3. HYPOTHETICAL-DEDUCTIVE METHOD AND EXPERIMENTED CRUCES

3.1 HYPOTHETICAL-DEDUCTIVE METHOD: The **hypothetico-deductive model** or **method** is a proposed description of scientific method. According to it, scientific inquiry proceeds by formulating a hypothesis in a form that could conceivably be falsified by a test on observable data. A test that could and does run contrary to predictions of the hypothesis is taken as a falsification of the hypothesis. A test that could but does not run contrary to the hypothesis corroborates the theory. It is then proposed to compare the explanatory value of competing hypotheses by testing how stringently they are corroborated by their predictions.

1. Basic definition of hypothetical-deductive reasoning

Hypothetical-deductive method (HD method) is a very important method for testing theories or hypotheses. The HD method is one of the most basic methods common to all scientific disciplines including biology, physics, and chemistry. Its application can be divided into five stages:

1. Form many hypotheses and evaluate each hypothesis
2. Select a hypothesis to be tested
3. Generate predications from the hypothesis
4. Use experiments to check whether predictions are correct
5. If the predictions are correct, then the hypothesis is confirmed. If not, the hypothesis is disconfirmed.

HD reasoning involves starting with a general theory of all possible factors that might affect an outcome and forming a hypothesis; then deductions are made from that hypothesis to predict what might happen in an experiment.
In scientific inquiry, HD reasoning is very important because, in order to solve science problems, you need to make hypotheses. Many hypotheses can't be tested directly; you have to deduce from a hypothesis and make predictions which *can* be tested through experiments.

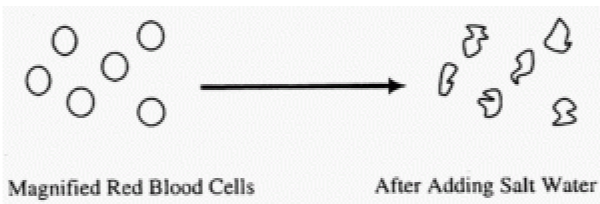
2. Review of hypothetical-deductive reasoning in research

According to Piaget's theory of intellectual development, HD reasoning appears in the formal operational stage (Inhelder & Piaget, 1958). Lawson et al. (2000) claim that there are two general developmentally-based levels of hypothesis-testing skill. The first level involves skills associated with testing hypotheses about observable causal agents; the second involves testing hypotheses about unobservable entities. The ability to test alternative explanations involving unseen theoretical entities is a fifth stage of intellectual development that goes beyond Piaget's four stages.

II. Simplified examples of hypothetical-deductive reasoning

1. Question ID: 20500121100 and 20500122100

A student put a drop of blood on a microscope slide and then looked at the blood under a microscope. As you can see in the diagram below, the magnified red blood cells look like little round balls. After adding a few drops of salt water to the drop of blood, the student noticed that the cells appeared to become smaller.



This observation raises an interesting question: Why do the red blood cells appear smaller? Here are two possible explanations:

1. Salt ions (Na+ and Cl-) push on the cell membranes and make the cells appear smaller.
2. Water molecules are attracted to the salt ions so the water molecules move out of the cells and leave the cells smaller.

To test these explanations, the student used some salt water, a very accurate weighing device, and some water-filled plastic bags, and assumed the plastic behaves just like red-blood-cell membranes. The experiment involved carefully weighing a water-filled bag in a salt solution for ten minutes and then reweighing the bag.

What result of the experiment would best show that explanation I is probably wrong?

A. the bag loses weight
B. the bag weighs the same
C. the bag appears smaller

Answer: A

What result of the experiment would best show that explanation II is probably wrong?

A. the bag loses weight
B. the bag weighs the same
C. the bag appears smaller

Answer: B

This question gives students two alternative hypotheses and the experiment to test these two hypotheses. Students need to make a prediction about the results of the experiment according to each hypothesis and consider what result could confirm or disconfirm the hypothesis.

If hypothesis I is right, then the weight of the bag won't change because there are no molecules or ions coming into or going out of the bag. If hypothesis II is right, the bag will lose weight because water molecules move out of the bag. From HD reasoning, we know the answers are A and B.

Importance of hypothetical-deductive reasoning

1. The importance of hypothetical-deductive in learning

HD reasoning is important in concept construction because students typically do not come to the learning situation as blank slates. Rather, they come with alternative conceptions (i.e., hypotheses) that must be modified or replaced by scientific conceptions. Thus, concept construction often engages hypothetical-deductive reasoning skills (cf. Lawson, Abraham, & Renner, 1989; Lawson & Renner, 1975; Lawson & Thompson, 1988; Lawson & Weser, 1990; Lawson et al., 2000).

Through HD reasoning and experimentation, students can test their preconceptions against scientific concepts and find out which match experimental results. This promotes conceptual change.

2. The importance of hypothetical-deductive reasoning in society

HD reasoning could be useful in everyday life. Here is an example:

1. Suppose your portable music player fails to switch on. You might consider the hypothesis that perhaps the batteries are dead. You decide to test whether this is true.
2. Given this hypothesis, you predict that the music player should work properly if you replace the batteries with new ones.
3. You proceed to replace the batteries, which is the "experiment" for testing the prediction.
4. If the player works again, then your hypothesis is confirmed, and you throw away the old batteries. If the player still does not work, the prediction was false, and the hypothesis is disconfirmed. You might reject your original hypothesis and come up with an alternative one to test, such as the batteries are fine but your music player is broken.

3.1.1 PHASES OF THE HYPOTHETICAL-DEDUCTIVE METHOD:

The **hypothetico-deductive model** or **method** is a proposed description of scientific method. According to it, scientific inquiry proceeds by formulating a hypothesis in a form that could conceivably be falsified by a test on observable data. A test that could and does run contrary to predictions of the hypothesis is taken as a falsification of the hypothesis. A test that could but does not run contrary to the hypothesis corroborates the theory. It is then proposed to compare the explanatory value of competing hypotheses by testing how stringently they are corroborated by their predictions. To do so follow the following steps:

1. Use your experience: Consider the problem and try to make sense of it. Gather data and look for previous explanations. If this is a new problem to you, then move to step ***2***.

2. Form a conjecture (hypothesis): When nothing else is yet known, try to state an explanation, to someone else, or to your notebook.

3. Deduce predictions from the hypothesis: if you assume ***2*** is true, what consequences follow?

4. Test (or Experiment): Look for evidence (observations) that conflict with these predictions in order to disprove ***2***. It is a logical error to seek ***3*** directly as proof of ***2***. This formal fallacy is called *affirming the consequent*.

One possible sequence in this model would be ***1***, ***2***, ***3***, ***4***. If the outcome of ***4*** holds, and ***3*** is not yet disproven, you may continue with ***3***, ***4***, ***1***, and so forth; but if the outcome of ***4*** shows ***3*** to be false, you will have to go back to ***2*** and try to invent a ***new 2***, deduce a ***new 3***, look for ***4***, and so forth.

Note that this method can never absolutely **verify** (prove the truth of) ***2***. It can only **falsify** ***2***. (This is what Einstein meant when he said, "No amount of experimentation can ever prove me right; a single experiment can prove me wrong.

IT IS FURTHER DEFINED AS FOLLOWS: Observations And Data Collection

- Before a hypothesis can be formulated or an experiment conducted a scientist needs to collect data and make some observations on the subject being studied. A hypothesis needs to be an educated guess, so the observation and data collection step gives some background to be able to formulate a good hypothesis. The more observations a scientist makes and research he does, the better the hypothesis will be and the more credibility his own research will get.

Formulate A Hypothesis

- Once observations are made and data is collected the scientist needs to formulate a hypothesis. The hypothesis needs to be able to be proven true or false through the experiment with scientific data and proof to back it up. The hypothesis needs to be specific and not leave room for interpretation, because different interpretations cannot be backed up with scientific proof. For example, using words such as "good" or "bad" should not be used in a hypothesis because what the scientist constitutes as good may be different from what others see as good.

Test The Hypothesis Through Experiment

- Once the hypothesis has been formulated the experiment can be conducted. The experiment should have a control group and a real group so the scientist can compare the differences between the two groups. The experiment should contain some way to measure changes in both groups, so that data can be collected and research shown.

Identify Results By Confirming or Disproving Hypothesis

- At the conclusion of the experiment it should be easily seen if the hypothesis contains validity or not. Once the experiment is complete and data has been collected it is important for the researcher to state whether the hypothesis was correct or not. If the hypothesis was disproved then the experiment can be concluded. However, if the hypothesis has validity, either completely true or partially true, then more research need to be done. A hypothesis may be valid but much more research will need to be conducted before it gains validity in the field of science as a whole.

3.1.2 EXPERIMENTED CRUCES: In the sciences, an ***experimentum crucis*** (English: **crucial experiment** or **critical experiment**) is an experiment capable of decisively determining whether or not a particular hypothesis ortheory is superior to all other hypotheses or theories whose acceptance is currently widespread in the scientific community. In particular, such an experiment must typically be able to produce a result that rules out all other hypotheses or theories if true, thereby demonstrating that under the conditions of the experiment (*i.e.*, under the same external circumstances and for the same "input variables" within the experiment), those hypotheses and theories are *proven false* but the experimenter's hypothesis *is not ruled out*. Francis Bacon in his *Novum Organum* first described the concept of a situation in which one theory but not others would hold true, using the name ***instantia crucis***; the phrase *experimentum crucis*, denoting the deliberate creation of such a situation for the purpose of testing the rival theories, was later coined by Robert Hooke and then famously used by Isaac Newton.

The production of such an experiment is considered necessary for a particular hypothesis or theory to be considered an established part of the body of scientific knowledge. It is not unusual in the history of science for theories to be developed fully before producing a critical experiment. A given theory which is in accordance with known experiment but which has not yet produced a critical experiment is typically considered worthy of exploration in order to discover such an experimental test.

In his Philosophiæ Naturalis Principia Mathematica, Isaac Newton (1687) presents a disproof of Descartes' vortex theory of the motion of the planets. In his Opticks, Newton describes an optical *experimentum crucis* in the *First Book, Part I, Proposition II, Theorem II, Experiment 6*, to prove that sunlight consists of rays that differ in their index of refraction.

A famous example in the 20th century of an *experimentum crucis* was the expedition led by Arthur Eddington to Principe Island in Africa in 1919 to record the positions of stars around the Sunduring a solar eclipse. The observation of star positions confirmed predictions of gravitational lensing made by Albert Einstein in the general theory of relativity published in 1915. Eddington's observations were considered to be the first solid evidence in favor of Einstein's theory.

In some cases, a proposed theory can account for existing anomalous experimental results for which no other existing theory can furnish an explanation. An example would be the ability of the quantum hypothesis, proposed by Max Planck in 1900, to account for the observed black-body spectrum, an experimental result which the existing classical Rayleigh–Jeans law could not predict. Such cases are not considered strong enough to fully establish a new theory, however, and in the case of quantum mechanics, it took the confirmation of the theory through *new* predictions for the theory to gain full acceptance.