



## DESIGN A RIGOROUS AND METHODOLOGICAL EXPERIMENTAL PROTOCOL

Create a scientific protocol to question and evaluate a specific research question



The scientific approach is a rigorous and methodical process used to explore, understand, and explain natural phenomena. It consists of several key steps that allow hypotheses to be formulated, these hypotheses to be tested, and conclusions to be drawn based on empirical data:

**Observation:** The first step is to observe a specific phenomenon or problem. Scientists use their senses, along with tools and instruments, to gather precise and detailed information.

**Question:** Following the observation, a specific question is formulated. This question must be clear, concise, and focused on a specific aspect of the observed phenomenon.

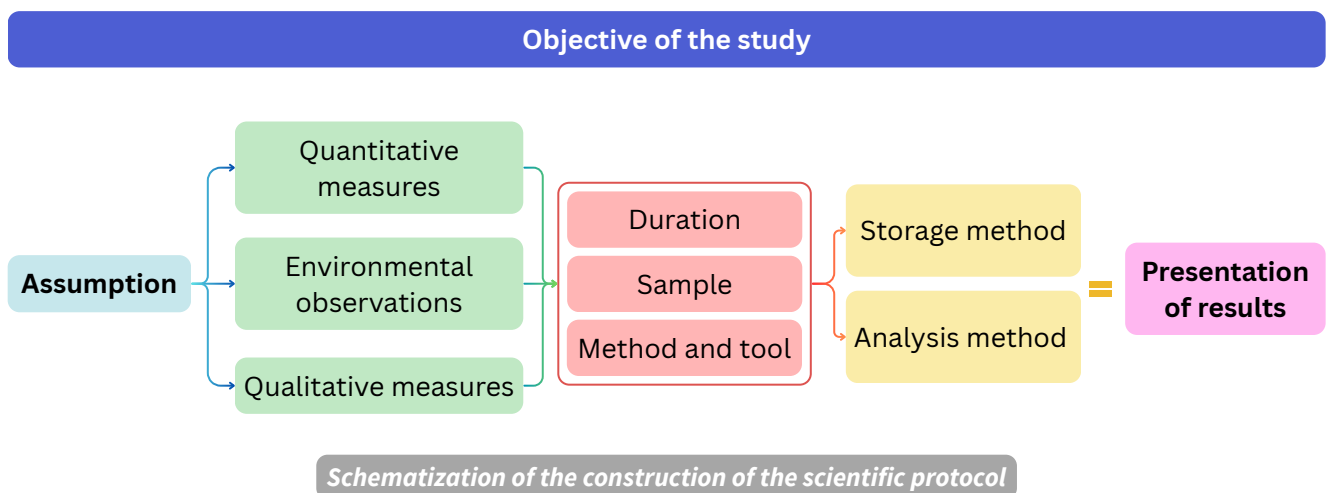
**Hypothesis:** Scientists then propose a hypothesis, that is, a possible explanation or tentative answer to the question posed. A good hypothesis must be testable and falsifiable.

**Experimentation:** To test the hypothesis, controlled experiments are designed and conducted. These experiments must be repeatable and include controlled variables to ensure that the results obtained are reliable and unbiased.

**Data analysis:** Data collected during experiments are systematically analyzed. Scientists use statistical tools and analytical methods to interpret the results and assess the validity of the hypothesis.

**Conclusion:** Based on the data analysis, a conclusion is drawn. If the results support the hypothesis, it is tentatively accepted. If the results do not support the hypothesis, it is rejected or modified.

**Publication and Replication:** Results and conclusions are shared with the scientific community through publications in peer-reviewed journals. Other scientists can then repeat the experiments to verify the results and strengthen the validity of the conclusions.



*This methodological sheet completes the experimental protocol outline directly usable by students and provides a framework and the definitions necessary for its use.*



## THE TYPES OF MEASUREMENT AND THEIR COLLECTION TOOLS

### Quantitative measures

Quantitative measurements provide an objective dimension to scientific investigation. This section describes the numerical parameters that will be measured and the methodology for collecting the numerical data.

Systematic sampling involves strictly repeated, identical measurements, such as weighing the same object three times under the same conditions. Adaptive sampling allows for changes in frequency based on results, such as measuring more often if values change rapidly. Probability sampling involves randomly selecting from a population, such as randomly selecting 50 students from 200 for a survey. Stratified sampling first divides the population into groups and then samples from each group, such as selecting 10 boys and 10 girls from each class.

Students should consider how many measurements are needed to get reliable results, the units used, and the accuracy of the instruments.

### Environmental observations

This section of the protocol details the methods and tools used to observe the phenomenon in its natural or experimental context. Students must specify the conditions under which the observations will be carried out, specifying the duration, frequency, and most appropriate times of observation.

The choice of observation tools depends on the nature of the phenomenon being studied and may include sophisticated measuring instruments, recording devices, or direct observation methods. It is essential to define a precise collection plan that guarantees the reproducibility of observations and the reliability of the data collected.

Collection can follow different temporal modalities. Point-in-time collection captures a state at a specific point in time, such as photographing a plant on a specific day. Time-series collection involves repeated observations at regular intervals, such as observing the same plant every week for two months. Continuous collection requires a permanent record, such as continuously filming animal behavior. Conditional collection is triggered by specific events, such as observing only when it rains.

### Qualitative measures

Qualitative measures capture non-numerical but essential aspects of the phenomenon under study. This approach allows for an in-depth exploration of perceptions, opinions, and behaviors that cannot be reduced to numbers.

To gather testimonies and perspectives, students can, for example, use individual interviews, which allow them to understand each interviewee's personal experience. Group discussions offer another option by creating a dynamic of exchange where participants react to each other's ideas. Open-ended questionnaires are also an interesting option for collecting a large number of detailed opinions on a given topic.

Direct observation of behavior represents another important dimension of qualitative data collection. Students can document people's natural reactions in their usual environments, note social interactions, or analyze traces left by human activities.

These different approaches can be combined according to the needs of the study and adapted to the specific research context. The important thing is to choose the most appropriate methods to explore the research question and to plan how to organize and interpret the information collected. Students should also consider ways to validate their observations and minimize personal bias in the analysis of qualitative data.



## DATA PROCESSING AND ANALYSIS

### Data storage and organization

Effective data management is a fundamental aspect of scientific rigor. Students should consider early in their protocol how they will organize, store, and secure all the information collected during their experiment.

Storage can take different forms depending on the type of data. Digital data can be recorded in structured tables, computer files, or simple databases. Qualitative observations often require laboratory notebooks, observation sheets, or audio-video recordings. It is essential to plan a backup system to prevent information loss, for example, by keeping hard copies of important data or using multiple digital media.

Data organization should facilitate their consultation and subsequent analysis. This involves creating a logical filing system with clear identification codes, precise dates, and consistent nomenclature. Students must also document the conditions under which each piece of data was collected so that they can interpret it correctly later. This traceability ensures the reliability and reproducibility of their scientific work.

### Methods of analysis and interpretation

Analysis transforms raw data into meaningful information that helps answer the research question and test the hypothesis. This crucial step requires choosing the right methods based on the type of data collected and the objectives of the study.

For quantitative data, analysis may include calculating averages, percentages, or trends that reveal patterns in the results. Students can create graphs, charts, or comparison tables to visualize their data and identify important relationships. Comparing different groups or experimental conditions helps measure the impact of the variables being studied.

For qualitative data, analysis often involves grouping similar observations, identifying recurring themes, or categorizing responses. Students can compare the collected testimonies, analyze the frequency of occurrence of certain words or concepts, or highlight interesting contradictions in the narratives.

The final interpretation should always return to the initial hypothesis, explaining whether the results confirm or refute it, and why. Students should also identify the limitations of their analysis and suggest ways to improve future research.



## RETURN OF RESULTS

Communicating scientific results is the final step in sharing discoveries with a wider audience and contributing to the advancement of knowledge. Students must consider the most effective way to present their findings so that they can be understood and used by others.

Visually presenting data is often the most impactful way to communicate results. Students can create graphs that clearly illustrate observed relationships, such as curves showing the evolution of a phenomenon over time or diagrams comparing different study groups. Infographics can summarize the entire protocol and results in an attractive and accessible way, combining short texts, explanatory diagrams, and numerical data.

Diversifying communication media broadens the impact of research. A detailed written report can accurately document the methodology and analyses for a scientific audience. An oral presentation to the class allows for methodological choices to be explained and peer questions to be answered. Creating digital content adapted to social media can raise awareness among young audiences about the scientific approach and the results obtained.

Adapting the message to the target audience is a key element of presentation. Students must learn to popularize their complex results to make them accessible while maintaining their scientific rigor. This involves choosing appropriate vocabulary, prioritizing concrete examples, and highlighting the practical implications of their findings. This scientific communication skill is essential for promoting research work and fostering dialogue between science and society.

### **The importance of the experimental design**

Creating a detailed diagram of the experiment is not just a simple drawing exercise: it is a fundamental scientific tool that clarifies students' thinking and improves the quality of their research.

The diagram forces students to visualize their protocol concretely and anticipate practical difficulties. By drawing their experimental setup, they can more easily identify missing elements, unclear steps, or uncontrolled variables. This graphic representation often reveals flaws in reasoning that are not obvious from simply reading the written protocol.

For their peers and teachers, the diagram greatly facilitates understanding of their approach. A well-designed image makes it easy to immediately grasp the spatial organization of the experiment, the relationships between the different elements, and the overall logic of the protocol. This makes discussions and suggestions for improvement much more productive.

Finally, the diagram is an excellent communication tool for presenting the results. It allows the audience to quickly understand the experimental context in which the data was collected, thus giving more credibility and clarity to the students' scientific conclusions.