewing time of that journal. Be patient during this time, it will take at least a few weeks.

Decision

Based on the reviewer's recommendation, the editor will send you one of the following decision letters:

Revise

Revise manuscript according to the comments and resubmit. Here you need to do some work. First of all, understand whether the comments made by the reviewers are valid or out of scope for the current study. For example, instead of running directly to the lab and performing additional experiments as suggested, it may be more important to provide a rebuttal to explain to the editor why the way you have done your experiment is acceptable or if there is a flaw with the suggestion. It is often helpful to provide references of other papers with similar experiments.

It is also possible that you can decline to revise. In this case, you may choose another journal (typically with a lower impact factor), reformat the current manuscript (perhaps incorporating some changes raised by reviewers as it may improve the manuscript), and resubmit.

Reject

Although you may have been provided with reviewer comments, the editor may not feel that the manuscript will be strengthened enough to warrant publication in their journal.

At this point, you must choose another target journal, reformat the manuscript accordingly, and resubmit as a new manuscript.

Accept

It is time to celebrate, your manuscript will be typeset by the journal for publication.

Publication

After acceptance of the manuscript, you will receive a galley proof version for final proofreading corrections and your paper will be published.

It's time to share your published work and cite in other related papers as per the licensing policy of the journal.

Topic 4. Writing Successful Grants

Learning Objectives

At the end of the session the students will be able to:

1. Evaluate the relevance and eligibility of grants
2. Describe key tips for writing effective grant applications
3. Describe how to find relevant grant sources

What is a grant proposal?

A grant proposal or application is a document or set of documents that is submitted to an organization with the explicit intent of securing funding for a research project. Nonetheless, there are some general rules for writing successful grants.

Grants are available at nearly all career stages - including pre-doctoral fellowships or highly experienced and well-established faculty - and encourage trans-national, inter-sectoral and interdisciplinary mobility.

Why is grant writing an important skill?

Obtaining a grant is an intense and competitive process, therefore the development of sharp grant writing skills is important.

As examples of the competition:

- the European Commission's Horizon 2020 Programme (the largest-ever research and innovation programme in the European Union), with nearly €80 billion (US$89 billion) in available funding, reported a 14% success rate for its first 100 calls for proposals, although submissions to some categories had lower success rates.
- In 2020, the Marie Skłodowska-Curie Actions Individual Fellowship received the highest number of proposals ever, with over 11,500 from across the world.
- The United States National Science Foundation (NSF) received 49,415 proposals in 2017, and only awarded 11,447 a funding rate of less than 25%.

What skills are important in grant writing?

Successful grant acquisition requires specialized skills in research, organization, networking, writing and follow-up. What sort of supporting data will you need to support your proposal?

General approach

In each grant application, there are a number of components that must be clearly explained:

- What is the topic? Why is this topic important?
- What are the research questions that will be answered? What relevance do your research questions have to the current knowledge base?
- What are your hypotheses?
- What are your research methods?
- Why your proposed approach is special and exciting?
- What the outcome of the project will be,
- Why this research will be of such enormous benefit,
- Where it fits to the call
- How the impact benefit will be achieved.

Once you have identified your needs and focus, you can begin looking for prospective grants and funding agencies.

Introduction to Grantsmanship

When choosing a grant funding organization, it is important to find out as much information as possible about the organization. With grants, it is better to send out few targeted proposals that aligns with the mission statement of the organization, than a general proposal to several organizations.

Although each funding agency will have its own (usually very specific) requirements, there are several elements of a proposal that are fairly standard, and they often come in the following order:

1. Title page
2. Abstract
3. Introduction (statement of the problem, purpose of research or goals, and significance and innovation of research)
4. Project narrative (methods, procedures, objectives, outcomes or deliverables, evaluation, and dissemination)

5. Personnel
6. Budget and budget justification

Note: Format the proposal so that it is easy to read. Use headings to break the proposal up into sections.

Title page

The title page usually includes a brief yet explicit title for the research project, the names of the principal investigator(s), the institutional affiliation of the applicants (the department and university), name and address of the granting agency, project dates, amount of funding requested, and signatures of university personnel authorizing the proposal (when necessary). Most funding agencies have specific requirements for the title page; make sure to follow them.

Abstract/specific aims

The abstract or specific aims page provides readers with their first impression of your project.

It sets the stage for your entire proposal, and most often, is where you will make or break it with the reviewers. To remind themselves of your proposal, readers may glance at your abstract when making their final recommendations, so it may also serve as their last impression of your project. The abstract should explain the key elements of your research project in the future tense. Most abstracts state: (1) the general purpose, (2) specific aims, (3) research design, (4) methods, and (5) significance (contribution and rationale). Be as explicit as possible in your abstract. Use statements such as, “The objective of this study is to ...”

Impact statement - overall goal of the proposal

Your proposal needs a strong explanation of the overall benefits at different levels from the individual to society as a whole, such as the following:

- **Personnel** - your research may allow for improved career opportunities in a new/expanding/developing area of science: reducing the international migration of scientists searching for better opportunities, better level of training to further individual careers in less developed nations.
- **Hosts** - Better research, improved/new collaboration – and why this will benefit, shared resources/facilities, targeting of new research frontiers.
- **Research** - Complex problems which can only be resolved by such an approach and why it is important to resolve such problems.
- **UK/European** - Increased dissemination of scientific activity; catching up to or exceeding the productivity or capability of USA or China; removing reliance on USA or China; improved industrial competitiveness/health/environment. It is important to bring the concept of a focused network of Partners/Disciplines, where appropriate, as an integral aspect of the structuring of the Electronic Research Administration enabling future more competitive research.
- **International** - increased competitiveness; becoming a leader in this technology.

It may also be helpful to consider the potential beneficiaries of the research by the following categories:

- Private sector
- International, national, local or devolved government and government agencies, including policy-makers
- Public sector, third sector, or others (e.g. museums, galleries, charities)
- Professional or practitioner groups (such as the legal profession, architects, planners, archivists, designers, creative and performing artists)
- General public

Introduction

The introduction should cover the key elements of your proposal, including the current knowledge and knowledge gap, the purpose of research, research goals or objectives, and significance of the research. The statement of the problem should provide background and rationale for the project and establish the need and relevance of the research. Is your proposal innovative - how is your project different from previous research on the same topic? Will you be using new methodologies or covering new theoretical territory? The research goals or objectives should identify the anticipated outcomes of the research and should align with the needs identified as the gap in knowledge. List only the specific aims or principle objective(s) of your research and save sub-objectives for the project narrative.

Project narrative

The project narrative is generally the largest component of your proposal and may require several subsections. The project narrative should supply all the details of the project, research objectives or goals, hypotheses, specific details on methods and procedures, expected outcomes or deliverables, potential pitfalls and alternatives, and sometimes a timeline is included.

Significance

The significance section justifies the need for this research. Here you must explain:

- why the project is important and needed
- why the proposed approach is special and exciting
- what the outcome of the project will be
- the value add of the project (financial/social/environmental/health etc. to the European community).

Approach

Given the highly technical nature of the approach section and the importance of demonstrating your expertise in the field, include as much information as possible on preliminary studies, whether from your own work, your mentor's lab, or a collaboration.

For the project narrative, avoid assuming that the reviewers will be familiar with your proposed experimental techniques and be sure to provide adequate details. For example:

- if proposing to conduct unstructured interviews with open-ended questions, be sure you have explained why this methodology is best suited to the specific research questions in your proposal.
- if using item response theory rather than classical test theory to verify the validity of your survey instrument, explain the advantages of this innovative methodology.
- if you need to travel to Valdez, Alaska to access historical archives at the Valdez Museum, make it clear what documents you hope to find and why they are relevant to your historical novel on the '98ers in the Alaskan Gold Rush.

Clearly and explicitly state the connections between your research objectives, research questions, hypotheses, methodologies, and outcomes.

Methodology

Key points:

- This is what we are going to do
- This is how we are going to do it
- This is why we are doing it this way
- It is the best/optimized way
- There is a clear defined plan
- Objectives and target deliverables are set and identified
- Risk is analysed, understood and accounted for in the planning
- Management activities and support structure are appropriate
- Dissemination and exploitation routes are identified and planned

Tasks

For each task, include:

- a justification (WHY)
- a description (What/How)
- an outcome (Achievement)
    - Deliverable: MUST be tangible and concrete (technical data, best practice guidelines and protocols, supporting data sets and etc.)
- purpose (How does this advance the field)

- the interrelationships with other tasks - however, ensure that tasks are not entirely dependent on one another.

Some grants (e.g. Marie-Curie Fellowship) have a section for the description of the research environment. The experience and specific expertise that you and your lab/group brings to the proposal, as well as the support, equipment, and facilities at your school, department, Research Centre, or University will need to be explained. It is important to give a clear and concise description of your assembled team, including named individuals if possible. Although not always essential, networking and collaboration with other research centres is often a major plus to your proposal.

Personnel

It takes a team to successfully complete a research proposal, including for example: Principal Investigator, post-doctoral fellow, pre-doctoral student, lab technician, engineer, software designer, collaborator. Explain the role of each person on the research team in explicit detail including the skill sets necessary for the particular proposal. You will most likely need to include the curriculum vitae or bio sketch of anyone on your team as part of the proposal. It is acceptable to list roles in which the specific person has not been identified, in which case you will need to explain the necessary skill sets and functions of the person you will recruit for that position.

Budget

The budget details the project costs and usually consists of a spreadsheet or table with the budget detailed as line items and a budget narrative (also known as a budget justification) that explains the various expenses. Even when proposal guidelines do not specifically mention a narrative, be sure to include a budget justification, generally a few sentences detailing for what each category of funds will be used.

Make sure that all budget items meet the funding agency's requirements as some organizations will not cover equipment purchases or other capital expenses.

Many universities require that indirect costs (also called "overhead", which may include for example, rent, utilities, and general and administrative expenses) be added to grants that they administer. Check with the appropriate offices to find out what the standard (or required) rates are for overhead. This will often require approval of a draft budget by the university officer in charge of grant administration, who can provide assistance with indirect costs and costs not directly associated with research (e.g. facilities use charges).

Timeframe

Explain the timeframe for the research project in detail to help reviewers understand and evaluate the planning and feasibility. When will you begin and complete each step? It may be helpful to reviewers if you present a visual version of your timeline. For less complicated research, a table summarizing the timeline for the project will suffice.

Dissemination of information

Dissemination is the means to promote the Impact Statement that you created as part of your overall goals. Examples of dissemination include:

- Publishing research papers and reports
- Presenting at conferences
- Web activities; promotion by social media
- Public engagement
- Networking.

Topic 5. Project and Time Management | Lab Management

__Learning Objectives__

At the end of the session the students will be able to:

1. Define project management
2. Describe the project management cycle
3. Describe key techniques for effectively managing scientific projects
4. Define the goal and main concepts of Good Laboratory Practice
5. Describe the main rules of effective lab management

Technical development and manufacturing projects of great complexity led to creation of organized project management more than 50 years ago. In its early days, it was a highly technical field known best, perhaps, for generating reams of paperwork.

What is project management? According to the Association for Project Management, **project management (PM)** is the application of processes, methods, skills, knowledge, and experience to achieve specific project **objectives** according to the project acceptance criteria within agreed parameters. Project management has **final deliverables** that are constrained to a finite timescale and budget.

A project is a temporary effort to have a defined beginning and end (usually by date, but can be by funding or deliverables), and which is undertaken to meet unique goals and objectives.

The **temporary nature of the project** requires distinct technical skills, and separate management approaches compared to well-established permanent or repetitive operations (business-as-usual) projects. [43]

Successful PM will seek to:

- Develop an appropriate feasibility study
- Have realistic objectives
- Appoint a competent leader and team
- Assign adequate resources: i.e. budget, time, people, and facilities

[43] Association for Project Management, What is Project Management?, https://www.apm.org.uk/resources/what-is-project-management/

- Ensure proper information flow within the team
- Establishing, and adhere to, progress milestones
- Anticipate problems and prepare for solutions

In the lab, the three key steps of project management are

- **Planning**, to clarify:
  - Expected outcomes of the project
  - Stakeholders: who will be affected by, are needed to support, or will be interested in the project outcome?
  - Events that have to be performed to complete the project
  - Dates on which each project activity will start and end
  - Finances for all required project resources
  - Risk mitigation
- **Organizing**, to specify roles and responsibilities for project personnel
- **Controlling**, the performance of project work including:
  - Organizing, focusing, and continually motivating project personnel
  - Tracking and comparing project work and results
  - Considering and making changes to plans when needed
  - Keeping everyone informed of project accomplishments, issues, and changes
  - Continuously tracking and managing evolving project risk44

The primary challenges of project management are:

- To achieve the (engineering or scientific) project goals and objectives,
- while at the same time adhering to a set of agreed project constraints, which are typically scope (objectives), time, and risk.

The Project Management Institute (PMI) has identified nine areas of knowledge within project management:

1. Integration management
2. **Scope management**
3. **Time management**
4. Cost management
5. Quality management

[44] Stanley E. Portny, Jim Austin, Project Management for Scientists
Project Management for Scientists | Science | AAAS

6. Human resource management
7. Communication management
8. **Risk management**
9. Procurement management[45]

In this course, we will discuss only three areas - scope, time, and risk - considered the most important for PM in scientific projects.

Scope management

Scope: The work content and products of a project or component of a project. Scope is fully described by naming all activities performed, the resources consumed, and the end products which result, including quality standards.

Scope management is the function of controlling a project in terms of its objectives through the concept, development, implementation, and termination phases.

The first step in effective Scope Management is the identification, definition, and documentation of the project objectives as well as selecting the best approach to achieving the project objectives. The project work is then identified and defined to a common framework.

The definition of project scope and associated planning documents are then reviewed for formal work authorization before work begins. Following authorization of work, baseline changes are controlled in a structured manner through a control system. Authorization is necessary before work is initiated on the change, thus providing a good audit trail of baseline changes.

As the project progresses, project process/status information is recorded, accumulated, and transformed into structured information necessary to judge project performance. The data is analyzed to determine the current status of the project, significant problem areas, developing trends and to forecast future status.

[45] Usability.gov, Project management basics: https://www.usability.gov/what-and-why/project-management.html

Time management (TM)

Time management is defined as the third major function of project management. This is one of the traditional concerns of the project manager — an area in which much research has been conducted and much material written, and is perhaps the founding concern of modern project management[46].

As one researcher can be engaged in more than one project or have multiple roles and responsibilities in one project, it is very important to have effective time management skills in the lab. It will help to maintain focus on work, contributing to research productivity. Good time management also decreases stress and improves job satisfaction.

Strategies for time management fall into three broad categories: time assessment behaviors, planning behaviors, and monitoring behaviors. Using a variety of personalized strategies in each category is essential to effectively TM.

A researcher's productivity is often measured in terms of "deliverables" produced within a unit of time. These are outcomes of scientist's activity and are often considered quantifiably and qualitatively. The deliverables may vary between organizations, but commonly include publications, presentations, proposals submissions, funded research, service as a reviewer or editor, and mentorship of students and fellow faculty. Consider two researchers that produce the exact same high-quality deliverable, for example a publication. If the first researcher produces a manuscript in 3 months, he or she would be considered more productive than the researcher who produced the manuscript in 6 months. Thus, time is a critical component of research productivity in an academic environment[47].

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[46] MacDonald, D. H. (1983). PMI/ESA project time management function. Project Management Quarterly, 14(1), 20–26

[47] Chase JA, Topp R, Smith CE, Cohen MZ, Fahrenwald N, Zerwic JJ, Benefield LE, Anderson CM, Conn VS. Time management strategies for research productivity. West J Nurs Res. 2013 Feb;35(2):155-76. doi: 10.1177/0193945912451163. Epub 2012 Aug 6. PMID: 22868990.

Time management is crucial to the successful completion of a project. Not only is the short-term realization of success or failure of the project at stake but also the personal reputation of the project manager and the project team members. In some large projects that run for several years at costs in excess of a billion dollars, the financing charges can approach $1 million per day. Even in many smaller projects, especially in a competitive market, it is essential to complete projects on time or lose the edge in the marketplace.

The function of Time Management has been divided into four processes:

1. Planning
2. Estimating
3. Scheduling
4. Control.

Like the functions of project management these processes are ever changing. However, the four processes are in line with the thinking of the Project Management Institute and are a good starting point in describing the Time Management Function.

1. Planning

Planning consists of identification of the intention of the project management group with respect to the methods and procedures they intend to follow towards the management of the project's time function. In other words, it includes depicting what the project management group intends to do, how it will be done, and what will be used to do it.

2. Estimating

Estimating, as it relates to time management, is the determination of the duration of an activity. Despite all the sophistication, however, it is something we can only attempt with a limited degree of accuracy due to the uncertainties associated with imperfect humans and their working conditions. Although it is a difficult task to estimate work durations with assured accuracy, it is not totally impossible to quantify. The estimator has many modern techniques available, as well as historical or past performance data.

3. Scheduling

Scheduling is, in essence, the recognition of realistic time and resource restraints which will, in some way, influence the execution of the plan. Schedules are an important part of project management because they help you measure your progress as the project moves along by creating dates on which activities are started and completed and when milestones are reached. They also reflect the project lifecycle broken down into specific deliverables and touch points. It defines the amount of work effort expended by people on project activities and who is the point of contact responsible for the work.

4. Control

Control, therefore, must contain the recognition of what has been happening, and some overt action to ensure that the objectives of the project are met.

Each of the above four processes must contain part of its predecessor, but need not necessarily contain any component of its successor.

Risk management

Risk management is inextricably tied into cost, schedule and quality and is, therefore, a key component of the project management process.

Risk management, in the project context, is the art and science of identifying, analyzing, and responding to risk factors throughout the life of a project and in the best interests of its objectives.

Risk identification

On most projects, responsibility for project risk is so pervasive that it is rarely given sufficient central attention. It should be noted, therefore, that not all risk events are independent. Indeed, the total amount at stake may be highly dependent upon a series of interacting events. Unfortunately, the old saying, “It never rains, it pours!” is not an uncommon experience. Moreover, a series of risk events can, and frequently does, cross traditional functional responsibility boundaries with disastrous consequences[48].

[48] Pym, D. V. (1987). Risk Management. PM Network, 1(3), 33–36.

The sociological trends of our society and current philosophy of team building emphasize the need to be positive-problems are opportunities; risks are challenges to be overcome; negative thoughts are socially suppressed. In this environment, to emphasize risks is to be labeled as a negative thinker and noncontributor-almost a pariah. It's as if we've forgotten a basic survival instinct: risk aversion. Our evolution from the African savanna was a systematic process of learning to avoid risks. Risk-averse behavior is a survival trait and should be included as a balancing factor, even in today's sophisticated civilization.
There are positive, proactive steps to manage risk. When practiced consistently within an organization, these proactive steps can form the basis of a formal project risk management methodology.

Risks can be divided into two classes: **recognizable risks** and **unmanaged assumptions.**

Recognizable risk classification and mitigation

Recognizable risks are those that can be identified during planning and engagement contracting activities. For the most part, they are highly visible and immediately apparent to everyone (or at least someone) involved with the project. Typical examples include new technology, financial resource constraints, staff resource limitations, changes to business processes. Historically, mitigation strategies have often been put in place for these kinds of risks.

Unfortunately, mitigation strategies can introduce risks of their own. For example, if the project calls for the introduction of new technology, training could be included in the project plan as a risk mitigation strategy. However, while training is necessary to acquire new skills, it is usually not sufficient. Coaching, mentoring, or at least a readily available experienced practitioner is often required to ensure skill transfer and proficiency in a short period. Therefore, it would be advisable to include a contingency plan for an onsite expert or consultant, should the need arise.

Risk mitigation strategies and contingency plans cost time, money, and resources to develop and implement. Rare is the project where every risk manifests and every contingency plan is triggered. In addition, project sponsors often do not want to spend the time (or money) for detailed risk mitigation planning. Consequently, it may be more appropriate to set an overall risk mitigation budget as a percentage of the overall projected costs, rather than detail costing each identified risk's mitigation strategy and contingency plan. Industry experience suggests a 5% contingency budget for identifying and tracking risks.

Unmanaged assumptions

Unmanaged assumptions are risks that cannot be seen or are not apparent, therefore, they can pose significant danger to a project. As a new source of risk, assumptions should be managed similarly to risks. Assumptions should be documented and monitored so that a change in circumstances will not negate the assumption and transform them into risks. For every assumption we define and document, a metric can be defined to test its continued accuracy. By establishing measures and monitoring for our assumptions, contingency plans can be proactively developed.

Assessing risk

Brainstorming-based risk assessment. Facilitated brainstorming sessions with client stakeholders, project team members, and infrastructure support staff are the primary technique used to define risks and their mitigation strategies and contingency plans. The process defines risks in one column, mitigating strategy(s) in a second column, and potential contingency plans in a third column. Multiple mitigation strategies or contingency plans can be identified for risks. Using this technique, one can readily determine where the organization is exposed to an unmitigated risk. This form of facilitated session is also known as “force field analysis”[49].

Impact analysis

In broad terms, a risk impact analysis requires the project to be broken down into management tasks closely allied to the project's work breakdown structure.

[49] Royer, P. S. (2000). Risk management: the undiscovered dimension of project management. PM Network, 14(9), 31–39

During the analysis, especially on large projects, it is often necessary to develop a further breakdown in which each activity is numbered and documented for reference. As with the project work breakdown structure, this breakdown serves to focus discussion, to aid in identification of all risks, and to provide a basis for formalizing dependency links within the project. Using this breakdown, the risks within each activity are identified by mentally stepping through all aspects of the activity to produce a comprehensive list of uncertainties.

A significant time and resource commitment may be required for an in-depth impact analysis. Therefore, this analysis may only be appropriate at the level of detail where the stakes are high and where there is substantial uncertainty

Data applications

The actual database used to quantify the risk events and probabilities must be obtained from objective sources such as recorded experience on past projects. Data collected on the current project, as it proceeds, will be even more valuable for updating the assessment of overall project risk. All such data should be archived to form part of the post-project assessment and the organization's eventual historic data base.

However, for many risks, especially at the initial impact analysis stage, the data are necessarily subjective in nature and must be obtained through careful questioning of experts or persons with the relevant knowledge.

Response system

Risk response should be considered in terms of avoidance, reduction, transfer, or retention. Thus, in dealing with risk, it may be ignored (by default), recognized but no action taken (as a matter of policy), or reduced, transferred or shared (as part of response planning). These approaches may also be combined. The first step, then, is to set policies, procedures, goals and responsibilities for risk management for the project. This will set the scope and framework for the management function, whether it is simply a recognition of a task to be undertaken by the project manager, or the responsibility of a specialist or team under his direction.

The project risk may also change substantially as a result of changes in the scope of the project or changes in the method of working. Consequently, continuous review of the situation with appropriate adjustment of response planning is recommended[50].

Project management software

It is common to use both software and paper-based methods for PM.

Recently, special PM software for biotech labs was created: LabScrum is a process framework developed to manage work in academic scientific research. LabScrum uses a system of structured but flexible feedback loops to manage complex work and increase

- Productivity,
- Scientific rigor,
- Quality of training and quality of life for the teams.

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[50] Pym, D. V. (1987). Risk Management. PM Network, 1(3), 33–36

Topic 6. Teamwork and Brainstorming

<u>Learning Objectives</u>

At the end of the session the students will be able to:

1. Define critical principles of effective teamwork
2. Describe the main types of brainstorming and their differences
3. Describe principal methodologies for effective brainstorming
4. Effectively brainstorm ideas as a group

What is teamwork?

Teamwork is the joint endeavor of a group to achieve a common goal or complete a task in the best way possible. During brainstorming, individuals work together to produce the desired intellectual outcome. Teams must have sufficient size to have an efficient brainstorming session. The number of members is usually at least two or more but can sometimes be upwards of 100. The optimal team size depends on various factors that are assessed before the sessions in order to maximize productivity.

Teamwork is conducted anywhere where it is required for a group of people to work together to achieve a common objective. Various spheres of human activity can require cooperation, such as sports, education, industry, healthcare, etc. In any of the spheres where teamwork is needed, teamwork and independence can differ depending on how much collaboration, communication, and interaction are required between individuals[51].

Effective teamwork characteristics

There are definite interrelated aspects that teams should have to work together efficiently. Teams must have practical group coherence. Higher coherence ensures better team performance. Clear and consistent communication is another attribute of excellent teamwork. In order to avoid confusion, conflicts, and unnecessary difficulties, each team member should adequately communicate with each other, enhancing cohesion. The common goal is an important objective that

[51] E. Salas et al. On Teams, Teamwork, and Team Performance: Discoveries and Developments. The Journal of Human Factors and Ergonomics Society, 2008. DOI:10.1518/001872008X288457.

needs to be clearly defined by having effective communication. Concentration on the team's objectives is also required, along with accountability that provides all the milestones that have been achieved. If all team members are held accountable, the team commitment is secured[52].

Characteristics of effective teamwork

- Every team member is viewed as an independent individual with a unique experience and has distinct views, beliefs, and opinions contributing to the common goals.
- To appoint tasks, ensure accountability of team members, documentation of commitments and decisions, and evaluate progress, participative leadership is used during meetings.
- Innovation, cleverness, and broad imagination are expected and welcomed.
- There is a firm sense of affiliation to the team.
- The group is continually self-improving by doing an honest and unbiased examination of the practices, interactions, and processes.
- The intercommunication is appreciative, transparent, and fair.
- The difference in opinions is not discouraged.
- There is mutual respect and trust between team members.
- The procedures for proceeding with analysis, diagnosis, and troubleshooting are agreed upon beforehand[53].

[52] Benishek LE, Lazzara EH. Teams in a New Era: Some Considerations and Implications. Front Psychol. 2019;10:1006. Published 2019 May 9. doi:10.3389/fpsyg.2019.01006
[53] Ritter, S. M., & Mostert, N. M. (2018). "How to facilitate a brainstorming session: The effect of idea generation techniques and group brainstorm after individual brainstorm". Creative Industries Journal, 11(3), 263–277.

What is brainstorming?

Brainstorming is a technique conducted by a group of people whose efforts aim to find solutions to specific problems by collecting several ideas generated by the team members. Indeed, brainstorming sessions encourage people to neglect shyness and develop novel solutions and ideas about a definite topic of interest. This environment enables the participants to express their views and opinions more effectively and explore new concepts. The generated ideas are accepted without any criticism, and are assessed after the session [54].

Guidelines for brainstorming

- **Go for quantity -** This assumes that through the constant generation of numerous ideas, there is a greater chance of finding a solution. It augments the distinct creation of ideas.
- **Abstain from criticism -** During brainstorming sessions, criticism should be avoided. Participants should concentrate on enhancing ideas even if there is disagreement. Criticism is usually applied at the later stages when statements are evaluated. This approach helps to tackle timidity and allows innovative and unconventional ideas to be produced.
- **Amend and incorporate ideas -** This follows the concept that "1+1=3", which assumes that combining individual ideas stimulates the generation of even greater ones.

Brainstorming techniques

Nominal group technique

The coordinator asks all team members to write ideas separately and then collects all of them, and the group ranks the ideas according to the preliminary set rules. This stage is called distillation and can be as simple as voting with hands. After this, the favorite ideas can be sent back to the subgroups for the second stage of discussion and improvement. Each subset may be assigned to rate the views on a particular feature. After this process, previously low-ranked ideas can be re-evaluated and previous favorites can be substituted. The coordinator should be a well-trained professional who will manage and control the whole process. This

[54] Ibid

process may require a few practice sessions to handle profound ideas efficiently.

Group passing technique

In this case, groups are circular, and each member writes down one idea and transfers that idea to another who improves the vision. It continues until everyone has developed an original idea. Then, each group member would have the chance to elaborate and improve on all suggested ideas [55].

Team idea mapping method

This method incorporates the association method and can improve teamwork and partnership, enhance idea quantity, and facilitate participation by all team members. Every member brainstorms separately on a well-marked topic, and then all ideas are grouped, and a significant concept or idea map is created as a final product. Usually, participants discover ideas that were beyond their imagination. By associating diverse ideas during the merging process, novel ideas can be generated that will also be added to the map. After the map is finalized, the most important ideas are selected.

Directed brainstorming

Directed brainstorming is a type of electronic brainstorming that is performed either using computers or manually. It is used when the criteria for assessing the most viable ideas are known before brainstorming sessions. Those criteria are used to deliberately limit the ideation process. Each participant is assigned specific questions and asked to give a concrete answer. Then, those answers are swapped randomly to other participants who will be tasked to improve those ideas. The ideas are exchanged independently again randomly, and this routine can be repeated multiple times.

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[55] Glenn P., "Team Players and Team work: the new reality", San Francisco, CA, 2008: https://archive.org/details/teamplayersteamw00park_l/page/n25/mode/2up

Guided brainstorming

Guided brainstorming applies to time and subject and is conducted both independently and as a team. This type of brainstorming removes constraints and encourages critical thinking by providing a welcoming environment[56].

Group members are assigned to apply different methodologies in a fixed timed period as well as to contribute to the agreed-upon central mind map. Thanks to this multifaceted perspective approach, the collective effort vastly exceeds the individual one.

After guided brainstorming, team members will have an idea that will be used in the following brainstorming sessions. Next, research questions and tasks are distributed between participants to identify future goals and main focus areas.

Individual brainstorming

Individual brainstorming is applied in particular situations and encompasses mind map drawing, accessible speaking, word association, etc. This type of brainstorming can be advantageous during creative writing and, in some scenarios, can be more productive than traditional brainstorming.

Question brainstorming

This type of brainstorming focuses on relevant questions instead of short-term answers and prompt solutions. This approach should not limit participants and force them to contribute solutions. Well-thought out questions give ample opportunity to construct a framework where further action plans can be designed. Like other brainstorming types, priorities should be established, and questions identified. Sometimes this approach is called "Questorming"[57].

[56] Ritter, S. M., & Mostert, N. M. (2018). "How to facilitate a brainstorming session: The effect of idea generation techniques and group brainstorm after individual brainstorm". Creative Industries Journal, 11(3), 263–277.
[57] Ibid

Methods to improving brainstorming sessions

- Avoid face-to-face groups
- Follow the rules
- Respect everyone's ideas
- Incorporate both singular and team approaches
- Take breaks if necessary
- Do not hurry
- Keep resolute attitude
- Assist the progress of the session

Alternatives to brainstorming

Buzzgroups

When a bigger group's ideation process stagnates, it can be divided into smaller subgroups that will create ideas separately. After that, the subgroups will merge back together and review each other's ideas.

Bug list

Each member of the group writes down their problems (called "bugs") then everyone else helps them to find solutions to these "bugs."

Stepladder technique

Here every team member expresses their own opinion without knowing the group's position as a whole.

Synectics

A leader navigates the team and discusses their goals, ambitions, and difficulties using analogies, comparisons, and metaphors[58].

Potential challenges to efficient brainstorming

- Social Matching
- Collaborative fixation
- Blocking
- Free-writing
- Evaluation apprehension
- Personality Characteristics.

[58] M. R. Shirey. "Brainstorming for breakthrough thinking". J Nurs Adm 2011 Dec;41(12):497-500. DOI: 10.1097/NNA.0b013e3182378a53.

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51. Simple Collaborative Mind Maps & Flow Charts - Coggle

Instructor Manual

Topic 1. What is Science/Research?

Main Learning Outcomes	• Define science. • Define basic science/research. Give examples of basic research. • Define applied science/research. Give examples of applied research. • Describe the relationship between basic research and applied research.
Activities	Students will be discussing and filling out a worksheet on scientific statements. Students will do two activities on types of research.
Outcomes Assessment Samples	"Assessment Worksheet" (Appendix I) for comprehension of material where students will apply concepts of types of research and data.

Discussion Topics	Key Learning Objectives	Activities (Appendix I)
What is science?		
Emphasis on what science is.	Students should be able to understand the definition of science and what makes a scientific statement.	"How Scientific Is It?"

Discussion Topics	Key Learning Objectives	Activities (Appendix I)
Types of research		
Emphasis on the differences between qualitative vs quantitative research and basic vs applied research	Students should be able to determine what types of data are considered qualitative and quantitative. Students should also understand the fundamental differences between basic and applied research.	"Applied or Basic Research?" "Qualitative vs Quantitative Data"

What is science?

Emphasize that science is the pursuit and application of knowledge of the natural and social world through a systematic method based on observation, experimentation, and evidence.

Characteristics of science

- **Innovative:** Emphasize that scientific discoveries do not need to be changing the paradigms of science to be important. For example, innovation might be changing the way a bridge-building material is made making it more environmentally friendly, economical, and/or durable.
- **Essential:** Emphasize that everything we use in day-to-day life was developed by scientists and engineers from the cell phone to aspirin to the airplane. Science is not just the understanding and observation of natural phenomena but the application and integration of this knowledge in our everyday lives.
- **Continuous systematic exploration:** Emphasize that scientific knowledge is always growing and evolving. There are areas of science that are still unknown.

- **A global human effort:** Emphasize that global efforts contribute to the scientific body of knowledge, improving technologies and the world around us.

Key scientific concepts

Emphasize that science aims to systematically explain the natural world. This is done through testable and measurable ideas that are evidence based. The scientific community is continuously evolving and experimental results testing initial ideas can lead to ongoing research, exploring new avenues that may benefit society. However failed experiments and hypotheses that lead to a dead end are also valuable in the pursuit of scientific knowledge and understanding.

In-Class Activity

Hand out the worksheet called "How scientific is it?" (Appendix I).
Have students get into pairs to fill out the worksheet and discuss (10-15 minutes).
Then, as a class, have the students discuss why they thought certain statements were more or less scientific and what order each group ranked them.

Types of research

Basic (fundamental) research

Emphasize that basic research usually does not have immediate commercial objectives, may not result in an invention, or solve a practical problem (not always). Basic research is knowledge driven, increases the understanding of fundamental problems and answers the questions of why, what, and how. The understanding of how things work may then lead to new products, technologies, and processes.

Applied research

Emphasize that applied research aims at answering specific questions and solving problems with practical solutions, generally with a commercial objective. Applied research creates new products, technologies and processes that can lead to new fundamental questions.

These two types of research are interconnected and rely upon each other, leading to a cycle of advancement.

Examples of basic research

Asking:

1. How did the universe begin?
2. What is the composition of a neutron?
3. What is the genetic code of a seahorse?
4. How do certain bacteria withstand the high heat of a thermal vent?
5. How to determine if someone is bored using their EEG signal?

Examples of applied research include

Investigation of ways to:

1. Improve agricultural crop production in a dry environment.
2. Treat or cure a specific disease.
3. Improve energy efficiency of electric cars.
4. Improve the strength and longevity of building materials.
5. What is the impact of pandemics on consumer retail behavior?

In-Class Activity

Hand out "Applied or Basic Research?" (Appendix I) and ask students to choose which studies are basic or applied research (15 minutes). Once completed, go through the statements with the students to explore their reasoning.

Quantitative research

Emphasize that quantitative research data is based on numbers (counts, measurements) where simple or advanced mathematics and statistics are applied to find commonalities, relationships, differences, and patterns in data. Analysis of this type of data tends to be more structured and objective. Data output is typically in a graph or table format.

Qualitative research

Emphasize that qualitative research is generally applied when trying to understand concepts, thoughts, or experiences. Data is typically represented by text, images, audio and video recordings, or transcript conversations instead of numbers. Analysis of this type of data can be more difficult and subjective. Data output can be presented in a variety of formats.

Research can also take a mixed methods approach using both qualitative and quantitative data. It does not need to be strictly one or the other, as both types of data complement each other. Typically, experimental results are represented by showing examples of captured images (qualitative data) followed by the quantification of the total measurements (quantitative data).

In-Class Activity

Hand out "Qualitative vs Quantitative Data" worksheet (Appendix I). Have students organize the types of data into the categories of qualitative and quantitative (5-10 minutes). The filled-out table is below. Then, as a class, organize the types of data together. Ask if any of them were difficult to categorize.

Qualitative Data (Categorical)	Quantitative Data (Numerical)
Gender	Age
Religion	Height
Marital Status	Weight
Native Language	Income
Social Class	University size
Qualifications	Group size
Type of instruction	Self-efficacy score
Method of treatment	Percent of lecture attended
Type of teaching approach	Number of clinical skills performed
Problem-solving strategy used	Number of errors

In-Class Activity

Hand out Assessment Worksheet (Appendix I) and ask students to fill it out and hand it back when completed. (20 minutes)

Additional Resources

1. Curiosity Creates Cures: The Value and Impact of Basic Research. https://www.nigms.nih.gov/education/fact-sheets/Pages/curiosity-creates-cures.aspx
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Appendix I

I.I How Scientific Is It?[59]

After reading the knowledge claim statements below, rate each statement from 1-10 with 1 being least scientific and 10 being most scientific. Be prepared to justify your decision.

Knowledge claim statements

A. All living things are composed of one or more cells. We know this because every living thing examined to date has been found to be composed of one or more cells.
B. If you break a mirror, you will have seven years of bad luck.
C. The Earth is flat. Anybody can see that!
D. Taking Vitamin C prevents the common cold. Linus Pauling, the Nobel laureate who discovered the structure of Vitamin C, says it does.
E. Humans have a soul. I believe this because it says so in the Bible. The soul is what separates us from animals.
F. The rate of acceleration of all falling objects on Earth is constant. Two spheres of identical diameter and volume are dropped from the top of a building; one is made of steel, the other made of a plastic polymer. They both will accelerate at the same rate (32 ft/s^2) and hit the ground at the same time.

[59] Adapted from Scharrman et al. 2005. Explicit reflective nature of science instruction: Evolution, Intelligent Design, and umbrellaology. Journal of Science Teacher Education 16:27–41.

1.2 Applied or Basic Research?

Label each of the statements below as applied or basic research.

A study on how to improve illiteracy in teenagers
A study looking for ways to market products for millennials
A study trying to decrease fraud on social media platforms
A study searching for ways to encourage high school graduates to attend college
A study looking at how alcohol consumption impacts the brain
A study to discover the components making up human DNA
A study to find ways to make car tires last longer
A study assessing whether stress levels make people more aggressive
A study exploring ways to cook gluten-free meals with a limited budget
A study looking to see if gender stereotypes lead to depression
A study searching for the causative factors of cancer
A study on the growth process of oak trees
A study trying to find out what makes up a proton
A study on how to treat patients with insomnia
A study looking for ways to improve patient retention at a dentist's office
A study seeing what areas of the United States have the most rain
A study on methods for diagnosing patients with schizophrenia
A study examining whether a vegetarian diet is healthier than one with meat
A study providing solutions for how to train dogs to stay in their yard
A study on how to prevent mosquito bites from itching
A study on the origin of cryptocurrency
A study on the various types of kiwis grown in Chile
A study to find what marketing strategies to use on college campuses

Answer Sheet: Applied or Basic Research?

Applied Research: the statements below are finding practical solutions to existing problems

A study on how to improve illiteracy in teenagers
A study looking for ways to market products for millennials
A study trying to decrease fraud on social media platforms
A study searching for ways to encourage high school graduates to attend college
A study to find ways to make car tires last longer
A study exploring ways to cook gluten-free meals with a limited budget
A study on how to treat patients with insomnia
A study looking for ways to improve patient retention at a dentist's office
A study on methods for diagnosing patients with schizophrenia
A study providing solutions for how to train dogs to stay in their yard
A study on how to prevent mosquito bites from itching
A study to find what marketing strategies to use on college campuses

Basic Research: the statements below focused on improving the understanding of a particular phenomenon, study or law of nature.

A study looking at how alcohol consumption impacts the brain
A study to discover the components making up human DNA
A study assessing whether stress levels make people more aggressive
A study looking to see if gender stereotypes lead to depression
A study searching for the causative factors of cancer
A study on the growth process of oak trees
A study trying to find out what makes up a proton
A study seeing what areas of the United States have the most rain
A study examining whether a vegetarian diet is healthier than one with meat
A study on the origination of cryptocurrency
A study on the various types of kiwis grown in Chile

1.3 Qualitative vs Quantitative Data

Qualitative Data (Categorical)	Quantitative Data (Numerical)

Age
Gender
Group size
Height
Income
Marital Status
Method of treatment
Native Language
Number of clinical skills performed
Number of errors
Percent of lecture attended
Problem-solving strategy used
Qualifications
Religion
Self-efficacy score
Social Class
Type of instruction
Type of teaching approach
University size
Weight

1.4 Assessment Worksheet

1. Topic of Study:

2. Is it Basic or Applied Research? Why?

3. Data Needed:

4. Divide data into qualitative and quantitative.

Topic 2. Scientific Method

Main Learning Objectives	• Define the stages of the Scientific Method. • Define the key components of each stage of the Scientific Method. • Explain the relationship between the stages of Scientific Method. • Understand how to conduct a research study by following relevant stages of the Scientific Method.
Activities	Students will be doing activities to prepare themselves to execute a proper scientific study by applying the key components of the Scientific Method. The activities include: 1. Complete the Scientific Method Worksheet to practice applying each step relative to one another. 2. Complete Qualitative vs Quantitative Observations Worksheet to practice making qualitative and quantitative observations. 3. Sorting experimental, comparative and descriptive research questions to help clarify the different type of scientific investigations. 4. Complete the Searching PubMed using Keywords Activity to help familiarize students with this important database of peer reviewed scientific literature. 5. Complete Formulating a Hypothesis Worksheet where students will practice formulating a hypothesis. 6. Experimental Design Worksheet will have students create a hypothesis and

	identify experimental variables. 7. Complete the Scientific Poster Worksheet to help students practice compiling a scientific presentation.
Outcomes Assessment Samples	Students will find a manuscript in PubMed on a topic of their choice. Applying the concepts discussed in class, the students will complete a Scientific Poster Worksheet including key information to present on a scientific poster.

Discussion Topics	Key Learning Objectives	Activities (Appendix 9)
Introduction to the scientific method		
Emphasize to students that this is a logical organization of steps that scientists employ to find answers to help us interpret the world around us. More specifically, it relies on critical thinking skills to develop a question that needs answering and plan an experimental process that will answer that question definitively.	• Define what the Scientific method is and be able to name the 6-key stages. • Explain the relationship between the stages.	"The Logic of Science and the Scientific Method"

Discussion Topics	Key Learning Objectives	Activities (Appendix 9)
Make an observation and ask a question		
Emphasis on the importance of understanding the difference between qualitative and quantitative observations. How observations lead to certain types of investigative scientific questions.	• Understand the process of making observations. • Distinguish between three types of investigative questions. • Create detailed observations of the natural environment.	"Qualitative vs Quantitative Observations Worksheet" "Name that Investigative Question Worksheet"
Background research		
Emphasis on the importance of reliable/validated scientific sources. This is the foundation of scientific research.	• Importance of conducting background research. • Describe key components of conducting quality background research. • Define criteria for assessing scientific publications. • Effectively read and analyze scientific literature.	"Searching PubMed using Keywords Worksheet"

Discussion Topics	Key Learning Objectives	Activities (Appendix 9)
Formulate a hypothesis		
Emphasis the primary components of a hypothesis being testable.	• Define what is a scientific hypothesis. • Understand how a hypothesis is used in the scientific method. • Differentiate between hypothesis and theory. • Describe the main types of scientific hypotheses. • Formulate good scientific hypotheses.	"Formulating a Hypothesis Worksheet"
Experimental design		
Emphasis that experimental design means creating a set of procedures to test a hypothesis.	• Define what is an experiment. • Describe what are experimental controls. • State the relationship between experiment and hypothesis. • Define the types of experiments. • Conduct high quality experiments.	"Experimental Design Worksheet"

Discussion Topics	Key Learning Objectives	Activities (Appendix 9)
Data collection and analysis		
Emphasis on the strength of a scientific research study depends on the ability to gather and analyze empirical data in an unbiased and controlled manner.	• Understand the difference between qualitative and quantitative research. • Make simple data tables. • Present data using graphs and tables. • Write a conclusion statement.	
Communicate the results		
Emphasis on the importance of communicating your data with clarity and accuracy.	• Understand the purpose of scientific conferences. • How to prepare for conferences. • Prepare a good poster and deliver a good speech during oral presentations. • Learn to deliver a good speech during oral presentations.	"Scientific Poster Worksheet"

What is scientific method?

Scientific method is a logical organization of steps that scientists employ to find answers to help us interpret the world around us. More specifically, it relies on critical thinking skills to develop a question that needs answering and plan an experimental process that will answer that question definitively.

The scientific method was first outlined by Sir Francis Bacon (1561–1626) and allows for logical, rational problem solving across many scientific fields. Across all scientific disciplines, the major precepts of the scientific method are verifiability, predictability, falsifiability, and fairness. Thus, science is not linear but rather it is cyclical and ever changing. Looking at science as a fluid model, you can find many entry points into the process. Within the scientific process, there is a continuous exploration and discovery phase. A scientist finds out what other scientists have learned by exploring previous research, sharing data and ideas with other researchers, asking questions, making more observations, and refining or expanding the scope of what is investigated based on what is learned. Researchers often revisit phases during a study, as there are many routes through the scientific process.

The scientific method consists of the following steps:

1. Make an observation and ask a question
2. Background research
3. Formulate a hypothesis
4. Experimental design
5. Data collection and analysis
6. Communicate the results

As you cover the content in the curriculum, emphasize that this method is a way of thinking and will take time and practice to cultivate.

2a. Introduction to the scientific method

Go over the points in the curriculum in stage 2a. Emphasize that having a scientific area of interest is not enough, students must have sufficient scientific evidence to initiate the project, a clear understanding of how it will be executed the and what outcomes they expect.

In-Class Activity

Have students complete the worksheet titled "The Logic of Science and the Scientific Method" in class and then go over the answers in class. (Appendix 2)
This exercise will help students start thinking about the logical order of the steps and how they are related/build on top of one another.

2b. Make an observation and ask a question

Go over the points in the curriculum in stage 2b. Emphasize the definition of an observation vs an inference. Emphasize the difference in a qualitative observation vs a quantitative observation. Remember, a qualitative observation is a subjective description; that is, you observed a quality about an object (it smelled good, it was green, etc.). A quantitative observation is one that can be described/measured in concreted numerical terms.

In-Class Activity

- Hand out the Qualitative vs. Quantitative Worksheet (Appendix 2)
    - The concept of this worksheet is for students learn to distinguish between qualitative and quantitative observations. Thus, begin to discern between measurable data and subjective data. Go over the answers in class and discuss any confusion.
    - Then have them break into pairs and have them come up with 2 qualitative observations and 2 quantitative observations about an object in the room.
- Hand out the Name that Investigative Question Worksheet (Appendix 2)
  The concept of this worksheet is for students to begin to recognize the difference in the types of investigative research questions. After completing the worksheet they will be prompted to apply this knowledge by providing 2 examples of each type of investigative question in their subject of interest.

2c. Background research

Go over the curriculum. Emphasize the importance of identifying a well-designed study when conducting a thorough background search on your topic of interest. Application of the Scientific Method ensures well-controlled experimental design for the unbiased collection and interpretation of results. Define the criteria for assessing scientific publications (journal impact factor, experimental design, accurate interpretation of results) and the role of peer-review as a way to hold ourselves accountable to provide the most accurate interpretation of data.

In-Class Activity

Watch this video in class
https://www.youtube.com/watch?v=eEYlr_GDzcg
After watching this video guide the students through the same type of keyword search in PubMed using a topic of their choice. Hand out the Searching PubMed using Keywords Worksheet (Appendix 9) as a guide for them to find an article they are interested in. They will use this article again for an activity in Stage 2g so have them pick a topic that is of interest to them.

2d. Formulate a hypothesis

Follow curriculum. Emphasize the need to have a testable hypothesis.

In-Class Activity

Hand out Formulating a Hypothesis Worksheet (Appendix 9).
This worksheet provides the students an opportunity to practice generating a hypothesis. Give them time to do this independently and then go over it together as a class. Have the students build the hypothesis together as a class based on what they did independently. Write out the hypothesis on the board so all students are involved and can see how a hypothesis is constructed.

2e. Experimental design

Follow the curriculum. Emphasize the need to have your experimental design that will enable your hypothesis to be unbiasedly tested. Highlight the difference between the types of variables and the importance in experimental design.

Home Assignment

Hand out Experimental Design Worksheet (Appendix 2).

- Students will apply concepts of experimental design discussed in the class to three different experimental scenarios by answering the same first two questions for each example and then complete the remaining two questions that is asked of them.
- Instructor should either go over in class next period or correct the worksheet and hand back with feedback.

2f. Data collection and analysis

Follow the curriculum. Emphasis on the strength of a scientific research study depends on the ability to gather and analyze empirical data in an unbiased and controlled manner

2g. Communicate results

Emphasize the importance of communicating your data clearly, concisely, and accurately. Discuss the different ways to present and continue to communicate to the students how long it will take them to prepare for their presentation of data, whether it will be for a poster or an oral presentation. They must practice, practice, and practice some more!

Home Assignment

Using the concepts presented in this module, have the students pick a scientific manuscript they find in PubMed and fill in the Scientific Poster Worksheet (Appendix 2) as if they were going to create their own electronic poster. The instructor should approve the paper of choice and help the student find a replacement if the paper is not appropriate for this activity.

Additional Resources

For The Scientific Method

1. Project Guide for Steps of the Scientific Method: Science Buddies https://www.sciencebuddies.org/science-fair-projects/science-fair/steps-of-the-scientific-method
2. The Scientific Method: How Scientific Method is used to test a Hypothesis – Kahn Academy https://www.khanacademy.org/science/biology/intro-to-biology/science-of-biology/a/the-science-of-biology
3. PubMed User Guide: How do I Search PubMed. NCBI https://pubmed.ncbi.nlm.nih.gov/help/#how-do-i-search-pubmed
4. The Scientific Method/Analytic Method. Encyclopedia Britannica https://www.britannica.com/science/scientific-method
5. Expert Searching: PubMed. Welch Library at John Hopkins University and Medicine. https://browse.welch.jhmi.edu/searching/pubmed-search-tips
6. The Scientific Process. American Museum of Natural History (New York, NY) https://www.amnh.org/explore/videos/the-scientific-process
7. Video: Conducting a literature search using PubMed. The Medical College of Wisconsin Libraries https://www.youtube.com/watch?v=OIill6yUmk8
8. Video: The Scientific Method: Steps, Examples, Tips, and Exercise. Sprouts https://www.youtube.com/watch?v=yiOhwFDQTSQ&list=RDLVUdQreBq6MOY&index=3
9. Video: The Scientific Method: Steps and Examples. Science Buddies. https://www.youtube.com/watch?v=Xxm_beTs9LU

For Presentation of Data

10. How to give a dynamic scientific presentation. By Maryilynn Larkin at Elsevier Connect. https://www.elsevier.com/connect/how-to-give-a-dynamic-scientific-presentation
11. Creating a 10-15 minute scientific presentation. Collaborative Learning and Integrated Mentoring in the Biosciences (CLIMB) at Northwestern. https://www.northwestern.edu/climb/resources/oral-communication-skills/creating-a-presentation.html
12. Presenting in the Sciences: A Guide. Tulane University Libraries. https://libguides.tulane.edu/presentingscience

13. Communicate: Science Communication Through Scientific Posters and Blog Posts. Long-term Monitoring Program and Experimental Training for Students (LiMPETS) Rocky Intertidal Monitoring Program Curriculum Guide. https://limpets.org/wp-content/uploads/2015/01/RIM-Unit-5_Jan4.pdf
14. How to Create a Research Poster. Brock University. https://researchguides.library.brocku.ca/poster
15. Quick Guide to Science Communication. Brown University Science Center. https://www.brown.edu/academics/science-center/sites/brown.edu.academics.science-center/files/uploads/Quick_Guide_to_Science_Communication_0.pdf
16. Communicating in Scientific Ways. OpenSciEd. https://www.openscied.org/wp-content/uploads/2019/08/OpenSciEd-Communicating-in-Scientific-Ways-Poster.pdf

Appendix 2

2.1 Logic of Science and the Scientific Method

Part 1: Using the numbers 1 – 6, indicate the order of events in using the scientific method.

_______ Test the hypothesis by performing an experiment.
_______ Make observations and record data.
_______ Make a hypothesis and an experimental prediction.
_______ Identify the problem to be studied.
_______ Use data and results to support a conclusion.
_______ Perform background research on the problem.

Part 2: Provide the letter of the definition that matches the scientific terms below.

____ 1. Control	a) Using a set of observations to test a hypothesis
____ 2. Conclusion	b) An idea about the system being examined.
____ 3. Hypothesis	c) The numerical values recorded during an experiment/observation
____ 4. Experiment	d) A decision based on the data from an experiment.
____ 5. Variable	e) A well-supported set of observations/explanations for natural events.
____ 6. Data	f) Name the type of value measured that may vary in an experiment.
____ 7. Theory	g) Set of observations used as a reference and compared to experimental observations in order to show that the result is due to the experimental treatment.

Answer Key: Logic of Science and the Scientific Method

Part 1: Using the numbers 1 – 6, indicate the order of events in using the scientific method.

___4___ Test the hypothesis by performing an experiment.
___5___ Make observations and record data.
___3___ Make a hypothesis and an experimental prediction.
___1___ Identify the problem to be studied.
___6___ Use data and results to support a conclusion.
___2___ Perform background research on the problem.

Part 2: Provide the letter of the definition that matches the scientific terms below.

_g_ 1. Control	a) Using a set of observations to test a hypothesis
_b_ 2. Conclusion	b) An idea about the system being examined.
_e_ 3. Hypothesis	c) The numerical values recorded during an experiment/observation
_a_ 4. Experiment	d) A decision based on the data from an experiment.
_f_ 5. Variable	e) A well-supported set of observations/explanations for natural events.
_c_ 6. Data	f) Name the type of value measured that may vary in an experiment.
_e_ 7. Theory	g) Set of observations used as a reference and compared to experimental observations in order to show that the result is due to the experimental treatment.

2.2 Qualitative vs. Quantitative Observations

Time: 5 - 10 Minutes
Determine which of the following statements are qualitative or quantitative.

1. ____________ The cup had a mass of 454 grams.
2. ____________ The ScrubDaddy is the best kitchen scrub ever.
3. ____________ It is warm outside.
4. ____________ The tree is 30 feet tall.
5. ____________ The building has 25 stories.
6. ____________ The building is taller than the tree.
7. ____________ The sidewalk is long.
8. ____________ The sidewalk is 100 meters long.
9. ____________ The race was over quickly.
10. ____________ The race was over in 10 minutes.
11. ____________ The people are friends.
12. ____________ The basketball player scored 20 points.
13. ____________ She is a good gymnast.
14. ____________ The food is good here.
15. ____________ The temperature outside is 25° C.

Answer Key: Qualitative vs. Quantitative Observations

Time: 5 - 10 Minutes
Determine which of the following statements are qualitative or quantitative.

1.	Quantitative	The cup had a mass of 454 grams.
2.	Qualitative	The ScrubDaddy is the best kitchen scrub ever.
3.	Qualitative	It is warm outside.
4.	Quantitative	The tree is 30 feet tall.
5.	Quantitative	The building has 25 stories.
6.	Qualitative	The building is taller than the tree.
7.	Qualitative	The sidewalk is long.
8.	Quantitative	The sidewalk is 100 meters long.
9.	Qualitative	The race was over quickly.
10.	Quantitative	The race was over in 10 minutes.
11.	Qualitative	The people are friends.
12.	Quantitative	The basketball player scored 20 points.
13.	Qualitative	She is a good gymnast.
14.	Qualitative	The food is good here.
15.	Quantitative	The temperature outside is 25° C.

2.3 Name That Investigative Question

Read each question and decide what type of investigation would best to conduct to answer this question.

- What is the difference in temperatures at location A and B at 12:00 pm?
- What is the difference in pH of the water in a clean aquarium vs dirty aquarium?
- How many insects are there in a given area?
- How does running affect heart rate?
- What are the similarities and differences among prokaryotes and eukaryotes?
- A student used a microscope to observe an amoeba's movement?
- How frequently does it rain in the month August?
- How does temperature affect the growth of mold?
- What is the effect of sugar on yearst?

Comparative	Descriptive	Experimental

After completing the above exercise, provide 2 examples of a Descriptive Question, Comparative Question, and Experimental Question in your topic of interest.

Answer Key: Name that Investigative Question

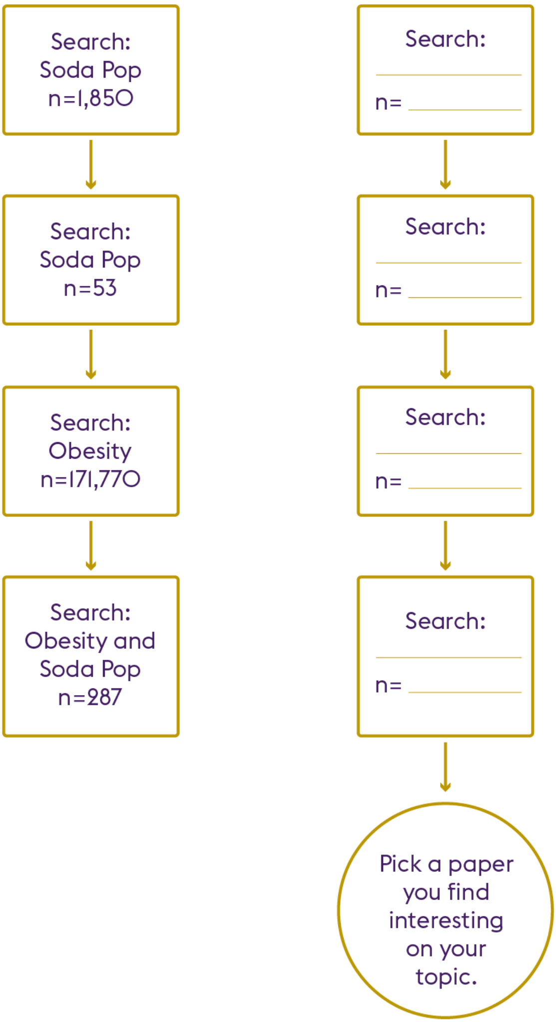
Read each question and decide what type of investigation would best to conduct to answer this question.

- What is the difference in temperatures at location A and B at 12:00 pm?
- What is the difference in pH of the water in a clean aquarium vs dirty aquarium?
- How many insects are there in a given area?
- How does running affect heart rate?
- What are the similarities and differences among prokaryotes and eukaryotes?
- A student used a microscope to observe an amoeba's movement?
- How frequently does it rain in the month August?
- How does temperature affect the growth of mold?
- What is the effect of sugar on yearst?

Comparative	Descriptive	Experimental
What are the similarities and differences among prokaryotes and eukaryotes?	How many insects are there in a given area?	How does running affect heart rate?
What is the difference in temperatures at location A and B at 12:00 pm?	A student used a microscope to observe an amoeba's movement?	What is the effect of sugar on yearst?
What is the difference in pH of the water in a clean aquarium vs dirty aquarium?	How frequently does it rain in the month August?	How does temperature affect the growth of mold?

After completing the above exercise, provide 2 examples of a Descriptive Question, Comparative Question, and Experimental Question in your topic of interest.

2.4 Searching PubMed



Download the paper of your choice and set aside. You will need this for an activity in Stage 2g.

2.5 Practice Formulating a Hypothesis

Name: ______________________________

Date: ____________________

Hypothesis practice: Write a testable hypothesis for these situations.

1. The Safety Officer at a large corporation is concerned that there might be an accident either in the parking lot or on the road just outside the plant. It seems that employees are speeding out of the parking lot when their shift is over. The Safety Officer wonders if the company should ask the police to station a patrol car near the exit at shift change.

2. Your class is in charge of filling the bird feeders at the Nature Center at your school. You notice that the nuthatches seem to prefer to eat at the sunflower seed feeder more than they stop at the mixed seed feeder.

3. Your cat just had six kittens. There is a new kitten chow on the market that claims to be healthier for young kittens. Your family has raised kittens before and fed them a different brand of food. You would like to find out for yourself if the brand is better.

Answer Key: Practice Formulating a Hypothesis

Hypothesis practice: Write a testable hypothesis for these situations.

1. The Safety Officer at a large corporation is concerned that there might be an accident either in the parking lot or on the road just outside the plant. It seems that employees are speeding out of the parking lot when their shift is over. The Safety Officer wonders if the company should ask the police to station a patrol car near the exit at shift change.

   If there is a police officer stationed at the gate at shift change, employees will not speed when leaving the parking lot.

2. Your class is in charge of filling the bird feeders at the Nature Center at your school. You notice that the nuthatches seem to prefer to eat at the sunflower seed feeder more than they stop at the mixed seed feeder.

   If nuthatches have a choice between mixed seed or sunflower seeds, they prefer to eat sunflower seeds

3. Your cat just had six kittens. There is a new kitten chow on the market that claims to be healthier for young kittens. Your family has raised kittens before and fed them a different brand of food. You would like to find out for yourself if the brand is better.

   If kittens are fed the new brand instead of the old brand, the kittens on new brand will___ (grow taller, have higher acuity, gain more weight, etc.). Need a characteristic to measure for "healthier".

2.6 Experimental Design

Name: ______________________________

Date: __________________

1. In a taste test consumers preferred Healthy Meal brand frozen enchilada dinner over the other best-selling brand.
   a. Title of the experiment:
   b. Hypothesis:
   c. Independent variable:
   d. Dependent variable:
   e. Control variable:

2. Walking on treadmill three times a week helps to lower blood pressure.
   a. Title of the experiment:
   b. Hypothesis:
   c. Independent variable:
   d. Dependent variable:
   e. Control variable:

3. A tooth paste company wants to show a reduction in gum disease with their new formula of toothpaste.
   a. Title of the experiment:
   b. Hypothesis:
   c. Independent variable:
   d. Dependent variable:
   e. Control variable:

4. Cars get less gas mileage if the tire pressure is lower than the amount recommended by the manufacturer.
   a. Title of the experiment:
   b. Hypothesis:
   c. Independent variable:
   d. Dependent variable:
   e. Control variable:

Answer Key: Experimental Design

Name: ___________________________

Date: _________________

1. In a taste test consumers preferred Healthy Meal brand frozen enchilada dinner over the other best-selling brand.
    a. **Title of the experiment:** Determining Preference in Frozen Enchilada Dinners.
    b. **Hypothesis:** In a taste test consumers will prefer Healthy Meal brand frozen enchilada diner over the other best-selling brand.
    c. **Independent variable:** Brand of frozen enchilada dinner.
    d. **Dependent variable:** Consumer rating of taste.
    e. **Control variable:** The other best-selling brand.

2. Walking on treadmill three times a week helps to lower blood pressure.
    a. **Title of the experiment:** Determining the Effect of Walking on a Treadmill on High Blood Pressure.
    b. **Hypothesis:** Walking on a treadmill three times a week will lower blood pressure.
    c. **Independent variable:** Walking on a treadmill.
    d. **Dependent variable:** Blood pressure measurement.
    e. **Control variable:** People with high blood pressure who do not walk on a treadmill.

3. A tooth paste company wants to show a reduction in gum disease with their new formula of toothpaste.
    a. **Title of the experiment:** Reduction in Gum Disease using the New Toothpaste.
    b. **Hypothesis:** People who use the new toothpaste will experience less gum disease.
    c. **Independent variable:** The brand of toothpaste used.
    d. **Dependent variable:** The amount of gum disease.
    e. **Control variable:** People who do not use the new toothpaste.
4. Cars get less gas mileage if the tire pressure is lower than the amount recommended by the manufacturer.

a. Title of the experiment: Testing the influence of Tire Pressure on Gas Mileage
b. Hypothesis: Cars get less gas mileage if the tire pressure is lower than the amount recommended by the manufacturer.
c. Independent variable: Tire pressure.
d. Dependent variable: Gas Mileage.
e. Control variable: Cars with correct tire pressure.

2.7 Scientific Poster

What is a Scientific Poster? Posters are common way for scientists to communicate their research at conferences, meetings and lectures. A scientific poster is focused on the research question and has a similar outline to research papers (see below). In this instance, text should be concise (bullet points are often used here) and kept at a minimum so a person can read your poster in under 5 minutes. Listed below are the common components of a poster. Using the paper you chose from Stage 2c fill in each heading as if you were going to create your own scientific poster based on this paper.

Title: Indicates what the paper is about and list of authors.

Title List of Authors

Introduction: Provides the background information for the study. Briefly describe relevant history of the topic.

Relevant Background information Usually 3 to 4 points

Purpose: State your study objective/purpose.

Study objective

Methods: Describe how the study was conducted.

Study type, location, etc. Chemical inventory (if applicable) and technical methodology

Results: Presentation of data.

Data: graphs, charts, or pictures with short text explanations

Discussion: Explain what the results mean.

Usually 3 to 4 take home/conclusive points of what your results mean

References/Acknowledgements:

List all references cited in the poster Funding sources and those that assisted with poster preparation

Topic 3. Writing: Manuscript/Thesis

Main Learning Outcomes	1. Arrange data from project into required structure for a manuscript/thesis submission 2. Plan and write a manuscript/thesis using appropriate language 3. Follow appropriate steps in effective manuscript/thesis writing and submission
Activities	Students will construct a short introduction on a topic and review a scientific paragraph for writing improvements.
Outcomes Assessment Samples	Students will write an outline for a research paper on their topic of choice following the IMRaD format (take home assignment).

Discussion Topics	**Key Learning Objectives**	**Activities (Appendix 3)**
Drafting the structure of your thesis/paper		
Emphasis on the differences between papers and thesis	Understand writing style requirements between papers and thesis	
Title		
How to develop a good title	Describe project succinctly and accurately	Title Exercise

Discussion Topics	Key Learning Objectives	Activities (Appendix 3)
Introduction		
Emphasis on establishing context and background for the paper/thesis	Understand the information to include in an introduction	Introduction Exercise
Methods		
Emphasize that methods need to be in enough detail to be reproduced	Understand what to include in methods and the level of detail needed in a paper versus a thesis	
Results		
Emphasize that results are objectively reported without further discussion	Know what is included in the results	
Discussion		
Emphasize that the discussion is where the results are interpreted	Know how to structure a discussion and what information needs to be included	
References		
Formatting is dependent on the journal or institution of submission	Know how to look up reference formatting guidelines	Writing Exercise

Discussion Topics	Key Learning Objectives	Activities (Appendix 3)
Publication Process		
Explain the sequence of activities in a typical publication process	Students should understand the basic process of submitting a publication through to its evaluation	

Drafting the structure of your thesis/paper

Publishing a paper or a thesis are critical for communicating information with the world and moving technology and knowledge forward. Therefore, it is important for students to be able to take their research projects and break them down into salient points of discussion and exchange of information.

What is a paper?

Academic papers share information on original scientific research. When beginning to write a paper, it is helpful to write out the key message of the paper since this will be the central theme of the paper. The message should ideally be 1-2 sentences long and not complicated. Knowing the target journal will help direct and structure the paper. Different journals have different requirements and occasionally have different sections that need to be added. Other considerations are that different journals have different target audiences which can change the information presented in the introduction. Choosing what type of article to write is also important since each will have different requirements on length, types of data included, etc. For example, a review article is not original research but an overview of the current scientific landscape in a specific field. Once these things are taken into consideration an outline can be created.

Journal impact factor is important and will be dependent on the research that is being published. Typically, more prestigious journals will have higher impact factors. However, submitting to a high impact journal may not always be the best choice if the results do not significantly impact the field on a higher level or if the project was smaller in scope. A good way to get familiar with the journal of interest is to read its aims and scope and some of its recent published articles. Another way to select a target journal is to consider journals which feature prominently in your reference list.
Developing a title can be a good way to keep the focus of your paper.

In-Class Activity

- Hand out Title Exercise and ask students to write relevant words and phrases related to a topic that express the most important information about the project (5 min)
- Arrange the words into combinations relevant to the project (15-20 min)
- Narrow down your Top 10
    - Have students pair up and review each other's title options to determine and critique clarity (10 min)
- Cull the list to the top 3 and discuss as a class (20 min)

What is a thesis?

Emphasize that a thesis is a much longer publication, more in depth and typically only written as part of a Master's or PhD program.

Writing style requirements

Emphasize that use of poor language and grammar can delay or even block a publication. If the work cannot be described and relayed in a comprehensible manner, then it does not matter how impactful and cutting edge the research is. Publishers do not correct language in a manuscript, that is the responsibility of the author(s).
Emphasize that scientific writing is direct unlike creative writing. Make sure to use proper English and spell check. Also, students should check the journal specification for other language requirements they may have. For example, certain journals prefer British spelling of words over

American. Some journals also prefer first person versus third person writing.
Emphasize that the Introduction, Methods, Results, and Discussion (IMRaD) format is the typical style for papers, however journal specifications should always be checked. Some journals prefer to have the methods at the end of the manuscript and others have a separate section for conclusions after the discussion. There may be extra sections like a highlights section or relevance section. Students should be prepared for these possibilities.

Introduction

- **For a paper**
  Emphasize that the introduction should establish the context and background for the paper. Information shared in the introduction should only be pertinent to the research that is being discussed. The introduction should have a clear path leading to the research objective and should be up-to-date. Students can begin their introduction by using some keywords from the title in the first few sentences so that the topic is focused on quickly. This can help them keep focus and avoid generic information.
- **For a thesis**
  Emphasize that the introduction section in a thesis is broader and longer than that in a paper. Information presented should be about the topic of research however there is a more in-depth overview of the topic. References can be older to show progress in the field although up-to-date research should also feature as in a paper.

In-Class Activity

Hand out Introduction Exercise and ask students to pick a topic and following the context, problem and solution format, write 2-3 sentences for each. (15-20 min)
After they finish, have students pair up and review each other's introductions to determine and critique clarity. (10 min)

Methods

- ### For a paper
  Emphasize that the methods should be clear enough that someone else could replicate the experiments. There should not be any critical missing steps. A common mistake is including results in the methods. Only describe how the experiments were performed in this section including equipment, statistics, mathematical modeling or calculations, study populations etc. How data was analyzed and summarized also needs to be included. This is dependent on the type of research. Some journals require a detailed protocol to be submitted with a paper as supplemental material. Experiments should be described in a logical order.
- ### For thesis
  Emphasize that the level of detail required in both the paper and thesis methods are similar. There should be enough detail to replicate the experiments. In a thesis the methods section is generally longer and more in-depth.

Results

In both a thesis and a paper, the results section is the same. Emphasize that the results section is ONLY results, there should not be discussion of the methods. Results of experiments are objectively reported in a logical order, without any interpretation. Results can be supported by figures and/or tables. For example, say sample populations A, B and C had 6, 8, and 10 errors, respectively, students should not add any more information on the reasoning for the errors. Significant and non-significant results should be both reported. Results should be organized by the figure and/or table that is presented.

Discussion

Emphasize that the discussion section should interpret the results in the context of what is already known about the topic. Any new understanding of the topic/problem can be taken into account when discussing new results.
Questions that should be answered in the discussion:

1. Do the results provide support (or no support) to the posited hypothesis of the paper?
2. Are the findings in line with previous work? If not, why? (Is it a flaw in experimental design, an added or omitted variable, etc.)
3. In relation to the conclusions of the paper, what is the new insight and understanding for the issue that was outlined in the introduction?
4. What are the next steps/future directions for research in this area?

References

Emphasize that, for both papers and thesis, the reference format is highly dependent on the target journal or institution. Students should make sure they include the most relevant and seminal papers in the field because the reviewers will know the subject material.

In-Class Activity

Hand out the Writing Exercise. Ask students to read the paragraph from The Science of Scientific Writing by George D. Gopen and Judith A. Swan. American Scientist 78(6):550-558 (Nov-Dec 1990). Based on what they have learned, evaluate what can be improved in the paragraph. The students should pick 4-5 sentences to re-write. (15-20 minutes)

- Once they have completed the activity, have the students pair up and discuss the paragraph. (10 minutes) Students should discuss (not limited to these topics):
  - Is the context and message clear?
  - Is the writing concise and direct?
  - Is the grammar and sentence structure correct?
  - Should there be any citations included and if so, where?
  - Is there anything else that the students noticed?
- The pairs of students could then take turn to present the results of their discussion to the class for a broader discussion.

Submission and review process

Emphasize that before submitting the paper, it is good practice to have someone provide a friendly review of the paper. This is often done by mentors or colleagues who have some knowledge in the research field. In addition, a writing service might be used to check for spelling and grammar. The review process can be time consuming depending on the journal. Journals often publish their review process and its expected length, e.g. 6 months after the paper submission. If the initial review process takes much longer than the journal's published target, feel free to contact the journal's editor to politely enquire the progress of the review. As reviewers are typically busy academics, it is not uncommon for delays in the review. A polite progress enquiry helps to move your submission back on the editorial board's agenda.

Submit manuscript

Articles are typically submitted through the journal's online submission system. Students should be prepared to provide detailed information about the paper and authors. Journals will need author information including affiliation, email address and sometimes phone numbers. If there were animal or human subjects, there may be a separate section to fill out about ethical guidelines and consent.

Desk review

The journal Editor will often provide a first review of the paper, to check that it meets submission guidelines and is suitable to send out for review. This can result in a desk rejection of a paper, or it can be sent out for Peer Review.

Peer review

This is where the paper is sent to experts in the field and is reviewed for validity, significance, and originality. Reviewers recommend: a manuscript is accepted without changes; a manuscript is conditionally accepted and will be accepted once some minor changes are made; a manuscript can be subject to minor or major revisions prior to resubmission to the journal (e.g. the second/third round or review); or a manuscript can be rejected.

Decisions

- **Revise**
  Emphasize that not all requests for revisions are valid. A rebuttal or withdrawal are legitimate. However, revisions can also be helpful in improving the quality of the submission. All comments should be addressed when re-submitting a revision. Often responses to reviewer comments are included in the re-submission as a separate letter or document.
- **Reject**
  Emphasize that a rejection is not uncommon; an estimated 4 out of 5 manuscripts are rejected at popular scientific journals. Top journals may have acceptance rates as low as 5%. The paper may be better suited elsewhere or need revision to improve its scientific quality and/or clarity in its presentation.
- **Accept**
  Students should be proud to get a paper accepted, as it is a major achievement.

Publication

Let students know that even after acceptance the publication is not done. There will be a galley proof to proofread. Sometimes journals may request higher resolution images or other requests.

Home Assignment

Students should pick a topic and make an outline for a research paper using the IMRaD format and apply the knowledge they learned in class. For methods and results, students should outline the types of experiments they would need to conduct and what results would support their hypothesis. The discussion section should be outlined on the premise that their hypothesis was supported.

Additional Resources

1. Hoskins SG, Stevens LM, Nehm RH. Selective Use of the Primary Literature Transforms the Classroom Into a Virtual Laboratory. Genetics. 2007;176(3):1381. doi:10.1534/GENETICS.107.071183
2. Strunk W, White EB. The Elements of Style. 4th ed. (Strunk Jr. W, Tenney EA, eds.). London: Pearson Education; 2000. http://www.jlakes.org/ch/web/The-elements-of-style.pdf.
3. Thomas B, Skinner H. Dissertation to Journal Article: A Systematic Approach. Educ Res Int. 2012; 2012:1-11. doi:10.1155/2012/862135
4. Gewin V. How to write a first-class paper. Nature. 2018;555(7694):129-130. doi:10.1038/D41586-018-02404-4
5. Armani A. 10 Simple Steps to Writing a Scientific Paper. SPIE The international society for optics and photonics. https://spie.org/news/photonics-focus/janfeb-2020/how-to-write-a-scientific-paper?SSO=1. Published 2020.
6. Structuring Your Scientific Paper. Nature Education. https://www.nature.com/scitable/ebooks/english-communication-for-scientists-14053993/118519636/. Published 2014.
7. How to write a journal article - Tips and Structure Guide - Author Services. Taylor and Francis. https://authorservices.taylorandfrancis.com/publishing-your-research/writing-your-paper/writing-a-journal-article/. Published 2022.
8. Choosing a journal - Author Services. Taylor and Francis. https://authorservices.taylorandfrancis.com/publishing-your-research/choosing-a-journal/#. Published 2022.
9. Borja A. 11 steps to structuring a science paper editors will take seriously. Elsevier. https://www.elsevier.com/connect/11-steps-to-structuring-a-science-paper-editors-will-take-seriously. Published April 5, 2021.
10. Scientific Paper: What is it & How to Write it? (Steps and Format) - Bit Blog. https://blog.bit.ai/how-to-write-a-scientific-paper/.
11. Hyatt JPK, Bienenstock EJ, Tilan JU. A student guide to proofreading and writing in science. https://doi.org/10.1152/advan.00004.2017 2017;41(3):324-331. doi:10.1152/ADVAN.00004.2017
12. Stirling JW. Writing articles for scientific journals: A basic guide. 2001; 22:171-182. https://www.aims.org.au/documents/item/615
13. Chandrasekhar C. How to Write a Thesis: A Working Guide. January 2008.

https://www.student.uwa.edu.au/__data/assets/pdf_file/0007/1919239/How-to-write-a-thesis-A-working-guide.pdf.
14. How to structure a thesis - Paperpile. https://paperpile.com/g/thesis-structure/. Published 2022.
15. Pain E. How to write your Ph.D. thesis. Science (80-). April 2018. doi:10.1126/SCIENCE.CAREDIT.AAU0338
16. Cuschieri S, Grech V, Savona-Ventura C. WASP (Write a Scientific Paper): How to write a scientific thesis. Early Hum Dev. 2018;127:101-105. doi:10.1016/J.EARLHUMDEV.2018.07.012

Appendix 3

3.1 Title Exercise

Relevant words or phrases:

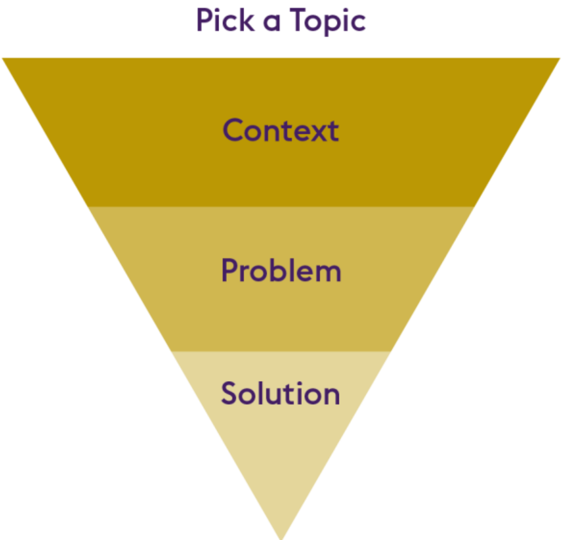
Top 10 Options

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________
6. ______________________________
7. ______________________________
8. ______________________________
9. ______________________________
10. ______________________________

Finalists

1. ______________________________
2. ______________________________
3. ______________________________

3.2 Introduction Exercise



3.3 Writing Exercise

Large earthquakes along a given fault segment do not occur at random intervals because it takes time to accumulate the strain energy for the rupture. The rates at which tectonic plates move and accumulate strain at their boundaries are approximately uniform. Therefore, in first approximation, one may expect that large ruptures of the same fault segment will occur at approximately constant time intervals. If subsequent main shocks have different amounts of slip across the fault, then the recurrence time may vary, and the basic idea of periodic mainshocks must be modified. For great plate boundary ruptures the length and slip often vary by a factor of 2. Along the southern segment of the San Andreas fault the recurrence interval is 145 years with variations of several decades. The smaller the standard deviation of the average recurrence interval, the more specific could be the long term prediction of a future mainshock.

Topic 4. Writing Successful Grants

Main Learning Outcomes	At the end of the session the students will be able to: 1. Evaluate the relevance and eligibility of grants 2. Describe key tips for writing effective grant applications 3. Describe how to find relevant grant sources
Activities	Students will be doing worksheets to prepare themselves for their final project of writing a 2-page grant proposal. Activities include 1. Reviewing a grant checklist 2. Complete a statement of needs worksheet where students break down their proposal idea 3. Complete an action plan worksheet to help clarify aim/objectives to support their hypothesis, 4. Complete a timeline planning worksheet so that students have an idea of feasibility to accomplish their projects in the time limit of a grant. 5. Draft a budget plan using a budget planning template where students can get a better idea of different items they need to consider when making a budget.
Outcomes Assessment Samples	Students will write a 2-page grant proposal that is both evaluated by the instructor and their peers.

Discussion Topics	Key Learning Objectives	Activities (Appendix 4)
Introduction, general approach		
Emphasis on the fact that just having an idea for a project is not enough, students must have a good reason why the project needs to be done, how they will execute the project, and the outcomes they expect.	• Understand how to choose a funding agency • Understand how the proposal (of the student) will help solve a defined problem	Introduction/ Statement of Needs
Introduction to essential grant writing skills		
Emphasis on understanding that all proposed research activities need to deliver unambiguous aims/objectives by defining success criteria, cost, having good time management, and availability of resources.	• Understand the parts of a proposal • Define clear, concise, and deliverable aims and objectives	Checklist Action Plan Worksheet Timeline Planning Worksheet Budget Worksheet

Discussion Topics	Key Learning Objectives	Activities (Appendix 4)
How to approach getting the message across		
Emphasis on that if a funding institution does not clearly understand your (the students') project benefits, then the chances of being funded are low	Understand how to get the message of their proposal across	Peer critiques of proposals
Understand the approach		
Emphasis that each aim/objective should support the testing of the hypothesis and have a clear and concise methodology of how to achieve it	Be able to clearly state an approach and methodology to carry out their hypothesis testing	
Impact and benefit		
Emphasize how the project of the proposal will be beneficial. This is where the funding agency interests and mission statement are very important. Align the project with their guidelines and how it will solve the problems the funding agency is looking to answer.	Be able to clearly state the benefits of their proposal	Ends with a home assignment of writing a 2-page proposal for a specified funding call

What is a grant proposal?

When describing a grant proposal also add the importance of securing funding in academia vs industry. There are small business grants that help technology startups and other grants for mid-level companies etc. Some grants require partnerships between industry and academia. There are grants for specialized instrumentation/equipment such as high-powered microscopes. Different terms and conditions apply depending on the funding agency.

Why is grant writing an important skill?

Cover the content in the curriculum. Emphasize that a well-written and thought-out grant can make a huge difference in securing funding. Grant writing is a skill that is developed through practice so do not get frustrated.

Common mistakes in grant writing:

1. Not aligning the grant with the funder's interest.
   Solution: Thoroughly review the guidelines, mission statement, and funding criteria of the funding institution.
2. The problem statement and project significance is not well-defined or clear.
   Solution: Make sure to clearly state the problem and what it affects (e.g., people with a certain disease who have no treatment options) and justify how YOUR (and team) work will uniquely improve the knowledge in the field and solve the problem (e.g., new curative drug for a certain disease).
3. The objectives/aims are not clear and do not support the problem statement.
   Solution: Each aim/objective should be well thought-out, support the problem statement, and test your hypothesis. Look for inconsistencies, show feasibility of the aims, have solid preliminary data, and have details on your approach. Outcomes should be quantifiable.
4. Overly ambitious goals.
   Solution: Make sure to be realistic in your timelines/budgets/abilities and that they align with the grant.

Construct a timeline covering the project and what it will take to achieve your milestones in terms of money/ability/labor.

5. Inexperienced investigators/researchers or not having personnel with the correct expertise or skill sets.
   Solution: If you have a project that needs high-level instrumentation which requires a PhD level scientist to operate, make sure they are included as a (co-)investigator instead of a research assistant. Make sure the proposed team has the skills relevant to the project and you do not omit team members with critical skill sets such as a statistician.
6. Lack any mention of limitations, problems that could arise, and what the contingency plan would be in each case.
   Solution: Always make sure to mention what potential problems might be and discuss the details. For example, mention if Aim I fails then our plan is to do A, B, and C. Your aims/objectives should not be dependent on each other. This will reduce the risks of your project and improve your chances of being funded.
7. Lack of editing/proofing.
   Solution: A poorly written proposal with several grammatical mistakes and misspellings not only affect the clarity of your proposed work, it will also damage your credibility and chances of obtaining funding. Have a few people read over the proposal and edit it for you. This can consist of colleagues, a hired scientific writer, or a mentor.

What skills are important in grant writing?

Emphasize to students that organization is key in making sure you have all the components needed for a grant. Tell students once they have chosen a grant many agencies do require a letter of intent before submission. So, it is important to identify funding agencies and grants early.

1. Introduction, general approach

Tell students that before looking for grants they need to try and solidify their ideas. Point out to students that a strong hypothesis and well-thought-out approach will be immensely helpful in not only writing the grant but finding the right funding institution for them.

Emphasize the importance of checking the eligibility requirements of the target grant scheme. Impress on students the need to make sure they and their organization qualify for the grant. For example, several US grants will allow foreign organizations if they collaborate with a US institution. Other considerations are if the organization is for profit or a nonprofit, or if the organization/research group is considered a special interest group. Even different grant schemes from the same funding agency could have very different eligibility criteria. If any of the stated eligibility criteria is not met, the proposal would be rejected regardless of the merit or importance of the proposed research work.

Go over the points in the curriculum in stage 1. Emphasize that having an idea for a project is not enough, students must have a good reason why the project needs to be done, the potential benefits it will bring to the wider community, how they will execute the project, and what are the outcomes they expect.

In-Class Activity

- Have students complete the worksheet titled 4.2 Introduction/Statement of Needs (Appendix 4)
- Ask students to include Key Words: A general list of definitions or descriptive words that fit their project for the grant. They are not usually required in a grant however it aids in searching for funding and grant applications. Also, this can help focus and define objectives before writing the grant/proposal. (20-30 minutes for keywords and worksheet)

2. Introduction to essential grant writing skills.

In-Class Activity

- Hand out the Checklist (Appendix 4)
  This worksheet is a generalized list of components often found in most grant proposals. Sections can be different depending on funding institution, type of grant, scientific field, etc. If there are collaborators there are sub-awards that can be granted. Not every grant will allow collaborations.
- Ask students if there were some unexpected items on the list.

Then go over the sections per the curriculum and worksheet. Emphasize that not all grants are the same and some of these sections are subject to change depending on funding agency and area of research. For example, a grant for clinical trials would be different than investigating tensile strength of novel building materials.

Explain the Action Plan Worksheet. (Appendix 4)

Defining milestones

The action plan is how you will accomplish your milestones/goals that support your aims/objectives. This is meant as a general examination of the grant proposal projects to aid in considering the feasibility of the project, help keep aims/objectives clear and plan for a realistic budget. When considering the milestones, you will need to successfully accomplish (the action) to complete your aims/objectives, you may need to reconsider the type of grant you are applying for, change the project or change certain parts of the project. This table is meant to solidify what you are trying to do and the actual feasibility in terms of resources and money.

Defining success criteria

Success criteria need to be defined for each milestone and must be specific. If you have an experiment planned, what is the threshold of an experiment that worked or did not work? For example, is it 5 runs out of 10 that complete a unit of measure above 8 to reach a go-forward to the next step? Or should it be 8 of 10 runs? Each experiment must have well-defined criteria corresponding to a specified cut-off value or threshold value. Criteria of experimental success must be specifically defined.

Defining timeframe

Once success criteria are known you need to indicate how long the experiment will take to reach the defined threshold for success. This is very important in planning timelines and feasibility of your project. If you are, for example, running a biological experiment in which you need to breed mice for specific genetic backgrounds, and then grow them, dose them with a substance over a certain amount of time, then harvest certain tissues and perform different measurements to see effectiveness of your substance, depending on if you are creating a new genetic strain or the types of tests performed this can take a year or multiple years. That consideration must be taken into account during your planning. Another factor to consider is that for animal or human experiments there will need to be approval from certain regulatory and ethics boards. How long does the required approval(s) take at the institution you plan on performing these experiments at? This may not be feasible in a 1-year grant but could be part of a 3-year grant.

Completing resources and costs

Next step is considering the resources that it will take to accomplish milestones. Consider the instrumentation you may need access to for sample analysis; will you need to rent time or buy the equipment outright for example? Who will be running the instrument? Will you need to hire a full-time technician/scientist/engineer, or would you send samples to be analyzed? Other considerations of resources are things like reagents, lab equipment, consumables etc. For example, biological experiments may require a biological safety cabinet or a chemical hood. Is this part of your lab already or will you need to upgrade? If you need special chemicals that are highly toxic for synthesis, do you have the proper safety equipment? If you are planning an archeological dig, what sort of equipment will you need, will you need to buy a new camera? Many reagents can be expensive and if you plan on needing a lot of that reagent, it needs to be factored in as a resource. These parameters directly affect cost. If you have a $250,000 budget but you need $500,000 for materials, personnel and equipment then you need to find a different way to achieve this milestone, a different project plan, or you need to apply for a different grant.

What you need to do for an experiment to be successful and how long it takes to reach that milestone affects the timeline and proposal. With this information the next step would be to do more in-depth timeline planning. The Timeline Planning Worksheet (Appendix 4) is divided up into months. For shorter grants monthly goals may be more pertinent, while complex projects might use quarterly goals instead. Some teams may require monthly reports and updates while others may require quarterly reporting. Again, this is dependent on the type of project you are doing and how flexible your timeline is. Tell students to fill out the form accordingly. They can choose to fill out by month or quarter. Considering all these items will help avoid some of the common grant mistakes described earlier.

In-Class Activity

At the end of the sections have students fill out the Action Plan Worksheet. (20-30 min) (Appendix 4)

Distribute the timeline planning worksheet and have students take one of their milestones from the action plan and fill out the Timeline Planning Worksheet. (5-10 min) (Appendix 4)

After students complete the worksheet, ask them if there were items they did not consider in the action plan.

3. How to approach getting the message across

Go over the curriculum. Emphasize that if a funding institution does not clearly understand the benefits of your project, your chances of being funded will be low.

In-Class Activity

Have students pair up to review and critique each other's proposals following the Peer and Instructor Evaluation. (20-30 min) (Appendix 4)

Home Assignment

Students should take the critiques into consideration and use the Introduction/Statement of Needs Worksheet (Appendix 4) to create a synopsis of their project and choose a funding institution for their grant.

4. Understand the approach

Follow the curriculum. Emphasize that a poorly planned project with ambiguous endpoints, goals, milestones, and overall aims/objectives will have a low chance of success. Each aim/objective should support the testing of your hypothesis and have a clear and concise methodology of how you will achieve it. Stress how your team is uniquely qualified to solve this problem and perform the work. Make sure to include limitations and contingency plans in case a project aim/objective fails.

5. Impact and benefit

Follow the curriculum. Emphasize how your project will be beneficial. This is where the funding agency interests and mission statement are crucial. Align your project with their guidelines and how it will solve the problems the funding agency is looking to answer.

Home Assignment

Using the worksheets and critiques students will write a two-page grant proposal with the following sections: Concept, Rationale for Research Action, Background, Objectives, Deliverables, Approach, Justification, Impact and benefit, Exploitation/dissemination.

6. Review

In-Class Activity

Have students review each other's grants using the Peer and Instructor Evaluation. (Appendix 4)

After peer evaluations, students should hand in their proposal to the instructor for feedback. Instructor is to review and hand back proposal so that students can hand in a final draft. Instructor should use the same evaluation criteria (Peer and Instructor Evaluation, Appendix 4): 25% of the grant grade should come from student evaluations and 75% from the instructor.

Additional Resources

1. 49 Grant Writing Resources: The Ultimate List in 2022 | Instrumentl. https://www.instrumentl.com/blog/best-grant-writing-resources. Published March 14, 2022.
2. Write Your Application | grants.nih.gov. https://grants.nih.gov/grants/how-to-apply-application-guide/format-and-write/write-your-application.htm.
3. NIH Center for Scientific Review. https://public.csr.nih.gov/.
4. A Guide for Proposal Writing nsf04016_Advice to Proposal Writers. https://www.nsf.gov/pubs/2004/nsf04016/nsf04016_5.htm.
5. Proposal writing | Topics | Candid Learning. https://learning.candid.org/topics/proposal-writing/
6. 9 Free Resources That Can Help Your Grant Writing — Peak Proposals. https://www.peakproposals.com/blog/2016/12/25/10-free-resources-that-can-help-your-grant-writing. Published December 31, 2016.
7. Council on Foundations |. https://www.cof.org/.
8. non-profit guides - grant-writing tools for non-profit organizations. http://www.npguides.org/.
9. Eby K. How to Write SMART Goals | Smartsheet. https://www.smartsheet.com/blog/essential-guide-writing-smart-goals. Published January 9, 2019.
10. Site Search | Minnesota Council on Foundations. https://mcf.org/search?keys=mcf grant writing.
11. 08 DC, Mukasey MB, Sedgwick JL. How to Submit Applications. https://www.ojp.gov/sites/g/files/xyckuh241/files/media/document/202948.pdf
12. NIMH Grant Writing Tips. https://www.nimh.nih.gov/funding/grant-writing-and-application-process/grant-writing-tips.
13. 230 Grant Writing Resources ideas | grant writing, grant proposal, writing resources. https://www.pinterest.com/grantinfo/grant-writing-resources/.
14. Sample Applications & More | NIH: National Institute of Allergy and Infectious Diseases. https://www.niaid.nih.gov/grants-contracts/sample-applications
15. Writing a Grant: Part 1 - First Things First. https://jetpubscientific.com/jetpub-blog/f/writing-a-grant-part-1. Published October 18, 2018.

16. Writing a Grant: Part II - Significance and Innovation. https://jetpubscientific.com/jetpub-blog/f/writing-a-grant-part-ii---significance-and-innovation. Published November 7, 2018.
17. Writing a Grant: Part III - The Experimental Approach. https://jetpubscientific.com/jetpub-blog/f/writing-a-grant-part-iii---the-experimental-approach. Published December 5, 2018.
18. Writing a Grant: Part IV - Timeline, Future Direction & Title. https://jetpubscientific.com/jetpub-blog/f/writing-a-grant-part-iv---timeline-future-direction-title. Published December 20, 2018.
19. Key Sentences are a PIPPIN for Communicators | Parker Derrington Ltd. https://parkerderrington.com/key-sentences-are-a-pippin-for-communicators/. Published November 8, 2019.
20. GuideStar nonprofit reports and Forms 990 for donors, grantmakers, and businesses. https://www.guidestar.org/
21. How to Develop and Write a Grant Proposal. Congr Res Serv. August 2019. https://sgp.fas.org/crs/misc/RL32159.pdf
22. Home | GRANTS.GOV. https://www.grants.gov/
23. Extramural Programs O. U.S. DHHS Public Health Service Grant Application (PHS 398). March 2020. https://grants.nih.gov/grants/funding/phs398/phs398.pdf
24. America's Seed Fund – NSF SBIR/STTR | NSF SBIR. https://seedfund.nsf.gov/?utm_source=google&utm_medium=cpc&utm_campaign=psc&utm_term=keyword&utm_content=technology
25. Government Grants and Loans | USAGov. https://www.usa.gov/grants
26. EPA Grants | US EPA. https://www.epa.gov/grants
27. Grants | SAMHSA. https://www.samhsa.gov/grants
28. Grants | DOJ | Department of Justice. https://www.justice.gov/grants
29. Grants | US Department of Transportation. https://www.transportation.gov/grants
30. FEMA Grants | FEMA.gov. https://www.fema.gov/grants
31. Candid | Foundation Center and GuideStar are now Candid. https://candid.org/?fcref=lr
32. Programs & Incentives | Invest in Canada. https://www.investcanada.ca/programs-incentives
33. Grants Database | Open Philanthropy. https://www.openphilanthropy.org/giving/grants
34. Global grants | My Rotary. https://my.rotary.org/en/take-action/apply-grants/global-grants

35. How to apply for grants | Program funding | Global Partnership for Education. https://www.globalpartnership.org/funding/applying-for-grants
36. Rutgers Global Grants | Rutgers. https://global.rutgers.edu/rutgers-global-grants
37. Grant Funding & Flexibilities - COVID-19 - The Global Fund to Fight AIDS, Tuberculosis and Malaria. https://www.theglobalfund.org/en/covid-19/grants/
38. Global Citizenship Global Grants - Santa Monica College. https://www.smc.edu/community/global-citizenship/mini-grants.php
39. Global Impact Cash Grant Program - Cisco. https://www.cisco.com/c/en/us/about/csr/community/nonprofits/global-impact-cash-grants.html
40. Global Health and Development Fund | Effective Altruism Funds. https://funds.effectivealtruism.org/funds/global-development

Appendix 4

4.1 Checklist

Item	
Cover sheet	
Proposal Title	
Table of Contents	
Proposal Contents	
• Abstract	
• Project Description	
○ Introduction-Statement of Needs	
○ Goals and Objectives	
○ Background-Literature Review	
○ Research Strategy	
○ Deliverables	
○ Limitations and contingency plan	
○ Timeframe	
○ Evaluation	
○ Summary-Outcomes	
References Cited	
Budget and Budget Justification	
Subawards (will there be any and are they allowed)	
Letters of Support	
Curricula Vitae/Bio sketch	
Agency Forms - are dependent on where you are applying	

*Know page limits for each section

4.2 Introduction/Statement of Needs

State your research question.	
What is the importance?	
What is the intellectual merit? (How your research contributes)	
Why is your method unique?	
What are the outcomes you expect?	
What is the broader impact of your research?	
Why are you (and your group) best/most exceptionally qualified for this project?	
What are the potential limitations for this project and what is your contingency plan?	
How does your research fit in the mission of the agency granting the funding? (i.e., military funds will need military applications)	

4.3 Action Plan

Milestone	Success Criteria	Time required	Resources	Cost

*If you know your team, you can add a column for who is responsible.

4.4 Timeline Planning

Milestone, Task, Deliverables	Months, Year X										
	1	2	3	4	5	6	7	8	9	10	11	12

4.5 Budget

Budget Item		Year 1	Year 2	Year 3	Total
A	Personnel (Direct labor)				
A1	List all personnel here and percentage of their time devoted to the grant each year				
A2					
A3					
A4					
A5					
A6					
A7	Total Salaries (A1 through A6)				
A8	Fringe benefits*				
	Fringe for faculty summer**				
	Fringe for full time personnel				
	Fringe for doctoral students**				
	Other fringe such as technicians, experts, etc.				
A9	Total personnel (A7+A8)				
B	Equipment†				
C	Alteration/Renovation				
D	Tuition Remission				
E	Other direct costs‡				
E1	Travel‖				
E2	Contractual††				
E3	Publication costs				
F	Facilities & Administration				
F1	Indirect Costs#				

F2	Co-funding				
G	Total Costs (A9 through F2)				

These items should be detailed in the budget justification.

* Fringe benefit rates change each year. Check with your institution for rates.

** For academic Institutions

† Generally, items costing less than $2,500 are considered to be supplies and items costing more than $2,500 are equipment.

‡ For items such as the cost of data acquisition, publication costs, etc.

‖ Allocation of a percentage of the budget to travel. Describe the intent of the travel in the budget justification/narrative.

†† Includes services provided by individual consultants, lease arrangements on equipment, etc.

‡‡ Can involve overhead from a university or company facility fee. This is a negotiated indirect cost rate that is added to base amount. For example, some universities require a 49% overhead.

4.6 Peer and Instructor Evaluation

This evaluation will be used for both peer and instructor evaluation.

Criteria	Grade (1-10)	Comments
Clarity of hypothesis/problem statement/purpose.		
Clarity of significance/importance.		
Clarity of objectives.		
Is the research unique?		
Clarity of the approach.		
Why the research should be conducted by that individual/group.		
Clarity of the overall impact.		
Clarity of the expected outcomes.		
Is the proposal well organized?		
Does the grant proposal fit the chosen funding institution?		
Do you have any other comments?		

Topic 5. Project and Time Management | Lab Management

Main Learning Outcomes	• Define project management • Describe the project management cycle • Describe key techniques for effectively managing scientific projects • Define the goal and main concepts of Good Laboratory Practice • Describe the main rules of effective lab management
Activities	Students will build a project outline during class
Outcomes Assessment Samples	At the end of this topic students will turn in their outlines

Discussion Topics	**Key Learning Objectives**	**Activities (Appendix 5)**
What is project management?		
Emphasis on what project management is and how it can organize and streamline projects	Learn to organize a project critical in their scientific careers and when managing laboratories	This will set them up to begin the activity in the next section.
Scope management		
Emphasis that all aspects of a project must be considered for success	Understand the criteria for success in a project	This section will begin the "Project Outline" worksheet

Discussion Topics	Key Learning Objectives	Activities (Appendix 5)
Creating a schedule		
Emphasis that creating a schedule is more involved than assigning due dates. There are many components to consider	Understand the basics of creating a schedule	Next set of questions in the "Project Outline" worksheet
Time management (TM)		
Emphasis on how to keep a project on track	Define processes involved in time management	
Risk management		
Emphasis on the identification, assessment, and prevention or mitigation of risks that could have a negative impact on project outcomes	Have a general idea of what is involved in identifying risk, mitigation planning, and impact analysis	Last set of questions in the "Project Outline" worksheet

What is project management?

Emphasize that project management is a process in which a team is led within given and defined constraints to complete project goals. Project management is the application of processes, methods, skills, knowledge, and experience to achieve specific project **objectives** according to the project acceptance criteria within agreed parameters. Project management has **final deliverables** that are constrained to a finite timescale and budget.

A project is a temporary effort to have a defined beginning and end (usually by date, but can be by funding or deliverables), and which is undertaken to meet unique goals and objectives.

In the lab, the three key steps of project management are

- **Planning**, to clarify:
  - Expected outcomes of the project
  - Stakeholders: who will be affected by, are needed to support, or will be interested in the project outcome?
  - Events that have to be performed to complete the project
  - Dates on which each project activity will start and end
  - Finances for all required project resources
  - Risk mitigation
- **Organizing**, to specify roles and responsibilities for project personnel
- **Controlling**, the performance of project work including:
  - Organizing, focusing, and continually motivating project personnel
  - Tracking and comparing project work and results
  - Considering and making changes to plans when needed
  - Keeping everyone informed of project accomplishments, issues, and changes
  - Continuously tracking and managing evolving project risk

There are 9 areas of project management. In this course, we will discuss only three areas – scope, time, and risk – considered the most important for PM in scientific projects.

Scope management

Emphasize that scope management is about all the work that must be accomplished in order that project plans are achieved. This includes all aspects of the work involved in the project and the criteria for success including deliverables, deadlines, and budgets.

In-Class Activity

Introduce the "Project Outline" worksheet (Appendix 5) to the students. Tell them that throughout this section they will be filling out project details as a project manager for building a shed in summertime. Ask each student to fill out questions 1, 2, and 3. (10-15 min)

Creating a schedule

Emphasize that creating a schedule is not just notating due dates for milestones. Schedule creation includes start and end dates of milestones, labor invested on different project activities (can be described as specific people or the number of people required for the activity), and the cost of the activities.

In-Class Activity

Ask each student to fill out question 4 in the "Project Outline" worksheet. (5-10 min) (Appendix 5)

Time management (TM)

Emphasize that time management is a central responsibility of a project manager ensuring that everyone involved in the project stays on task in the planned time constraints. Time management strategies can be categorized into time assessment, planning and monitoring behaviors.

For effective time management there are 4 processes:

1. **Planning**- This is to establish the timeline; tasks needed to accomplish, all the milestones assigned with responsibilities to each team member.
2. **Estimating**- This is to as accurately as possible estimate the length of time each task will take to reach a successful milestone. Since the unexpected does happen allocating some extra time is always wise.

3. **Scheduling-** Both planning and estimating are taken into consideration to make a schedule to ensure that the project stays within both time and resource constraints.
4. **Control-** Making sure the project is on track. Control accounts for what has been completed, what is in progress and what needs to be completed to adhere to the timeline and present the deliverables. A project manager needs to intervene if there is an issue keeping the project from moving forward, interventions are made in order to keep the project on track.

Risk management

Emphasize that risk management involves the identification, assessment, and prevention or mitigation of risks that could have a negative impact on the project outcomes. This is a continuous assessment to keep the project on track. To have an effective risk management plan the project objectives need to be clear.

Risk identification

Emphasize that risk identification is a continuous process since unexpected things can and will happen. Risks should be identified as early as possible so they can be dealt with and not compromise the project. There are 2 categories of risk: recognizable risks and unmanaged assumptions.
Emphasize that recognizable risks are predictable. A project manager can plan for these and minimize the impact they have on the project. Good project management include contingency plans. for unexpected risks. For example, planning timing buffers on milestones and having a contingency budget if there are unexpected costs. It is rare that risk is completely eliminated. Unmanaged assumptions are risks that cannot be seen or are not apparent, therefore, they can pose significant danger to a project.

Risk assessment

Emphasize that brainstorming can be a useful tool to examine potential risks in a project and develop a mitigation strategy.

Impact analysis

Emphasize that impact analysis is an in-depth analysis of risk and impact on project from the planned activities. Depending on the size of the project, needs of project, and resources, the level at which each activity or groups of activities are analyzed can be adjusted.

Risk prevention and mitigation

Emphasize that if risks have been correctly identified and assessed it is possible to reduce or prevent them.

Response system

Emphasize that risk response plans are part of project planning and should be integrated into the overall project scope. The response plan has a prioritized list of estimated project risks in order of the likelihood they could occur. A mitigation strategy can go into place to reduce the probability and impact of the risk. Mitigation activities can be assigned to different project team members. There should be continuous review of risks and adjustments as necessary.

Data applications

Emphasize that data collection is important in identifying risks early as well as providing information for risk assessment in future projects. Archived data can aid in risk assessments of current and prospective projects.

In-Class Activity

Ask student to fill out questions 5, 6, and 7 in the "Project Outline" worksheet. (10-15 min) (Appendix 5)

- Once completed ask students to share their plans with the class and compare each other's approach.
- At the end of class ask students to hand in their worksheet for evaluation.

Additional resources

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4. Kennett B. Planning and Managing Scientific Research: A Guide for the Beginning Researcher. ANU Press; 2014. doi:10.22459/PMSR.03.2014
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6. Harrin E. ProjectManagement.com - How to Implement Risk Responses. https://www.projectmanagement.com/blog/blogPostingView.cfm?blogPostingID=68438&thisPageURL=/blog-post/68438/How-to-Implement-Risk-Responses#_=_. Published April 7, 2021.
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8. Scope: How to manage projects for organization success, part 1. https://tobyelwin.com/scope-how-to-manage-projects-part-1/

9. Coursera. How to Manage Project Risk: A 5-Step Guide | Coursera. https://www.coursera.org/articles/how-to-manage-project-risk. Published January 24, 2022.
10. Halabuda P. 8 Project Time Management Strategies for More Productive Work. https://teamdeck.io/project-management/time-management-strategies/.
11. 9. Scope Planning – Project Management – 2nd Edition. https://opentextbc.ca/projectmanagement/chapter/chapter-9-scope-planning-project-management/.

Appendix 5

Project Outline

Project Goal: Build a shed in summertime

1. Identify the project scope.

2. Identify the desired outcome.

3. List the tasks that need to be completed. Ideally, the identified tasks should be listed in chronological order, but it is fine to simply list them in any order here.

4. Create a schedule for the identified tasks.

5. Identify the risks. I.e. what may prevent the project goal from being accomplished?

6. Uses the following table to create a risk management plan.

Risk	Trigger	Owner	Response	Resources Required

7. Create an impact analysis for this project.

Topic 6. Teamwork and Brainstorming

Main Learning Outcomes	• Define critical principles of effective teamwork • Describe the main types of brainstorming and their differences • Describe principal methodologies for effective brainstorming • Effectively brainstorm ideas as a group
Activities	Students will be asked to list top characteristics of effective teams using the "Effective Teams" worksheet. Then during a workshop, students will be asked to do brainstorming activities.
Outcomes Assessment Samples	At the end of their brainstorming workshop, students are asked to write a 1-page document reflecting on the brainstormed idea(s) they have developed at the session and describe how they might do things differently if they were to conduct a brainstorm session again.

Discussion Topics	Key Learning Objectives	Activities (Appendix 6)
What is teamwork?		
Emphasis on the importance of teams	Many jobs have teams that a student will likely have to work in	"Effective Teams" worksheet

Discussion Topics	Key Learning Objectives	Activities (Appendix 6)
Effective teamwork characteristics		
Emphasis that there are many characteristics for an effective team	Understand 9 effective team characteristics	"Effective Teams" worksheet
What is brainstorming?		
Emphasis that there are many different types of brainstorming, and it is important to choose one that works best for the situation and team	Understand that choosing the right kind of brainstorming for their team can help improve their success	Will lead to the brainstorming workshop
Brainstorming techniques		
	Understand some of the different brainstorming techniques and alternatives	Brainstorming workshop

What is teamwork

Emphasize that teamwork is a common and powerful way to accomplish research. Teamwork is the joint endeavor of a group to achieve a common goal or complete a task in the best way possible. Each team member has unique experience and distinct views, beliefs, and opinions contributing to the common goals.

Effective teamwork characteristics

Emphasize that there are many different characteristics that make a team effective and efficient.

In-Class Activity

- Ask student to fill out the "Effective Teams" worksheet. (10 min) (Appendix 6)
  - Once completed, ask students to discuss what they wrote as a class.
  - Then go over the common characteristics of effective teams below.
- Did the students identify most or all of these?

Characteristics of effective teams

Not limited to these characteristics:

1. **Clear goal/mission** - A team needs to understand and accept the project they are going to work on. Goals to achieve within the project must be clearly defined and understood by the whole team.
2. **Organization** - Teams should have defined roles and responsibilities for completion of the project. There should be an established protocol on how everyone finds forms, documentation, and information and how best to communicate with all team members for collaboration. This last part is often overlooked, and team members waste valuable time trying to find information resulting in a decrease in efficiency and productivity.
3. **Management** - Someone who will help the team communicate, collaborate, and work together through disagreements. This position can shift through different team members from time to time because it is about getting the project done not about control.
4. **Regular/Quality communication** - Team members need to communicate regularly and accurately. Everyone in the team should ensure this happens.
5. **Honest and respectful communication** - The environment should allow team members to speak freely even if they have dissenting

opinions. Members of the team should feel free to express ideas. For a team to be effective, they need to be honest about things that are working and things that are not.

6. **Accountability** - Team members take responsibility for their actions and their role(s).
7. **Adaptability** - Unexpected things can and will happen in projects and team members need to be able to adapt to new situations and be versatile and flexible.
8. **Respect for one another** - Team members need to have mutual respect for each other so that all team members are valued.
9. **Group Diversity** - Team members with different insights and backgrounds bring novel and fresh ideas of how to approach a problem or project. Multiple perspectives can result in ideas that are truly innovative, unique, and successful.

What is brainstorming

Emphasize that brainstorming is a helpful tool that aids in generating creative solutions to problems. In the team setting, it is especially useful since the diverse backgrounds and experiences of the team members can bring different perspectives and approaches.

Guidelines for brainstorming

1. **Defer judgment** - There are no bad ideas, this should be a judgment-free zone so team members can generate creative ideas from one another.
2. **Encourage wild and ambitious ideas** - Outrageous ideas can spark creativity without the limitations of immediate feasibility.
3. **Build on the ideas of others** - Combine and improve ideas positively by saying “and” instead of “but”. This creates a more collaborative atmosphere in a group and the combination of two ideas often generates more ideas and innovative solutions.
4. **Stay focused on the topic** - It is easy to get off topic so make sure that the discussion stays within the scope of the project.
5. **One conversation at a time** - The best results of brainstorming are when all team members get a chance to contribute. Everyone should be paying attention to the team member that is sharing a new idea.

6. **Be visual** - Write ideas down on a whiteboard or post it notes or notebook. Team members should feel free to draw diagram or sketch and the visualization will increase creativity by encouraging different ways of thinking.
7. **Go for quantity** - The more ideas the team comes up with, the increased likelihood that there will be worthwhile ideas to pursue and develop.

Brainstorming techniques

Nominal group technique

Emphasize that the nominal group technique is a structured method of brainstorming in a team. It encourages input from all team members and aims at quick agreement on the relative importance of problems or solutions. Best used in a setting: when there is a concern that not all members are participating whether from being less vocal or otherwise, when there is conflict, or when group members need some quiet time to explore their ideas.

Group passing technique

Emphasize that this technique aids in building ideas. Here, one person contributes an idea and then "passes" it to the next person, and so on around the group. This technique allows for each person to have some time to think of a response.

Team idea mapping method

Emphasize that this technique can reveal a common understanding of the problem among the team. Given a topic, team members brainstorm individually before their ideas are collated into one overall idea map. This method promotes collaboration between team members and increases quantity of ideas.

Directed brainstorming

Emphasize that directed brainstorming is good when the problem has well-defined constraints and the team wants to focus on one idea at a time. Directed brainstorming is a type of electronic brainstorming that is performed either using computers or manually. Each participant is assigned specific questions and asked to give a concrete answer. Then, those answers are swapped randomly to other participants who will be tasked to improve those ideas. The ideas are exchanged independently again randomly, and this routine can be repeated multiple times.

Guided brainstorming

Emphasize that guided brainstorming is more structured and is aimed at solving complex problems that are well-defined. It can be divided into 5 basic steps:

1. Define the problem
2. Generate ideas
3. Selection of the top ideas
4. Develop the selected ideas
5. Evaluate the results

Individual brainstorming

Emphasize that this is done alone and not as team. This method can stimulate a wide range of ideas.

Question brainstorming

Emphasize that questions asked are related to the problem with a goal to find short-term solutions. All questions are recorded by the team without worrying about the answer. Then the team can review and react to the questions. This method promotes creativity since answers do not have to be immediately known.

Alternatives to brainstorming

Emphasize that sometimes brainstorming does not work for different projects or teams so there are some alternatives.

Buzzgroups

Emphasize that buzzgroups are generally small and consist of no more than 3 people and typically focus on a specific question or precise information. Having many small groups discussing a common issue can create many different solutions and contributions.

Bug list
Emphasize that the bug list is a good way to lead to corrective action of a problem. There are four key steps:

1. The team identifies things that "bug" them, perhaps five or ten things
2. The team collates the bugs into a list, from most mentions to least
3. The team then votes on which bugs are most irritating
4. The team rates the perceived damage of each bug.
5. The team explains how each bug would impede the project if not addressed.
6. The team brainstorms ways to address the bugs

Stepladder technique
Emphasize that the stepladder technique encourages opinions from team members without being influenced by other team members and can result in a wider variety of ideas and solutions. The key steps are:

1. In advance of the group meeting, ask team members to think about a problem
2. When the team meets, put two members together to discuss the problem
3. Add a third member to the group and continue to discuss the problem
4. Continue until each member of the team has been added to the discussion

In-Class Activity

Preparation

- Create working groups (6-10 people in each)
- Define questions that the groups want to answer or the problem to be solved
- Give each group the same topic so that groups can see if they arrived at similar solutions
- Define the objectives of the brainstorming sessions
- Define evaluation criteria for how the groups will select top ideas and determine follow up action
- Come up with lists of prompting questions or lenses the groups can use to look at a problem
- Outline these beforehand, so each person has time to digest the information

During the brainstorm

- Make sure everyone is participating
- Defer judgment- creating an environment of openness and freedom to create will yield more ideas
- Build off ideas- "yes and" each other rather than "but"
- Go for a large number of ideas and resist the need to evaluate during the ideation phase
- Have fun and get weird - a wild idea may not make any sense, but it could prompt a vital line of inquiry
- Ask clarifying questions - query participants on how/why they arrived at an idea
- Set time limits
- Half-way through the brainstorming activity, ask each group to volunteer a member to move to a different group.

If the groups get stuck

- Control the energy in the room - take a break when you see the energy dwindling
- Systematically remove constraints - What if gravity didn't exist? What if it were possible to produce something at scale? What if technology X existed already?
- Look at problems from multiple lenses and various levels of abstraction

- Break a multipart idea down into small pieces and brainstorm around each subpart
- Bring in someone else to help brainstorm
- Mix and match ideas

Analysis and follow up

- Ask students which method of brainstorming they did and why
- Ask students if they worked well as a team and which characteristics of an effective team they employed, and which characteristics helped them be successful
- Ask each team to reflect on the effect of the team member swap on the dynamic of the discussion after the swap.
- Students should compare similarities and differences of their solutions
- Group ideas, look for common themes and connections
- Pay attention to ideas or themes that are underpopulated with ideas
- Determine your evaluation criteria and attempt to “rank” each idea
- Outline the relevant follow up or action items
- Introduction to coggle.it or other mind-mapping tools

Home Assignment

Ask students to write a 1-page document reflecting on the brainstormed idea(s) they have developed at the session and how they'd do things differently if they were to conduct a brainstorm session again.

Additional Resources

1. Haas M, Mortensen M. The Secrets of Great Teamwork. Harvard Business Review. https://hbr.org/2016/06/the-secrets-of-great-teamwork. Published June 2016.
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7. 8 brainstorming rules to spark your team's next big idea. https://robinpowered.com/blog/brainstorming-rules-next-big-idea
8. Mansfield D. Brainstorming Techniques: 15 Creative Activities to Do Solo or as a Team. https://blog.hubspot.com/marketing/creative-exercises-better-than-brainstorming. Published August 20, 2021.

Appendix 6

Effective Teams

Write down what you think are the top 5 characteristics of good teamwork and why. For inspiration think of the last time you were a part of a good team and what made you ideal to work with? What were the characteristics that helped you be successful?

1.

2.

3.

4.

5.

Research Design

Course Curriculum and Instructor Manual

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