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Review

The importance of defining the hypothesis in scientific research

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Among hypotheses supporters exists a belief that the hypothesis creates the research process framework, implying that the other elements of the research are not as important for reaching the goal. This opinion directly promotes a methodology built solely on a system of hypotheses with its variables and indicators as a sufficient road to project realization. Correctly constructing a hypothesis and its system of variables and indicators is never a trivial process. The conceptual definition of the hypothesis, its functionality, classification and structure requires additional research work and in most cases can be considered a separate research project. In this paper, special importance is assigned to the hypothesis and its conceptual definition; how it originates and is discovered along with its functionality, classification and structure and the derivation of the hypothesis and its variables and indicators with all their necessary scientific attributes.

Key words: Hypothesis, scientific research, scientific research method, subject of research, variables, indicators.

INTRODUCTION

It becomes a consistent question as to whether scientific research can be accomplished without defining a hypothesis, which requires a lot of additional research time. Answering this question is not possible outside of the scientific research context, where the hypothesis has a central role and a special meaning. What approach will be used depends on the subject of the scientific research, as well as the nature of the scientific research. For example, while a researcher in the natural sciences will most likely use the experimental method, a researcher in the sociological sciences will use the historical method, or combine this method with the quantitative method. While an experimental approach inevitably requires identifying a hypothesis as the basis for defining an experiment to test the experimental results, the historical approach can start and finish all research without ever defining a hypothesis. Experiments and experimental results are fundamental elements in the study of natural sciences, such as, mechanical sciences, physics and biology. On the other hand, the utilization of the experimental process can be criticized for having an over-abundance of active involvement by the researchers. This may cause interference that certainly influences the experimental results.

In the case of research in the field of natural sciences where results are based on experiments, it is quite normal and even necessary at times to define a hypothesis, because the hypothesis becomes a basis for defining the next steps, experiments and testing of results dictates and leads the whole process of scientific research.

A hypothesis narrows the scope of the research in order to identify the correct focus. An incorrectly defined hypothesis can hinder the researcher and limit, or even wrongly direct the process of gathering evidence to specific results that cannot be used to draw a general conclusion. Hypotheses supporters believe that a hypothesis makes up the research process framework, suggesting the other elements of the research goal are not as important. This assumption directly promotes a methodology built solely on a system of hypotheses and

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variables and indicators as a sufficient road to project realization. Constructing a hypothesis and its system of variables and indicators is never a trivial process. It is always necessary to invest additional research work for a hypothesis' conceptual definition.

The following sections "Definition," "Sources," "Types," "Structure," "Variables," and "Indicators," contain more details about the conceptual definition and functionality of the hypothesis.

DEFINITION

"The hypothesis is at the heart of scientific research and everything moves around the hypothesis" (Djuro Susnjic, 2007).

The origin of the word "hypothesis," according to the online version of Oxford Dictionaries, is from the Greek word hupothesis from the "late 16th century: via late Latin from Greek hupothesis 'foundation', from hupo 'under' + thesis 'placing'a," and is translated as a "supposition or proposed explanation made on the basis of limited evidence as a starting point for further investigation." The same source offers another definition used in case of philosophy: "a proposition made as a basis for reasoning, without any assumption of its truth."

A hypothesis is an unproved assertion. Very often, the hypothesis is wrongly identified as an idea or theme, or even a theory. An idea is immeasurably wider than a hypothesis and can be anything that a human brain can imagine or fabricate. A theme is much narrower than an idea and is usually related to a subject of discussion, branch of science, or research. The definition and choice of the theme is almost always known in advance.

A theory is something that is already proven and is usually based on verified hypotheses. A theory is also a source for new hypotheses that can be used to prove or disprove the same theory or other theories.

A hypothesis is both an assumption and an assertion. A hypothesis is an assumption where the successful execution of the assumption will cause the expected consequences described in the assertion. A hypothesis is used for planning the tests that the hypothesis must pass in order to be successfully proved.

A hypothesis is used for focusing within a research field and obtaining a better understanding of the general rules. This understanding of which legalities are valid for an entire category can be tested on a limited, measurable and understandable number of samples. A hypothesis is tested and verified in the process of scientific research. The final result is the conclusion that alleges that a hypothesis has been defended or not defended. The results of the scientific research are made public and described so that the results can be re-tested by independent parties.

A hypothesis is much easier to prove false than prove true, because it is not possible to test all the viable combinations and conditions that a hypothesis can cover. This is the main reason why it is taken for granted that a hypothesis cannot be proved, but only defended in a particular context.

"A hypothesis is not a prediction or even a guess. If I predict that the sun will rise in the east and I do the experiment, I am implicitly considering two hypotheses: Either it will rise in the east or it won't. The point is that here we have one prediction but two hypotheses" (Denker, 2004).

Robert Gerber defines a hypothesis as "a preliminary or tentative explanation or postulate by the researcher of what the researcher considers the outcome of an investigation will be. It is an informed/educated guess. It indicates the expectations of the researcher regarding certain variables. It is the most specific way in which an answer to a problem can be stated" (Gerber, 2011a) and explains differences between a problem and hypothesis as "a problem is formulated in the form of a question; it serves as the basis or origin from which a hypothesis is derived. A hypothesis is a suggested solution to a problem. A problem (question) cannot be directly tested, whereas a hypothesis can be tested and verified" (Gerber, 2011b).

In general, the authors of this paper can agree with Robert Gerber's definition of hypothesis (Gerber, 2011a), there is a dissimilarity in opinion regarding his interpretation of differences between a problem and a hypothesis. First of all, a problem is directly testable or at least "visible;" otherwise, how we would know that a problem exists? Second, there are hypotheses that cannot be tested or verified. The following is an example of such a hypothesis:

"If a spaceship is travelling at light speed, his mass will become infinite."

This hypothesis is not possible to test or verify, but it is still a hypothesis. A testable problem regarding space would be, for example, a problem related to travelling over huge distances that separate different solar systems. This is tested by sending space explorers to other planets in our own solar system and counting how many years it takes to reach a target planet or the moon. Then scientists multiply the findings with the estimated distance to the closest solar system. Other examples of hypotheses that cannot be directly tested or verified are:

"Material goods are corrupting humanity's morals."
"If National Gross Production is increasing, then so too is increasing the overall standard."

Both of these hypotheses use qualitative expressions indirectly quantified with other variables, such as the number of cars per 1000 people, the number of schools or number of medical institutions per 10,000 people, or the index of industrial production growth, etc. So, what does Gerber mean that a problem "*cannot be directly tested whereas a hypothesis can be tested and verified*"?

The scientific research project defines variables that are used for hypothesis testing and verification, so hypothesis is more or less indirectly tested and verified through those variables. See “Variable section” for more about variables.

SOURCES

Sources of hypotheses, according to Susnjic (2007), are needed to solve a problem, theoretical or practical (Susnjic, 2007).

Sources of a hypothesis can be divided according to the following categories:

i. Sources based on a need to solve a problem,
ii. Sources based on interests,
iii. Inspiration,
iv. Incident.

The first category is about the basic need for a theoretical origin as a precondition for practical implementation and includes the need to find a solution to a problem discovered during practical implementation.

In the second category there is the eternally human interest to compete with others on a personal, national and global level. Like-mindedness and personal and social interests have always been a strength and weakness of human beings, pushing them forward and driving them to ruin. In this category is the dream to be more developed, stronger and superior and is an inexhaustible source of ideas.

The third category is made up of those sources that do not belong to the previous two categories. These sources are the result of pure inspiration and vision and the inexplicable font of brilliant ideas and solutions that erupt on the surface without conscious awareness.

In the fourth category, are all the sources that start from direct research in different directions that accidentally discover something else as a surprise. The difference between inspiration and an incident is that the incident occurs as a consequence of an experiment that originally had a different purpose; the incident is usually discovered by observation. One example is X-rays, specifically roentgen. Without this accidental discovery, it would be very difficult to imagine diagnostics in the case of medical science.

The Stanford Encyclopedia of Philosophy (“Evolutionary Psychology” 2008) describes a source of a hypothesis derived from a particular scientific approach, for example, evolutionary psychology. “For philosophers of mind and cognitive science, evolutionary psychology has been a source of empirical hypotheses about cognitive architecture and specific components of that architecture.” (Stanford 2008). This kind of hypothesis fits very well in the third category of inspiration.

Other classifications of hypothesis sources identified three different sources of the hypothesis (“Hypothesis and research question”, 2009): “from the researchers’ own experiences,” “from previous research studies,” and “from theoretical propositions.” This last is identified as the most important sources of a hypothesis, because “a propositional statement is isolated from the study framework and is empirically tested.”

TYPES

Types of hypotheses can include (Susnjic, 2007:63):

i. General hypothesis
ii. Special hypothesis
iii. Working hypothesis
iv. Ad-hoc hypothesis
v. Null hypothesis

General hypotheses are all “*philosophical and theoretical*” (Susnjic, 2007) assumptions and anything that has not been scientifically proven. That would mean that all our thinking dedicated to the search of relationships between concepts belongs to the category of general hypotheses, as long as they have not yet been proved in the process of scientific research.

Special hypotheses can be described as hypotheses that are accepted to be true, but they are related to particular cases, such as axioms or assumptions, that are not verified directly, but rather through other hypotheses that have a “narrow scope and wide content” (Susnjic, 2007:65).

Working hypotheses are hypotheses that are still not defined precisely enough to be considered proven. They are used as conductors and limitations during the scientific research process. A working hypothesis enables the researcher to have freedom and flexibility to finish, re-form, or replace a hypothesis in later research phases, based on experiment results, observations, or measurements.

An ad-hoc hypothesis is “usually working and temporary,” or one that currently works and usually is used as an “explanation and understanding” of an unexpected result (Susnjic, 2007:65).

A null hypothesis is a hypothesis that is the opposite expectation of another and negates the links and relations of the test results. It is used during the approval process to disprove a hypothesis. A null hypothesis is always expressed in a negative sense in relationship to the alternate hypothesis.

Hypotheses can be distinguished according to their origins and by generalizations as well (Prasad et al., 2001):

i. Deductive,
ii. Inductive,
iii. Non-directional,

iv. Directional.

An inductive hypothesis makes generalizations based on a specific observation, and is moving from specific observation to broader generalizations and theories. A deductive hypothesis works the other way and is based on an established theory and previous experience. Deduction is sometimes called "Top-Down" approach, from more general to more specific (Burney, 2008). A non-directional hypothesis assumes that relations and differences exist. A directional hypothesis assumes there are expected relations and differences.

Outside of the scope of this paper there are many different variations and types of hypotheses, because it is easy to reclassify hypotheses by clarifying whether they are simple or composite, practical or theoretical, and so on. Hypotheses can be classified further according to their contents, or descriptions and it is possible to find all of these variations somewhere in books and on the Internet. The main purpose of this section is to introduce the most commonly used types of hypotheses and let the reader further research more specific types on their own.

In the end, this paper will just mention that hypotheses can also be divided according to their testing and verification, which is very important and interesting, and in real life is implemented in a miscellany of contexts. According solely to testing and verification, hypotheses can be divided into two groups:

i. Alternate hypotheses,
ii. Null hypotheses.

The alternate hypothesis states that an assumption about the relationships and differences within the subject of research exist. The alternate hypothesis is called a hypothesis that is accepted, and its opposite is the null hypothesis, where the alternate hypothesis is rejected. The null hypothesis negates the alternate hypothesis and assumes that the relationships and differences do not exist.

The null hypothesis has special meaning in cases of final verification and testing of a hypothesis, and its misuse can cause errors. It is possible to distinguish between the following types of error:

i. A Type I error known as false positive,
ii. A Type II error known as false negative.

A Type I error occurs when the null hypothesis is rejected, although this hypothesis is true. A Type II error occurs when the null hypothesis is not rejected, although this hypothesis is false.

There is a very interesting example of using the Type I error and Type II error from the American justice system (Rogers, 2001).

This article opens with a question as to why the American justice system allows criminals to go free in cases of technical issues, what I assume are omissionsor errors in the implementation of standard rules and procedures during the process of investigation. It explains how the errors affect the judgment and answers why "a defendant is found 'not guilty' instead of 'innocent'." The American justice system was inspired by the British justice system and is, in this case, a suitable example of Type I and Type II errors.

In the case of the American justice system, the alternate hypothesis assumes that a criminal is arrested because he committed a crime. Otherwise, the arrest would not happen. The first assumption of the arrest is that the prisoner is guilty.

A null hypothesis in the American justice system assumes that the prisoner is not guilty; what is in harmony with the basic null hypothesis definition is the negation of the alternate hypothesis. Providing evidence about the correctness of the hypothesis can last a long time and innumerable evidence can be presented.

The rejection of hypothesis can be executed simply and quickly. That is the reason why the prosecutor and defense are focused on the disproval and rejection of the null hypothesis. If the null hypothesis is rejected, the prisoner is pronounced guilty.

Another reason everyone is focused on rejecting the null theory is that the American justice system considers Type I errors much worse than Type II errors. If we go back and read again the definition of a Type I error, rejection of the null hypothesis, this error would mean that although this hypothesis is true, an innocent person is convicted and the actual criminal is still on the streets.

An error of Type II still means that a criminal is pronounced free, but no one else is blamed for his or her crime. This kind of error is more preferable than a Type I error. The final conclusion is that in the case of a Type I error, the error is twice as bad as a Type II error, because an innocent person is convicted and the criminal is still free.

STRUCTURE

A sound hypothesis needs to satisfy the following requirements (Susnjic, 2007:60):

i. Verification,
ii. Clarity,
iii. Must not contain evaluation opinion,
iv. Is based on previous knowledge or experience, or is a part of an already established theory or theoretical system,
v. Offers an answer or solution to a query.

The verification of a hypothesis is a key issue in methodology. Hypothesis verification is usually achieved by experiments and the experiment's results can accept, but also reject a hypothesis. In science it is not always possible to verify everything with one set of experiments and often it is acceptable to believe that some assumptions are true, although it is established in advance that these assumptions are valid only under particular conditions and in a specific context.

A scientific hypothesis requires clarity. That means that the assumption and consequences are expressed in a way that is easy to differentiate between the subject of research and the calculated results, and it must be possible to define the experiment or experiments necessary for others to test the hypothesis.

Any evaluation opinions such as better than, more intelligent, prettier, more stupid must be removed from a hypothesis, because, as Susnjic (2007) says, “such a hypothesis does not represent the relationships between real phenomena, but rather it represents our own attitude.”

A good hypothesis requires a theoretical framework, or should be based on existing knowledge and experience. Such a hypothesis is, by rule, testable, although there exists sound hypotheses where direct verification is not possible and these hypotheses are verified through secondary hypotheses that are derived from the original hypothesis.

A hypothesis needs to contain an assumption and prediction and must offer both an explanation and solution. A good hypothesis can be expressed as:

i. Question,
ii. Assertion,
iii. Condition(s) and expected consequence(s).

An example of a hypothesis expressed as a question is:
“Does water change from liquid to solid state if temperature is lowered enough?”

An example of a hypothesis expressed as an assertion is:
“By lowering temperature enough, water will change from a liquid to a solid state.”

An example of this hypothesis expressed as the condition and expected consequence is:
“If water temperature is lowered enough, then water will change from a liquid to a solid state.”

When a hypothesis is expressed as the condition and expected consequence, then such a hypothesis is called a “*formalized hypothesis*.”

The hypothesis can be expressed using descriptive words. Usually such a hypothesis also contains the conditions that need to be proven to validate the differences and relationships, or these conditions are used to make such relationships visible. Visible in this context means testable and verifiable. Such an approach enables an analysis of results that are usually invisible to human senses, and such visibility is established through logic and the use of special equipment and specialized processes and procedures.

VARIABLES

“A variable is a label or name that represents a concept or characteristic that varies (for example, gender, weight, achievement, attitudes toward inclusion, etc.).” (“Research Problems, Variables, and Hypotheses”, 2010)

If a hypothesis can be tested, the hypothesis is usually observed as a set of variables. The most standard classification divides variables into dependent and independent variables, control (mediator) variables, and extraneous variables.

A dependent variable, also called the outcome or criteria measure variable (Siegle, 2011; Marion, 2004), is the subject of the research, that which the researcher is exploring through observing, analyzing, and measuring. An independent variable, also called an experimental, manipulated, treatment, or grouping variable (Siegle, 2011; Marion, 2004), is a variable that research controls by changing characteristics, values, and other parameters. By applying these variables, the researcher can examine and directly or indirectly demonstrate relationships to the subject of research.

In the previous example, water would be a dependent variable, because water is the subject of the research. The temperature will be an independent variable because the researcher controls the temperature and by changing the temperature, observes water’s behavior.

The control variable affects the dependent variable, is constant, and “we wish to balance its effect across subjects and groups” (Marion, 2004). In the previous example, air pressure can be a constant control variable, while temperature, the independent variable, will change, resulting in the changes in water behavior, the dependent variable, which will be observed. The control variable is also known as a mediator variable and defined as a “factor which is measured, manipulated, or selected by the experimenter to discover whether it modifies the relationship of the independent variable to an observed phenomenon. It is a special type of independent variable” (Siegle, 2011).

Extraneous variables are independent variables that cannot be changed or controlled, and can influence the results and relationships between independent and dependent variables. In cases of qualitative research, an extraneous variable could be age, gender, or any other attribute that is constant and cannot be controlled or manipulated, but can make a difference to the final result. In times like this, it is recommended for the researcher to collect dependent variables in a group that has the same extraneous attributes.

One example is a research project where the purpose is to find out how shopping tours affect people, and the experiment consists of observing and analyzing the behavior of two groups of people where in each group are both females and males. This experiment will probably have very different results than experiments where the first group has only females and the second only males. While long shopping tours can have a positive effect on a female population, the same could have a negative effect on a male population.

"Often research studies do not find evidence to support the hypotheses because of unnoticed extraneous variables that influenced the results. Extraneous variables that influence the study in a negative manner are often called confounding variables" (Marion, 2004).

In the case of a well-formulated hypothesis, the number of variables should be limited but sufficient for the subject of research and verification of relationships. A lower number of variables narrow the field and subject of research, while an increased number of variables widen the field or subject of research. More variables also decrease focus on the details, but allow observation of the subject of research in a wider context. The number and type of variables are a matter of modifications or replacements that are applied to the hypothesis. If the research results are correcting a hypothesis, then it is necessary to correct or replace the variables currently in use.

INDICATORS

Variables used for working on a hypothesis are not always easily measurable. In order to make the variable measurable and comparable, and be able to objectify immeasurable qualitative concepts (standards, power, love), it is sometimes necessary to find indirect methods and discover measurable concepts that are related to immeasurable variables.

Such examples include the standard measurements of Gross National Product (GNP) per capita, development measured by growth of industrial production, education measured by number of citizens who successfully completed their education up to a certain level, health care measured by the number of doctors or medical institutions per capita inside of the particular region and can extend to a national level or even larger.

Indirect measurable concepts that relate directly to other concepts or variables used in a hypothesis are called indicators. In the previous example, a standard is measured over GNP per capita and development over an index of growth of industrial production.

Standards and widely accepted nomenclatures are excellent sources of indicators that can be used for comparison on national or global levels, although for this purpose imagination is also used. Imagination and creativity, as well as applying non-traditional methods or approaches, deserve their due in credit for the creation of many relationships and useful inventions.

"The Indicator Hypothesis" article is an interesting example of using indicators and relationships to subjects of research (Arcieri and Arcieri, 2007). In this case, the example analyzes a representation of two types of human beings in a population:

i. Givers,
ii. Takers.

To avoid any kind of subjectivity that can appear in cases where questionnaires or interviews are used, researchers search for a method that can calculate an objective measurement regarding the "placement of individuals in one or the other" group. In this case, it is decided to find the number of givers or takers by observing traffic and driver behaviors. Drivers are sorted in two groups: those who use turn signals, identified as givers, and those who do not use turn signals, identified as takers. Researchers counted for half an hour at a traffic crossing to determine the number of drivers that used signals when turning and the number of drivers that did not.

The results in this test showed that 68% used signals and 32% did not. This led to the conclusion that the small town population represented a relationship that can also be considered valid on a national level that there are 68% givers and 32% takers in a given population.

Practical implementation of this research is also discussed with an example of a driver who drove into a parking place in front of a cinema and did not use signals. The conclusion was made that other cinema-goers should avoid sitting too close to that driver inside the cinema, because it can be expected that person will probably talk loudly or use a phone and disturb those nearby.

By developing this idea further, it leads to the question of whether traffic culture and driver behavior relates to the general culture development, or the level of civilization or rate of criminal activities in a particular town, region, or on a national level. What would be the results of such research if those other variables are related?

This example, besides establishing the function of indicators, shows how important a hypothesis can be at discovering relationships between concepts and generalizations, as well as show how one research idea can be an inspiration for subsequent research.

CONCLUSION

Defining the alternate hypothesis without defining the null hypothesis and the system of variables and indicators is not sufficient, although a hypothesis is formalized and expressed as the condition and expected consequence. Correctly constructing a hypothesis requires proper definition of the system of variables and indicators. In cases when the hypothesis is defined, the definition is used to harmonize the definition with the operational title of the subject of research.

A hypothesis is used for the definition of an experiment and analyses that can be tested empirically. The incorrectly defined hypothesis can hinder the researcher, and limit, or even wrongly direct, the process of gathering evidence to specific results that cannot be used to draw a general conclusion.

During research based on the hypothesis, experiments directly determine the value of terms, and their relationships and differences with an object of observation. The results are recorded and often themselves are the subject of observation.

This does not mean that formal rules have to limit imagination, creativity and freedom. Imagination, creativity, and freedom are an important part of each scientific work and allow the researcher to expose and observe research subject behavior in interaction with different kinds of environments. One example of the scientist creativity is mentioned in the “Indicator” section.

On the other side, the scientific methodology requires that each process be controlled and properly documented. In research based on the hypothesis, it is possible to control debates technically, and keep the experiments and results on the exact same measurements and comparisons between quantitative indicators. Process control can be criticized when there is too much of the researcher’s active involvement, causing interference that certainly influences the experiment’s results. To avoid such pitfalls, it is very important to define a hypothesis with the correct title or a description that will clearly express the idea of the research and serve as a guide in further research.

The additional time used to construct a hypothesis can be justified by fact that a hypothesis narrows the scope of the research in order to identify the correct focus. This means that a correctly constructed hypothesis can also save a lot of time lost wandering in later research process phases as, for example, during results analysis and hypothesis defense. Results of experiments are crucial for confirming, correcting, and concluding a hypothesis, especially for the final recognition or rejection of the hypothesis. In cases when research begins without defining a hypothesis, the importance is switched to proving the reliability and credibility of sources and material that are used as the starting and ending points of the research.

The hypothesis’ conceptual definition, its functionality, classification and structure require additional research work. The hypothesis is the quintessence of the scientific research context and its role has a central place and a special meaning in science. The hypothesis becomes a basis for defining the next steps and dictates and leads the whole process of scientific research. In research based on hypotheses and experiments, the equipment used and each step in the experiment are precisely described, as well as any other kinds of auxiliaries. These descriptions make it possible not only to verify the original experiment but to allow other researchers to repeat the experiment just through the documentation.

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