Research Methodology for Engineers and Architects

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Practicing a Palestinian Achieved Model

By

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Cambridge Scholars Publishing

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To my deceased Father & Mother,
Wadie & Asma
To my deceased wife, Sirin
Who are celebrating in Heaven
To my wife, Salpi, my son Ramsey
And my daughter, Razan
To all youths studying engineering and architecture
Who are encouraged to conduct Research Methodology by
practicing a Palestinian achieved model
I dedicate this work
With rejoicing and eternal love

"On this land,
There is what's worth living for.
On this land,
Lady of Earth,
Mother of all beginnings,
Mother of all endings,
She was called Palestine.
Her name became Palestine.
My Lady …
Because you are my Lady,
I deserve my life because of you."

Translated from verses by
Mahmoud Darwish
Palestinian poet

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PREFACE

Research methods and research methodology are at the heart of the human endeavors that produce knowledge. Both are considered central aspects of the distinction between folk knowledge and the disciplined way in which disciplinary forms of knowledge are produced. However, in teaching research methods and methodology, there has traditionally been a significant gap between descriptions of how to do research, descriptions of research practices, and the actual lived research application.

Teaching a course in research methods and research methodology is considered at the prime of any engineering and architecture program, at the undergraduate and postgraduate levels. Palestinian universities have started envisioning the necessity to qualify for international accreditation of their engineering and information technology programs. Al-Najah University has recently received the license accreditation of nine engineering programs by an international body; the Accreditation Board for Engineering and Technology (ABET). Birzeit University received the ABET accreditation of two engineering programs while Palestine Polytechnic University has been working on the ABET accreditation of five engineering and information technology programs. Most interestingly, the ABET criteria define a set of seven (1-7) general student outcomes (SOs) that should derive from a customized set of intended learning outcomes (ILOs), for each course within the intended program, to be evaluated in the process of accreditation. A course in research methods and research methodology and the graduation project within each engineering program receive top priority for evaluation by the ABET committee, since both would carry the majority of the defined SOs that drive the course objectives. Likewise, a course in research methodology is considered core and mandatory in Master of Engineering courses, let alone at the Palestine Polytechnic University.

A paramount challenge faced by an experienced instructor in teaching, engineers and architects, is a course in research methods and research methodology at a Palestinian University. It starts at the undergraduate teaching level and continues, but slightly dissolves, at the postgraduate level. The undergraduate students enter the course with no basic knowledge of what research is and how it is applied. For them, research is rummaging for, and transferring, information. Formulating a

problem statement, writing an abstract, and citing references are only a few structural components that describe some great challenges to be met by students. The problem is compounded by the lack of English language skills and basic terminology, even at the postgraduate level.

The purpose of this project is to embark on the publication of a book that takes a very practical and pragmatic approach to research methods and scientific methodology. It will build on the concept of applying practical knowledge to writing project proposals, dissertations, and conference/journal articles. The book would demonstrate cases and examples from the real Palestinian environment that would encourage students to realize the transferring of components of a research structure and methodology into practice. Whether the research style is quantitative, descriptive or both in nature, the students would be able to develop their customized project proposals and tailor their methodology toward their objectives. At the postgraduate level, invited speakers, at a PhD level, would be one of the best practical means to demonstrate the research methodology and tools they applied in undertaking their doctorate-level projects. The discussion between students and the invited speakers would help in enlightening students to transfer knowledge into practice and pave the way to undertaking their project dissertations. Hence, experienced practitioners would bring to these decisions a scientific feel for the research journey that should allow them to do what they do while expressing their expertise. To transmit such a scientific feel would require teaching methods that are more like those in high-level arts or sports. Teaching a course in research methodology would, hence, occur through basic research principles and concepts that would smoothly develop into practical suggestions in actual cases. The book aims to publish contributions that teach methods much like a couch would tell an athlete. Most of the engineering research is quantitative in nature, but architecture is predominantly descriptive and may combine both styles.

The book will serve as a textbook for undergraduates and as an indispensable reference book for postgraduates, in Palestine and the rest of the world. The book covers concepts of science, scientific research, the basics of the scientific approach, and a literature review. It explains how research problems and hypotheses are selected, defined, stated and evaluated. It presents the main components of proposal writing. It then focuses on the experimental research approach and the experiment as a tool for obtaining data and demonstrates the main route of the descriptive approach and its tools, including observation and a questionnaire. Descriptive tools follow, with a full example of designing a questionnaire. In the final chapter, four proposals are suggested as a practical demonstration

of proposal writing on research problems of a Palestinian nature. Some included methodologies that were followed in the proposals were qualitative, quantitative, and a mix. I believe that undertaking such a project would lead students:

1- To focus on a book, much in demand for undergraduates and postgraduates specializing in engineering and architecture in Palestinian universities

2- To experience a different pragmatic approach and case studies, from the core of the Palestinian environment, that would motivate students to do research. Most of the available books that address research methodology are geared toward human sciences that do not conform to the needs of students studying engineering and architecture.

3- To get exposure to a Palestinian model worldwide through Cambridge Scholars Publishing.

ACKNOWLEDGMENTS

I deeply acknowledge all the engineering and architecture students, graduates and postgraduates who I have taught over the years. They indeed inspired me to write this book as a culmination of my taught lectures, homework, and the proposals they submitted, some of which were very interesting and simply creative.

I also acknowledge the colleagues and friends with whom I had discussions to collectively enhance the quality of the course, develop a unified standard and suggest worthy questions for the midterm and final exams.

Finally, yet importantly, I am deeply thankful for the patience and support of my wife and children throughout the long months of writing this work.

CHAPTER 1

SCIENTIFIC RESEARCH: CONCEPTS AND BACKGROUND

ABSTRACT

This chapter progressively portrays how the ancient Greeks described all aspects of knowledge: philosophy, medicine, history, politics, astronomy and culture, as science. They identified those who knew many disciplines of science as philosophers. With the emergence of Islam, more disciplines emerged: chemistry, optics, algebra, and surgical instruments. As science disciplines diversified, it became necessary to redefine science as a branch of cognitive thinking that is limited to researching the materialistic phenomena in nature, which are related to the civil sides of human problems. Hence, scientific research became identified with natural sciences such as physics, chemistry, biology, etc., and applied sciences such as engineering, agriculture, medical and environmental science. The chapter proceeds to identify the aims of science and its distinction from culture, scientific tools, research components, the characteristics of scientific researchers, and their subjective and objective motives.

1.1 Introduction

Perhaps a historical account of research would assist the reader to understand how the modern concept of "scientific research methodology" developed through the various phases of time. Research has associated itself with new knowledge and scientific methodology in modern times. The question is: has it always been like that throughout the history of humankind? The answer is not. Since the era of the ancient Greeks, science (derived from its Latin origin "Scientia" which meant knowledge) was used interchangeably to cover all aspects of "knowledge." It covered all aspects of philosophy, medicine, history, politics, astronomy, and culture, to name but a few. The ancient Greeks identified those who knew

many disciplines as philosophers or wise men; men such as Aristotle, Socrates and Plato. More disciplines, resulting from research efforts, emerged during the emergence of Islam, with great discoveries, such as chemistry, by Ibn Hayyan, algebra, by Al-Khawarizmi, optics, by Ibn Al-Haytham, the world map by Al-Idrisi, surgical instruments by Al-Zahrawi, the first flying attempt by Ibn Firnas and, most notably, Ibn Sina who was indeed a true polymath with his contributions ranging from medicine, psychology and pharmacology to geology, physics, astronomy, chemistry and philosophy.

Research efforts traditionally respond to whatever the human mind triggers regarding a certain situation, in order to understand, explain, expect or employ it, for the service of humanity. The human mind, through a thinking process, attempts to answer that question. The answer to the question becomes the result of the research effort. Hence, the research questions that trigger the human mind are multi-branched and unquantifiable. Consequently, a main question arises: would every "research" be interchangeably called "scientific research"? Would every thinking process be labeled as "scientific thinking"? To answer this fundamental question requires an exploration of the fields of questions in the mind and the tools that the researcher adopts in seeking answers and results. There are, accordingly, many disciplines of research:

- philosophical research, where a researcher may question the purpose of human existence, the universe, and life, and what existed before life? Where are we going after life?
- intellectual research where a researcher may question the principles for the development of humankind, what is democracy? What is socialism? Dogmatic affairs such as: do angels exist? What is the relationship between religions? Are the Bible and the Quran the words of God?
- political research where a researcher may question: what are the right policies for managing people's affairs? What was the goal of the USA in occupying Iraq? Can public demonstrations affect political change? Is it possible to build a country that solely depends on funds from external donors?
- economic research where a researcher may question: is it possible to develop water and electricity services, provided by municipalities, and resolve their problems through privatization? Is it possible to conduct industrial projects through bank funds? Can investment in tourism in Arab countries in North Africa lead to development in their financial situations?

- public administration research where one may ask: would it be possible to apply strategic planning concepts in the development of engineering education in a certain country? Are municipalities required to develop their administrative systems to improve their services to the public?
- social studies research where a person may ask: is early marriage a good or bad practice? What are the limitations of women's rights? Should university education be mixed in conservative countries?
- historical research where a person may ask: what instruments did Alexander the Great use in his battles? What were the causes of the First World War? How did the October 1973 war affect the zone of conflict in the Middle East?
- Islamic Fiqh (jurisprudence) research where one may ask: what is the ruling of Fiqh on the utilization of cloning in animals? What is the ruling on practicing human anatomy for medical learning? What is the ruling on using perfumes that contain a percentage of alcohol? What is the ruling on investment in insurance companies?
- field or survey research where one may ask: does the development plan of the state respond to the real needs of the people? Are the enrollment numbers of students in master's science programs on the increase?
- experimental science research where a researcher may ask: is it possible to hybridize apples and oranges to produce a new fruit? Is it possible to convert copper to gold through a nuclear reaction? What causes skin cancer and how can it be cured? How can an electronic chip be improved by adding a new material to its compound? How can wastewater in radioactive photographic solutions be treated to reduce its environmental effect?

Consequently, through the demonstrations of these disciplines and the pertaining questions that the reader may ask, it is obvious they are so diverse, and numerous, and cannot be classified under a single frame called "Science." As far as the tools that are used in researching the questions under the aforementioned disciplines, they vary from using the abstract mind and its processes, through the utilization of jurisprudence and laws, in answering political, economic and social questions, to using the questionnaire as a paper tool for collecting data or interviewing people to record their particular opinions. The researcher may conduct experiments to measure specific materials in laboratory research or utilize historical documents to understand a historical event or practice direct

observation to understand a natural phenomenon, whether the observation is tangible, such as the movement of the planets, or intangible, such as the level of people's acceptance of a particular product.orHence, the tools are also diverse and numerous, in answering all types of questions under those disciplines.

Can science answer all types of questions emerging from so many diverse disciplines? The emerging definitions of science in the literature are predominantly classified into a strict definition and loose definition While the strict definition embodies all curricula, built on experimentation and observation, which restricts science to the natural sciences, the loose definition defines science as every disciplined knowledge or specialized curriculum in research or topics investigation. Under such a definition, human sciences such as history, economics, education, and psychology would be included. In all modern definitions, the linguistic (original) meaning, which is knowledge, and the fundamentalist definition of certainty in Islamic knowledge (as opposed to uncertainty, doubt, or probability) are excluded from the word science, which is associated with scientific research. In all other definitions, science is associated with experimentation, observation and objectivity. It may be modified or even refuted. It indicates a defined system for obtaining knowledge, based on observation and experimentation for explaining and analyzing natural phenomena. Therefore, one can simply conclude that science is knowledge, obtained through observation, experimentation and conclusion, or is a vast field of human knowledge acquired through observation and experimentation, which can be explained by rules, laws, principles, theories and hypotheses. Accordingly, some authors consider that mathematics is not included in the modern science definition, since it is not based on observation and experimentation but on postulates and intuition. It is used as a tool for studying the laws of nature; hence considered “the language of science.”

We may conclude that science is limited to the natural sciences and can be generally classified into five branches; physics, chemistry, biology, astronomy and geology. Applied sciences is a branch of those fundamental sciences, such as engineering, medical sciences and classifications, agriculture, environmental science and others. The fields of science may be classified, according to the desired goals, into fundamental sciences such as physics and chemistry, and applied sciences such as medicine and engineering. Alternatively, they may be classified into experimental (laboratory) sciences and abstract sciences, which depend on abstract concepts, inferred by mathematics or logic. Therefore, the modern definition of science is natural sciences that require experimentation and observation, whether of fundamental or applied nature. Science addresses the matter

and can be acquired through observation and experimentation.

1.2 Aims of science and scientific research

Science serves humanity to make it understand and explain what goes around it. By understanding the natural phenomena, humanity can expect their occurrence and may practice control and utilization of them.

Science aims toward understanding and interpreting phenomena, characterizing and revealing their relationship to other various phenomena, and studying the reasons and affecting factors. This may lead to the development of mathematical models that describe them. As an example, science aimed toward characterizing the construction of matter by attempting to understand the components of the atom that described the movement of electrons around the atom, through Bohr's model which enabled the understanding of quantity of energy in the different orbits of the electrons.

Prediction and speculation are the second scientific aim. This would be based on available data for the current reality, which would enable prediction, if a factor changes. A researcher may generalize the results to predict realities in the foreseen future. Mathematical relations, derived from the previous aim, may be utilized to speculate a future occurrence by applying the concept of analogy between similar phenomena. An example is the periodic table of elements, in which scientists arranged elements according to their atomic number. They were able to predict undiscovered elements, such as Plutonium (Pu), Mendelevium (Md), and Nobelium (No), which, afterward, were discovered in the laboratory.

Control and setting is the third scientific aim, where variables are understood and specified through interpretation and explanation. The results of prediction are then applied to direct reality and utilized for the service of humanity. As an example, a researcher in a production process, may study the effect of operating conditions, such as temperature and pressure on the production effectiveness, like production quality or rate, and then proceed to control those operating conditions to increase the effectiveness. This might include increasing the temperature or pressure to increase the reaction rate, which, in turn, would increase the production rate.

1.3 Distinction between science and cultures

We must differentiate between the definition of scientific fields and cultural fields that have no association with science. Science is limited to material aspects and its methodology is based on observation and experimentation. Cultures that address mental and intellectual questions, on the other hand, cannot have a path to science. It is a grave mistake for some writers in this field to claim that scientific research is the basis of all types of knowledge for human beings.

In order to demonstrate, by example, a clear difference between the scientific fields and cultural fields, we pose some interesting questions before we analyze them:

1- Can we prove the existence of God through scientific research?
2- Can we prove heaven and hell exist through scientific research?
3- Can we prove the legitimacy of Islamic Jihad through scientific research?
4- Can we prove that Ataturk was the destroyer of the Ottoman Empire through scientific research?
5- Can we prove the nature of the COVID-19 virus through scientific research?
6- Can we research the possibility of life's existence on planet Mars?
7- Can we research how to establish industrial growth through scientific research?
8- Can we research the poverty level in a country through scientific research?

Undoubtedly, there is no "Yes" or "No" answer to every question. The answer to the first question is definitely "NO' since the method of reaching the answer does not rely on observation and experimentation but on the mind's thinking process. Hence, this is considered as about the mind's knowledge. The answer to the second question is not related to the materialistic world but can be obtained through a transferred knowledge process; transcendental or religious. Regarding the third question, the topic is not researched in laboratories but from sources that discuss Islamic legislation. Such a question pertains to legislative knowledge; similar in research method to the first two questions, despite the difference in the type of knowledge. As for the topic in the fourth question, despite its materialistic nature and possible observation by those contemporary to its era, researching it does not rely on experimentation and related

observation. The nature of it is historic and depends on past reality; hence, on the transfer of knowledge. In researching COVID-19 and the possibility of life's existence, the fifth and sixth questions are probably the only research questions among the rest that submit to scientific experimentation and observation and can be classified under the natural science discipline. Regarding the seventh and eighth research questions, these are topics of a realistic and materialistic nature that can be researched through observation but cannot be submitted to experimentation. Besides, there is no cultural aspect to deal with these topics. On the contrary, they are dealt with subjectively and can be researched with a similar methodology to that adopted in the natural sciences. Hence, these are topics or areas "attached to science."

To conclude, these examples demonstrate that there are research disciplines that are not related to science, in the strict sense or its methodology and tools, but to the mind's thinking, transferred, or transcendental knowledge processes. On the contrary, there are research disciplines that utilize the scientific methodology, based on experimentation and observation, or disciplines "attached to science," though not based on experimentation but on other tools such as the questionnaire or the interview. Thus, we realize that science is gained through observation and experimentation that lead to conclusions, such as nature, chemistry, biology, and all other experimental studies. Cultures, on the other hand, fall under the knowledge that is gained through informing, receiving, and eliciting, such as history, languages, philosophy, jurisprudence, and other non-experimental types of knowledge. There is also the non-experimental type of knowledge that is "attached to science," such as arithmetic, accounting, statistics, and programming.

The process of differentiating between the various categories of knowledge, between sciences in general and cultures in particular is imperative for two reasons:

1- The learner would be reminded to keep the borders between the knowledge categories, so as not to involve science in researching topics such as ideology or beliefs or in topics researching human behavior or history.
2- The learner would determine the appropriate intellectual position in every researched problem with objectivity. The determination would otherwise be biased if related to the cultural specificity of the nation.

At this point, it remains to shed some light on other branches of knowledge to determine their category:

1- Mathematics: although it may appear to fall under the natural sciences category, one may wonder if it could be submitted to laboratory experimentation. The answer is: not. Despite that, mathematics has always been described as the mother of all sciences, since it is involved in almost every branch of science.
2- Psychology: it is known that a man's behavior is connected to his beliefs about life and the principles that he or she follows. Such behavior in Islam, for example, is controlled by the Sharia rulings derived from the prophet's revelations. In Christianity, such behavior is adopted from the teachings and revelations of Christ. These conform to the general ethics and expected behavior of the society members. One can say that man's conduct is derived from transferred knowledge and is part of the cultural specificity as determined by religion or creed. Therefore, it is not related to science. On the other hand, a branch of psychology, called experimental psychology emerged as the branch of psychology concerned with the scientific investigation of the responses of individuals to stimuli in controlled situations. This branch is scientific as it can be submitted to experimentation and observation.
3- History: since this branch of knowledge involves studying and making account of events that happened in the past, the researcher may analyze, comment and learn lessons, but cannot subdue those events to experimentation. However, when history and archaeological excavations become related, the new history branch can be categorized as a scientific one. It is through excavations that we learn about past cultures and societies. Everything discovered on an archaeological dig was alive or in use a long, long time ago. Exploring these things teaches us about the people that came before us, so many years ago. The theories that are developed by archaeologists and historians help us to shape all of our beliefs and our versions of reality. An example of how archaeology has affected history is the uncovering of the ancient Pharaonic mummies in Egypt.
4- Regarding administrative sciences, such as information systems, administrative systems, or office automation, the research problems are materialistic and common to all people with no cultural specificity attributed to a specific society. Hence, those

disciplines are "associated with sciences" which can be researched in similar steps to the natural sciences but with different tools than the scientific experiment, such as the questionnaire or the interview.

1.4 Scientific versus cognitive method

Researchers often use the term scientific research methods and tools, as well as the term scientific methodology. Hence, some could mix between the method, the style, and the methodology and other expressions that indicate how and what steps the researcher may follow to realize their objectives and goals.

In a simple explanation, method and style are two words that express how we perform the work. If the way we conduct the research work is fixed and can be repeated without a change, then this expresses the method. On the other hand, if the way we conduct the research work is varied, then this expresses the style.

Unfortunately, many authors of scientific research methods consider scientific thinking as the source of all thinking and, hence, the scientific method is what humanity has achieved by obtaining knowledge in all disciplines. This, as previously indicated, contradicts the differentiation between science and culture, as well as between the cultural and civilization sides in research. Culture is the special characteristic associated with every nation, whereas civilization portrays the materialistic aspects of living, which are the secretions of the physical progress, associated with science and technology. Other authors, on the other hand, have indicated that knowledge goes in two lines: the rational method and the scientific method (or experimental) method. It is right to say, at this point, that rational thinking is the process of sensing reality, which is not merely produced through the transfer of brain sensations but also through linking those sensations with experienced information for judging them. Scientific thinking is, hence, fundamentally characterized by those aspects of cognitive thinking and may be considered as a branch associated with repeated steps in scientific research that are crystallized upon a fixed approach, which is limited to researching the physical matter through observation and experimentation.

What does the definition of the scientific method encompass? It is appropriate to say it starts by sensing a particular problem that arouses the human mind. Then the researcher crystallizes it on a specific pattern, by asking a question for researching its answer. He/she proposes a perception of the solution to the problem, which is defined as the hypothesis. They

then work to test the hypothesis through observation and experimentation to come up with a proposed solution and, thus, adopt, reject or modify the hypothesis. He/she could then repeat the work, based on the modified or new hypothesis, depending on the experimental results. Figure 1.1 shows a simplified flow chart of the scientific method.

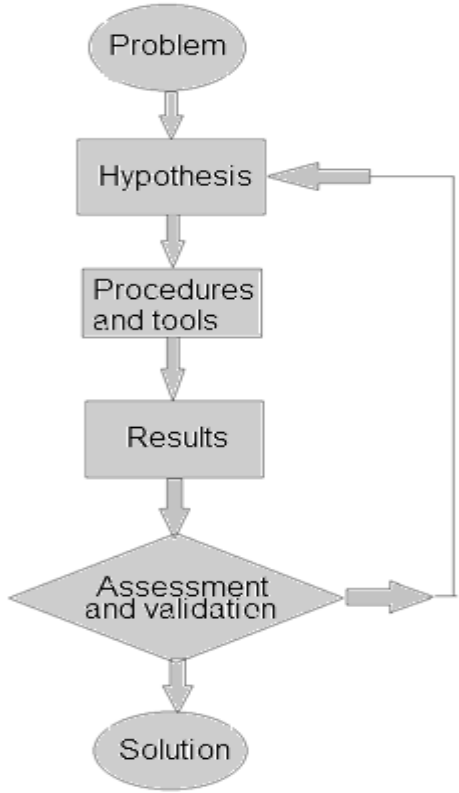

Figure 1.1: A flow chart of the simplified scientific method

1.5 Scientific approaches

Researchers may not follow the steps in Figure 1.1 to differentiate between the scientific and rational methods. They classify different methods for obtaining knowledge that could be summarized into three different approaches:

1- The deductive approach aims to test an existing theory. It is dependent on reason and moves from the whole to reach the parts. It consists of four stages:
   - **a. Start with an existing theory**
     - i. Low-cost airlines always have delays
     - ii. All biological life depends on water to exist
   - **b. Formulate a hypothesis based on existing theory**
     - i. If passengers fly with a low-cost airline, then they will always experience delays
     - ii. All land mammals depend on water to exist
   - **c. Collect data to test the hypothesis**
     - i. Collect flight data of low-cost airlines
     - ii. Study all land mammal species to see if they depend on water
   - **d. Analyze the results: does the data reject or support the hypothesis?**
     - i. 5 out of 100 flights of low-cost airlines are not delayed = reject the hypothesis
     - ii. All land mammal species depend on water = support hypothesis

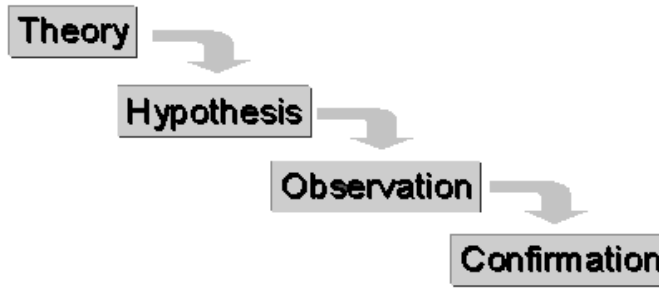

Figure 1.2: Deductive approach

2- The inductive approach moves from specific observations to broad generalizations; from the parts to reach general laws. This approach is mainly dependent on observation and experimentation and provides meaning to the scientific method. It consists of three stages:

a. Observation
   i. A low-cost airline flight is delayed
   ii. Elephants depend on water to exist

b. Observe a pattern
   i. Another 20 flights from low-cost airlines are delayed
   ii. All observed animals depend on water to exist

c. Develop a theory
   i. Low-cost airlines always have delays
   ii. All biological life depends on water to exist

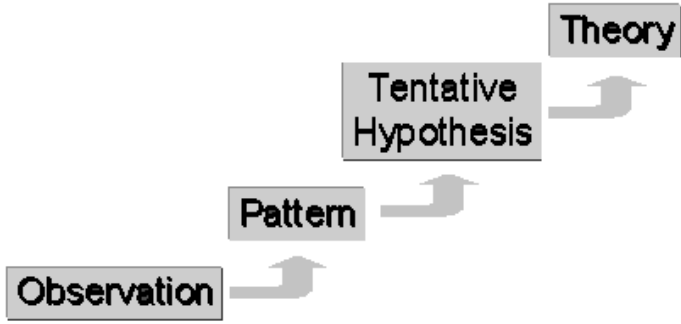

Figure 1.3: Inductive approach

3- The abduction approach is defined as "a syllogism in which the major premise is evident but the minor premise and, therefore, the conclusion only probable." It involves forming a conclusion from the information that is known. A familiar example of abduction is a detective's identification of a criminal by piecing together evidence at a crime scene. In an everyday scenario, you may be puzzled by a half-eaten sandwich on the kitchen counter. Abduction will lead you to the best explanation. Your reasoning might be that your teenage offspring made the sandwich and then saw that they were late for work. In a rush, they put the sandwich on the counter and left.

It is safe to say that the rational method is the basis of human thinking, which applies to all disciplines of knowledge. On the other hand, the scientific method is only applied to tangible scientific fields that are subject to observation and experimentation. Since science is one of the