Revista Iberoamericana de las Ciencias Sociales y Humanísticas

RICSH

ISSN: 2395 - 7972

Reflexiones en torno al método científico y sus etapas.

Reflections on the scientific method and its stages

Reflexões sobre o método científico e suas etapas

María de los Angeles Cienfuegos Velasco
Unidad Académica Profesional Chimalhuacán de la Universidad Autónoma del Estado de México, México
angelescien@hotmail.com
https://orcid.org/0000-0002-8423-8088

Resumen

El desarrollo de habilidades y competencias en el quehacer investigativo exige la revisión de las diferentes etapas de su método. Por ello, el principal objetivo de este ensayo es reflexionar acerca de la ciencia tanto básica como aplicada, su método y sus etapas de ejecución. En concreto, en el presente trabajo se consideraron las siguientes nomenclaturas: 1) población de estudio, 2) ejecución de la investigación (observacional o experimental), 3) resultados y 4) conclusiones, las cuales se superponen, por lo que es difícil establecer fronteras entre ellas. En tal sentido, se concluye que cuando se trabaja en cada una de estas es conveniente tener presente tanto las anteriores como las posteriores. Asimismo, se debe prever que el criterio experimental tiene un solo proyecto (el experimento) enfocado, tradicionalmente, en las ciencias naturales. En cambio, el criterio observacional (con nueve diseños o proyectos) se centra habitualmente en las ciencias sociales. A pesar de esto, ambos son complementarios, de modo que se pueden utilizar en un mismo proyecto de investigación, lo cual debe ser advertido por profesores, asesores, metodólogos e investigadores.

Palabras claves: ciencia, método científico y sus etapas.

Revista Iberoamericana de las Ciencias Sociales y Humanísticas

RICSH

ISSN: 2395 - 7972

Abstract

The development of skills and competences in the investigative task requires the revision of the different stages of its method. Therefore, the main objective of this essay is to reflect on both basic and applied science, its method and its stages of execution. Specifically, in the present work the following nomenclatures were considered: 1) study population, 2) execution of the research (observational or experimental), 3) results and 4) conclusions, which overlap, making it difficult to establish borders between them. In this sense, it is concluded that when working on each of these it is convenient to keep in mind both the previous and subsequent ones. Likewise, it should be foreseen that the experimental criterion has a single project (the experiment) focused, traditionally, on the natural sciences. In contrast, the observational criterion (with nine designs or projects) usually focuses on the social sciences. Despite this, both are complementary, so that they can be used in the same research project, which should be noticed by teachers, consultants, methodologists and researchers.

Keywords: science, scientific method and its stages.

Resumo

O desenvolvimento de habilidades e competências na tarefa investigativa requer a revisão das diferentes etapas de seu método. Portanto, o objetivo principal deste ensaio é refletir sobre a ciência básica e aplicada, seu método e seus estágios de execução. Especificamente, no presente documento foram consideradas as seguintes nomenclaturas: 1) População de estudo, 2) aplicação de pesquisa (ou observação experimental), 3) Resultados e 4) conclusões, que se sobrepõem, o que torna difícil estabelecer fronteiras entre eles. Nesse sentido, conclui-se que, quando se trabalha em cada uma delas, é conveniente ter em mente tanto as anteriores quanto as posteriores. Da mesma forma, deve-se prever que o critério experimental tenha um único projeto (o experimento) focado, tradicionalmente, nas ciências naturais. Em contraste, o critério observacional (com nove projetos ou projetos) geralmente se concentra nas ciências sociais. Apesar disso, ambos são complementares,

para que possam ser utilizados no mesmo projeto de pesquisa, o que deve ser percebido por professores, consultores, metodologistas e pesquisadores.

Palavras-chave: ciência, método científico e suas etapas.

Fecha Recepción: Agosto 2018 **Fecha Aceptación:** Noviembre 2018

Introduction

What is science? This is a question that philosophers have generally asked themselves, but most of the scientists are not interested in answering, since they have sought to respond to real and concrete phenomena that serve to create new knowledge and, with it, science. Even so, it is worth mentioning that the term science is defined as the method of search for knowledge that subordinates theory to empirical observation and to experimental results (Jaffe, 2016). This, in addition, is the result of the individual or collective effort of skeptical and pragmatic researchers who base their conclusions on a careful and progressive search for objective evidence that is usually obtained through multiple experiments that are based on the application of the scientific method (characteristic feature and inherent in science), which was used by Galileo (1564-1642) to bring down two thousand years of Aristotelian ideas.

In fact, unlike Aristotle (384-322 BC), who never bothered to test his hypothesis, Galileo focused on using the scientific method, and particularly the experimental method, to study different phenomena, which gave a giant and transcendental step for the benefit of the scientific community, to which it has influenced in a remarkable way, as shown by the works of different authors, such as Nicolaus Copernicus (1473-1543), Johannes Kepler (1571-1630), Francis Bacon (1561-1626), Isaac Newton (1642-1727), Blaise Pascal (1623-1662), Ivan Pávlov (1849-1936) and Albert Einstein (1879-1955). Added to this evidence, one can also add the definitions and explanations that around the scientific method have been issued by various philosophers such as René Descartes (1596-1650), Gottffried Leibniz (1646-1716), David Hume (1711-1770), Emanuel Kant (1724-1804), Georg W. Friedrich Hegel (1770-1831), Karl Raimund Popper (1849-1930) or Bertrand A. Russel (1872-1970). Even

so, it is fair to indicate that there are several philosophers (Feyerabend, 1981) and even some scientists who have written several pages to demonstrate the non-existence or limitations of the scientific method (Fernández, Gil, Carrascosa, Cachapuz and Praia, 2002).

Each of the contributions about science argue for or against the existence of the scientific method or its potential or limitations; debate that still exists today. Among this, what is clearly identified is that before Galileo scientific research was based on observational criteria, in the sense that observations are taken directly from nature or reality and after Galileo, the natural sciences have had an evolution and spectacular development with the discovery of numerous laws and theories.

These statements are based on highlighting that the scientific method has been used inadequately, since it has only focused on observation and experiment (observational-experimental). For this reason, it has been noted that there would be a need to add to this dichotomous criterion other criteria, as shown in Table 1, and which are identified as the prospective or retrospective, transversal or longitudinal and monogroup or comparative, whose combinations give product to 10 research designs (citado en Cienfuegos y Cienfuegos, 2016).

Tabla 1. Matriz de investigación científica

Combinación de los cuatro criterios de clasificación de la investigación: Diez tipos de diseño, estudios o proyectos de investigación científica y nombre común.					
Criterios de clasificación dicotómica					
1	2	3	**4**	**Diseño, estudio o Proyecto (Nombre común)**	
Observacional o Experimental	**Prospectivo o Retrospectivo**	**Transversal o Longitudinal**	**Monogrupal o Comparativo**		
Observacional	**Prospectivo**	**Transversal**	**Monogrupal**	**Encuesta Monogrupal**	**1**
Observacional	**Retrospectivo**	**Transversal**	**Monogrupal**	**Encuesta Monogrupal**	**2**
Observacional	**Prospectivo**	**Transversal**	**Comparativo**	**Encuesta Comparativa**	**3**
Observacional	**Retrospectivo**	**Transversal**	**Comparativo**	**Encuesta Comparativa**	**4**
Observacional	**Retrospectivo**	**Longitudinal**	**Monogrupal**	**Revisión de casos**	**5**
Observacional	**Retrospectivo**	**Longitudinal**	**Comparativo Efecto-causa**	**Casos y controles**	**6**
Observacional	**Retrospectivo**	**Longitudinal**	**Comparativo Causa-efecto**	**Perspectiva histórica**	**7**
Observacional	**Prospectivo**	**Longitudinal**	**Monogrupal**	**Una cohorte**	**8**
Observacional	**Prospectivo**	**Longitudinal**	**Comparativo**	**Varias cohortes**	**9**
Experimental	***Prospectivo***	***Longitudinal*** *o Transversal*	***Comparativo***	***Experimento***	***10***

Fuente Original: Ignacio Méndez.

However, to explain this idea, it is important to identify the stages of the scientific method.

Stages of the scientific method

Traditionally it has been determined that the main purpose of science (scientific research and scientific method) is to start from the hypothesis and objectives (in this order) to later establish laws and theories (basic or pure science). However, scientific practice also seeks to conduct research with laws and theories already established to try to explain facts and natural and social phenomena (applied science).

However, for this last type of research it is necessary to be aware of the stages, structure and functioning of the scientific method, since the importance of applied science lies in the influence and impact of the structure of the model built on the reality that is studied, as well as everything that is implicit in it according to that reality. In this sense, the following are some significant aspects of this model:

- The universe or population of individuals, the objects and the diverse things towards which the conclusions and inferences are directed.
- The statistical model, which is representative of the reality that is being studied.
- The variables that are made to intervene in the model.
- The type or class of measurements (continuous or discrete, quantitative or qualitative).
- The combination of the four dichotomous criteria of scientific research, which generate ten types of designs or research projects.
- The methodology used according to the type of research design (of the ten possible).
- The statistical techniques used (parametric and non-parametric).
- Statistical tests, according to the nature and type of data.

However, regarding the stages of the scientific method, it should be noted that there is usually no agreement between different authors, as evidenced in Table 1, in which reference is made to Kempthorne (1979) and Méndez, Namihira, Moreno y Sosa (1984):

Tabla 2. Comparativa de las etapas del método científico según Kempthorne (1979) y Méndez *et al*. (1984)

De acuerdo con Kempthorne	**De acuerdo con Méndez *et al.***
1. Planteamiento del problema	1. Observar los hechos significativos
2. Formular hipótesis y objetivos	2. Establecer objetivos e hipótesis
3. Comprobación de hipótesis	3. Deducir de éstas, consecuencias
4. Construcción de leyes y teorías	4. para probarse con un experimento

Fuente: Elaboración propia

As can be seen in Table 2, Kempthorne focuses exclusively on basic research (ie, construction of laws and theories) and leaves applied research aside. He even points out the hypotheses first and then the objectives. On the other hand, Méndez et al. they leave aside basic research (first objectives and then hypotheses), although they focus halfway on applied research, because they focus particularly on the experiment, even though in some projects such procedures are not executed or tested (Cienfuegos and Cienfuegos, 2016).

However, it is usually considered that the stages of the scientific method refer to basic research as applied, but with special emphasis on the second in both natural sciences and social sciences and in observational or experimental projects, where the population in study (first stage) is the starting point (Casas, 1974), which means that the concept of population is crucial for any scientific research process.

Indeed, for Casas (1974) the scientific method represents a process, and not necessarily a cycle, that materializes in the following stages: 1) study population, 2) sample, 3) results and 4) conclusions. Even so, in the present work the following nomenclatures are considered: 1) study population, 2) execution of the research (observational or experimental), 3) results and 4) conclusions.

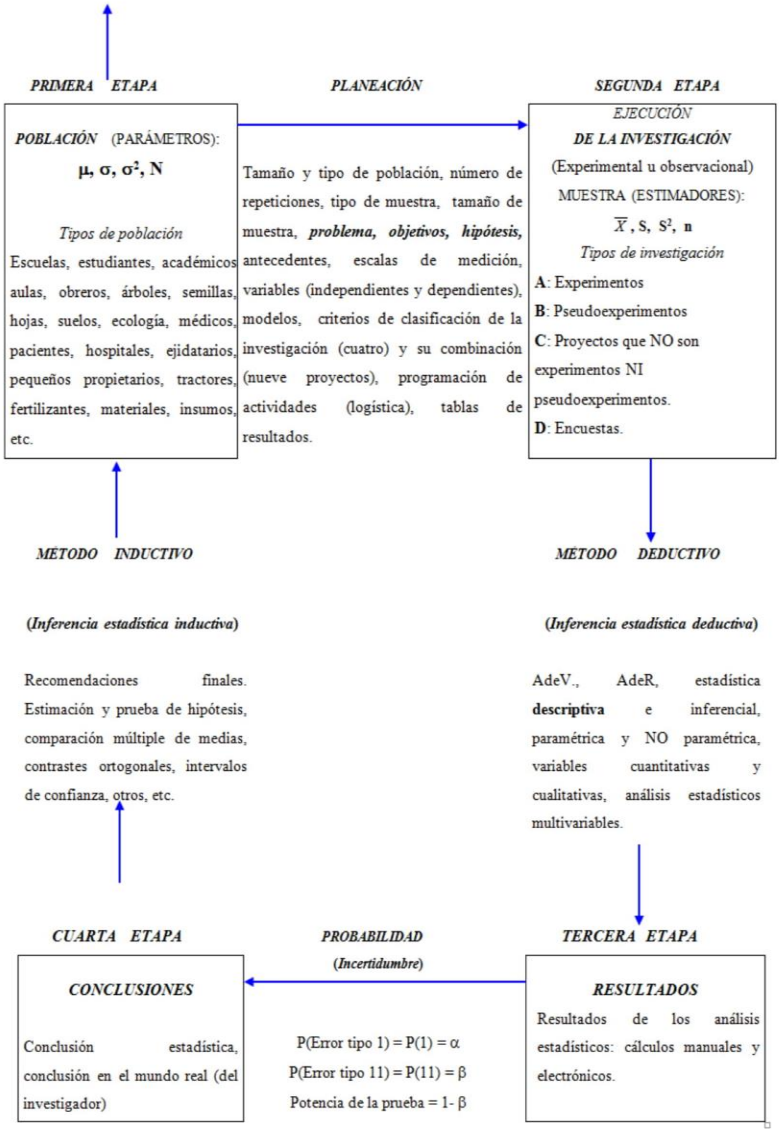
On the other hand, other methods are immersed in the cycle of the scientific method, such as the following:

- Statistical method (statistical analysis)
- Deductive method (deductive statistical inference)
- Inductive method (inductive statistical inference)

- Quantitative method (usually experimental)
- Qualitative method (usually observational)
- Experimental method (the experiment).

Figure 1 shows in more detail the cycle of the scientific method, which includes the aforementioned methods.

Figura 1. Etapas del método científico



Fuente: Actualización propia a partir de Méndez et al (1984)

Figure 1 shows that the inferences derived from the conclusions are not definitive, and that the process (as indicated by the arrow) does not end in the population (starting point), but continues, which represents the beginning of another or other cycles. This serves as a resource to force the researcher to constantly search for an absolute "truth" that he will never find (Méndez et al., 1984), since he will only be able to make approximations with the support of probability (Casas, 1974).

Conceived in this way, the cycle of the scientific method must be interpreted as a support or structure to facilitate its study and application, where the divisions between one stage and another are not so rigorous and sharp, but overlap (do not overlap); that is, when the second stage is processed, for example, the others are also present in a process of constant interrelation:

- Population
- Execution of the investigation
- Results
- Conclusions

Between the stages, deduction and induction are identified, that is, planning, deductive statistical inference (deduction), probability, inductive statistical inference (induction), as well as methods (statistical, experimental, observational, deductive, inductive, others).

First stage of the scientific method: Population

Different researchers affirm that the first point of interest of an investigation is observation, while for others it is the hypothesis. However, if in a study there is no set of individuals, objects or things (ie, a population or universe) where the scientific problems originate, then there would be no observations or hypothesis, hence it is fair to think that the population is the first point of interest of the scientific method. For this reason, for Tamayo and Tamayo (1997) "the population is defined as the totality of the phenomenon to be studied, where the population units have a common characteristic which is studied and gives rise to the data of the investigation" (p.). In other words, it can be said that this is an aggregate or set of diverse

individuals or things with an infinite number of characteristics in common or variables that, according to the interest of the researcher, are established when defining the size and characteristics of the population (controlled and uncontrolled factors). These variables, moreover, are implicit in the model, the problem and, mainly, in the hypothesis.

The origin of the concept of population goes back to the 18th century, when Dr. John Arbuthnot, doctor of Queen Anne of England, observed a certain consistency in the proportion of births of boys and girls. This event served to show that, although it was not possible to predict the sex of an individual before birth, with the study of a population, a phenomenon could be estimated provided that it was large enough (Carrillo, 1976). In this way, scientific knowledge was enriched notably, which meant a transcendental advance for research in general and for statistics in particular, since it was shown that there are laws that can determine the behavior of an aggregate or group of individuals (population) , even though the laws that determine individual behavior can not be explained.

The concept of population, therefore, established a difference between the deterministic and the statistical, because, for example, it revealed that the behavior of the laws of gases (pressure), apparently deterministic, is due to the random shock of their particles with the walls of the container that contains them. This fact served for scientists to discover that laws can be applied to a set of individuals or things, which originated the theory of aggregates or population. Subsequently, the population and sample concepts enriched the statistical method, which made possible the study and explanation of random phenomena. This means that when it is impossible to count all of its elements, a population can work with a sample, which must be representative, hence it is important to consider sampling techniques (Argibay, 2009).

From a qualitative perspective, this means that the number of subjects is not central to the research, but to describe what strategy and what type of sampling will be used-by quota, by convenience, by reference chain or snowball, proactive, sampling of cases and controls, sampling of volunteers, theoretical sampling (Mendieta, 2015), which should always be consistent with the question and the research design. The sample, therefore, is a subset or part of the population selected to describe the properties or characteristics that are to be studied.

Second stage of the scientific method: Execution of the investigation:

The execution of the research is the means used to try to achieve results that allow not only to respond to the problem detected in the population of interest, but mainly to check or reject the hypothesis or hypotheses. Until the 1970s the idea prevailed that the second stage should be experimental (Casas, 1974) and focused on the natural sciences, which is consistent with the traditional concept of doing research. However, it was later identified that in the second stage, not only experiments, but also surveys could be used. Then, in 1990, it was distinguished, through methodological and statistical advances, that it was not enough to consider only the survey and the experiment, but also the ten different types of research projects to carry out studies in both natural sciences and social sciences (Cienfuegos and Cienfuegos, 2016). This occurred as an adaptation of the works of Casas (1974) and Méndez et al. (1984) to the cycle of the scientific method, in which the following research modalities were identified:

a. ***Experiments:*** The experimental criterion is considered as part of the research execution stage and the experiment as one of the ten research methods, with the following characteristics:

   - Be comparative, prospective, longitudinal and experimental: Comparative because you work with two or more populations; prospective because the measurements are made in the future; longitudinal because two or more measurements are made; experimental because the treatments are randomized and because modifications or transformations are made to the research material. The latter is typical and characteristic of the experiment.

However, in addition to being longitudinal, it can also be transverse when a single measurement is made, usually at the end of the investigation, a very frequent situation in the fields of knowledge for the following reasons.

- Presents factors or random variables that give rise to random linear models.
- Your treatments have been randomized within each block (for designs that use blocks) or within homogeneous research material for completely random designs.
- Quantitative variables are presented more intensively in the experiment.
- The experiment is applied with greater intensity parametric statistics.

b. ***Pseudoexperiments:*** The observational criterion is considered within the execution stage of the research and as projects to the pseudoexperiment with the following characteristics (Campbell y Stanley, 1966):

- The pseudoexperiment, in addition to being observational, comparative and longitudinal (except for the comparative survey, which is transversal), is retrospective or prospective, depending on the phenomenon under study.
- The treatments have not been randomized, mainly because there is no manipulation of the research material.
- Repetitions (because they are not randomized) are not true or independent. It is samples of treatments that give rise to the restriction error and the hope of the average squares.

In addition to this, there are three types or pseudoexperimental projects: cases and controls, historical perspective and project of several cohorts. Also, there are projects that are not experiments or pseudoexperiments with the following characteristics:

- They are observational, longitudinal and monogroup, except the descriptive (transversal) survey.
- Sometimes they are prospective or retrospective, depending on the phenomenon of study; These are the prospective and transversal monogroup survey, and the review of cases and a cohort.

Likewise, there are projects that are sample surveys with the following characteristics:

- There are four modalities of sample surveys: two of a descriptive type (one prospective and another retrospective) and two of a comparative type (a prospective and a retrospective one).
- With the pertinent clarification that non-inferential projects can be presented; that is, without sample (typical case: the census).

Tercera etapa del método científico: Resultados

Once the variables of interest have been defined, whatever the research design has been (out of the ten possible), the original or transformed final data are subject to statistical analysis to obtain certain results. The independent variables involved can be quantitative (numerical) or qualitative (categorical). If they are quantitative, the measurement system

MKS (meter, kilo, second) or the CGS system (centimeter, gram, second) is considered. In addition, the following aspects should be clearly defined in the field book:

- Sketch of the location of the investigation (in field experiments).
- Sketch that shows the units of investigation or plot, in his case, with his treatments and repetitions (in field experiments).
- Indicate the units of measurement.
- Specify the observations corresponding to the variables of interest or variable to be measured.
- Record all observations of interest that occur during the management and execution of the investigation to facilitate correct interpretation.

On the other hand, if statistical analysis is used, researchers and methodologists must be able to define and recommend the necessary statistical models and analyzes. Otherwise, training courses in methodology and statistics should be developed. With appropriate knowledge about the type and nature of the variables, as well as the model corresponding to the phenomenon studied, correlations and regressions should be made with appropriate groups of variables. This analysis will yield results that will lead to certain conclusions.

Fourth stage of the scientific method: Conclusions

Obtained the results, statistical techniques help to draw conclusions that can be made from statistical (inductive) inferences. These conclusions require from the researcher not only experience in the investigative process, but also acceptable statistical knowledge to interpret in an appropriate way the data collected with the digital statistical packages. In this way, it is possible to respond, with greater or lesser precision, to the problem posed, which could have been an estimation or a hypothesis test.

These inferences, conclusions or recommendations, on the other hand, should be addressed to the population or sample of interest (the patient, the taxpayer, the teacher, the students, etc.). The hypotheses that are not rejected (the non-significant ones) deserve special attention, although frequently the mistake is made of ignoring or underestimating them. However, if small percentages are rejected (eg, 1% or 5%), an effort must be made to know the causes of this non-significance, among which the following may be mentioned:

- Little precision in the investigation.
- Insufficient number of repetitions.
- Insufficient number of treatments.
- Insufficient sample size.
- High detection capacity "d".
- High magnitude of the variance.
- Inadequate size of the level of significance.
- Failures and errors in the management and conduct of the investigation.
- Too many variables in the model (which cause difficulty in statistical calculations and interpretation of results).
- Do not take into account variables of importance.
- Being working with an inappropriate model.
- Deficiencies in the selection of the variation factors (of the treatments).
- Inadequate range of exploration of the treatments.
- Problems in the selection of the most suitable design and statistical techniques.
- Deficient or null definition of the population of interest, etc.

Conclusions on the stages of the scientific method

The four stages discussed in this article overlap, so it is difficult to establish boundaries between them. Therefore, when working a stage it is convenient to keep in mind the previous and subsequent ones. Also, it must be taken into account that the experimental criterion has a single project (the experiment) focused, traditionally, on the natural sciences. On the other hand, the observational criterion (with nine designs or projects), usually focuses on the social sciences, although it has lagged behind the experimental criterion due, among other reasons, to social and behavioral scientists They have not been able to give it an impulse. Even so, both criteria are not independent, but complementary, so that they can be used in the same research project, which should be noticed by professors, advisers, methodologists and researchers.

With respect to observation in the scientific method, according to Wittrock (1989), through

this process two ways of obtaining information are considered: one direct and one indirect, either through the questionnaire or a guide for the interview. On this aspect, it should be noted that this author, as a sociologist and educator, only includes research projects linked to the observational criterion and, in particular, to the projects via surveys, so that he does not take the experiment into account. The observation, however, is oriented to the study of both experimental and observational phenomena, hence the distinction between everyday and scientific observation.

The observations are taken from the experiment, from the previously randomized and transformed or manipulated research material, which is done by injecting two or more appropriately randomized treatments into blocks, in the case of using this concept coined by Fisher in the 1930s. in which modern experimentation begins.

Currently, however, scientific research must be classified into two broad categories: the one that uses the observational criterion and the one that uses the experimental criterion. But what is meant by observation within some of these two criteria? In the observational criterion (nine types of projects) the observations (improving what Wittrock says) are taken from the facts as they are presented in reality (without making manipulations or transformations, and without randomized treatments). This type of procedure is characterized by being careful, methodical, constant, objective, impartial, patient, exhaustive, reflective, precise, honest and ethical. Observation and theory (theoretical framework) are present throughout the research process.

In the experimental criterion, on the other hand, the researcher fixes and controls the (independent) variables with their respective levels or treatments, hence, criteria that are not of interest for the study are ignored. When this does not materialize, different faults, errors and, consequently, unreliable results can arise.

References

Argibay, J. C. (2009). Muestra en investigación cuantitativa. *Subjetividad y Procesos cognitivos*, *13*(1), 13-29. Recuperado de http://www.redalyc.org/articulo.oa?id=339630252001.

Cienfuegos, M. A. y Cienfuegos, A. (2016). Lo cuantitativo y cualitativo en la investigación. Un apoyo a su enseñanza. *Revista Iberoamericana para la Investigación y el Desarrollo Educativo*, *7*(13). Recuperado de http://www.ride.org.mx/index.php/RIDE/article/view/231/1062.

Campbell, D. T. and Stanley, J. G. (1966). *Experimental and Cuasi-experimental*. Design for research. Ran McNally, Chicago, III.

Carrillo, L. A, (1975). *Notas del curso Muestreo II*. Chapingo, México: Centro de Estadística y Cálculo. Colegio de Postgraduados.

Casas, D. E. (1974). *Notas del curso Introducción a la Estadística*. Chapingo, México: Centro de Estadística y Cálculo, Colegio de Posgraduados.

Fernández, I., Gil, D., Carrascosa, J., Cachapuz, A. y Praia, J. (2002). Visiones deformadas de la ciencia transmitidas por la enseñanza. *Enseñanza de las Ciencias*, 20(3), 477-488.

Feyerabend, P. K. (1981). *Contra el método. Esquema de una teoría anarquista del conocimiento.* Barcelona, Ariel.

Jaffe, Klaus (2016). ¿Qué es la Ciencia? Una vision evolutive interdisciplinaria. Tr. Manuel Bemporad. Caracas.

Kempthorne, O (1979). *The design and analysis of experiments.* Huntington, N. Y.: Krieger Publishing Comp.

Méndez, R. I., Namihira, D., Moreno, L. y Sosa, C. (1984). *El protocolo de investigación: lineamientos para su elaboración y análisis.* México: Editorial Trillas.

Mendieta Izquierdo, Giovane, Informantes y muestreo en investigación cualitativa. Investigaciones Andina [en línea] 2015, 17 (Abril-Septiembre): [Fecha de consulta: 14 de diciembre de 2018] Disponible en:**<http://www.redalyc.org/articulo.oa?id=239035878001>** ISSN 0124-8146

Tamayo y Tamayo, M. (1977). *El proceso de la investigación científica*. México: Editorial Limusa S. A.

Wittrock, M. (1989). *La investigación de la enseñanza I. Enfoques, teorías y métodos*. Barcelona: Ediciones Paidós.