Research, methodology, scientific, hypothesis

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THE ROLE OF HYPOTHESIS IN SCIENTIFIC RESEARCH

The paper deals with importance of hypothesis in the process of scientific research. The authors explain meaning of commonly used basic terms and characterize research methodology, research process and its structure as well as types of research problems. The main attention is paid to the role of hypotheses, their classification and possible formulations.

ROLA HIPOTEZ W BADANIACH NAUKOWYCH

Artykuł zajmuje się ważnością hipotez w procesie badania naukowego. Autorzy objaśniają znaczenie ogólne wykorzystanych terminów i charakteryzują metodologię naukową, proces badania i jego strukturę oraz rodzaje problemów naukowych. Główną uwagę zwracają na rolę hipotez, ich klasyfikację i możliwość formułowania.

1. INTRODUCTION

There are different definitions of what people from academic and research institutions understand by research. For example, the Webster‘s II New Riverside University dictionary [1] lays down the meaning of research as “scientific or scholarly investigation” or “close careful study”. The New Penguin English Dictionary [2] defines research as „careful and diligent search“ and/or „scientific or scholarly inquiry, especially study or experiment aimed at the discovery, interpretation, reinterpretation, or application of (new) facts, theories, or laws“.

More detailed surveys of available definitions can be found e.g. in [3] or [4] where the most frequented terms and definitions cover explanations such as „a scientific and systematic search for pertinent information on a specific topic“ (i.e. activities that aim only to describe a situation or circumstances and answer the questions „How many?“, „Who?“, What is happening?“); „a systematized effort to gain new knowledge“, „a movement from

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known to unknown“ or simply „the manipulation of things, concepts or symbols for the purpose of generalizing to extend, correct or verify knowledge, whether that knowledge aids in construction of theory or in the practice of an art”. The research is also „a systematic approach concerning generalisation and the formulation of theory“, „the manipulation of things, concepts or symbols for the purpose of generalising to extend, correct and verify knowledge, whether that knowledge aids in construction of theory or in the practice of an art“.

Within the context of these sample definitions one could distinguish different orientations of research activities: exploratory or formulative research, descriptive research, diagnostic research and hypothesis-testing research. Generally, each of them pursues different research objectives:

a) *Exploratory* or *formulative* research aims at gaining familiarity with a phenomenon or achievement of new insights into it;
b) *Descriptive* research aims to portray accurately the characteristics of a particular individual, situation or a group;
c) *Diagnostic* research is performed with the aim to determine the frequency with which something occurs or with which it is associated with something else;
d) *Hypothesis-testing* research aims to test a hypothesis of a causal relationship between variables.

In addition to classification mentioned above, research is often used to be classified to *fundamental* or *applied*, *qualitative* or *quantitative*, *descriptive* or *analytical*, *conceptual* or *empirical*, etc.

2. RESEARCH METHODOLOGY

2.1 Definitions

Research methodology is a way to systematically solve the research problem. It may be understood as a science of studying how research is done scientifically [4] . It is sometimes misinterpreted as a *research method*, *technique* or *instrument*. To avoid potential misunderstandings the hierarchy of mentioned terms is depicted in Fig. 1.

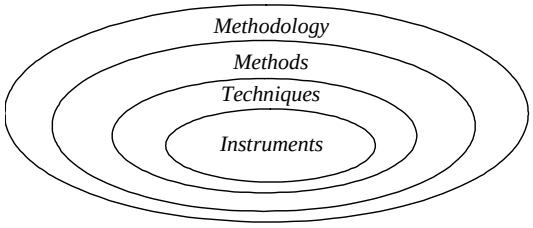

Fig.1. Mutual relationship among considered entities.

From a philosophical point a view, a *method* represents a particular conscious and meaningful procedure used to transform initial resources of a certain strong-minded activity to an intentional, partially or fully realized, objective [6]. *Research technique* refers

to the behaviour and instruments we use in performing research operations such as making observations, recording data, techniques of processing data and the like. For example, in case of software system design the method determines what should be done within a particular development phase of the life-cycle and what rules should be respected, i.e. the method provides rules and directives (guidelines) for reaching certain objectives. The rules specify the order of performed activities; directives and/or guidelines classify possible approaches (e g. structure-based or object-oriented based approach in software engineering). A methodology deals with examination of methods and represents a recommended summary of procedures saying who, what, when and why should perform in the life-cycle of the system. A relatively detailed and organized guideline saying how to apply the methodology is usually called a methodics.

The term *research method* is very close to the term *scientific method*. The research method is considered to be scientific provided that it is objective (free from personal prejudice), logical and systematic. Another looking at the nature of scientific method (sometimes called radiical empiricism) results from a widespread idea that a work only deserves to be qualified as *scientific* if it is supported by *empirical evidence* (from the Greek *empeiria*, experience) [7]). Critics of the so called radial empiricism like to say that the distinguishing feature of the scientific method is its *public*, *social* character. At present this criticism appears mostly in computer science domains.

2.2 Research process

Research process can be seen as a series of actions that are sequenced in a desired way and leads to effective performance of research. The flow diagram shown in Figure 1 well illustrates what activities the research process consists of.

Any problem can be classified to one three possible classes [10]. Let us have two finite or infinite sets of entities x_i and y_i that represent different phenomena, states, observations, measurements, trials, etc.:

$$X = \{x_1, x_2, x_3, ...\} \qquad (1)$$
$$Y = \{y_1, y_2, y_3, ...\}$$

and relation R defined as mapping:

$$x_i \xrightarrow{R} y_i \qquad (2)$$

where $i = 1, 2, 3, \ldots$

Situation when only 2 out of the triple [X, R, Y] is called a problem (task). Then problem solution is equal to searching for the third unknown component. That means there are three basic kinds of problems:

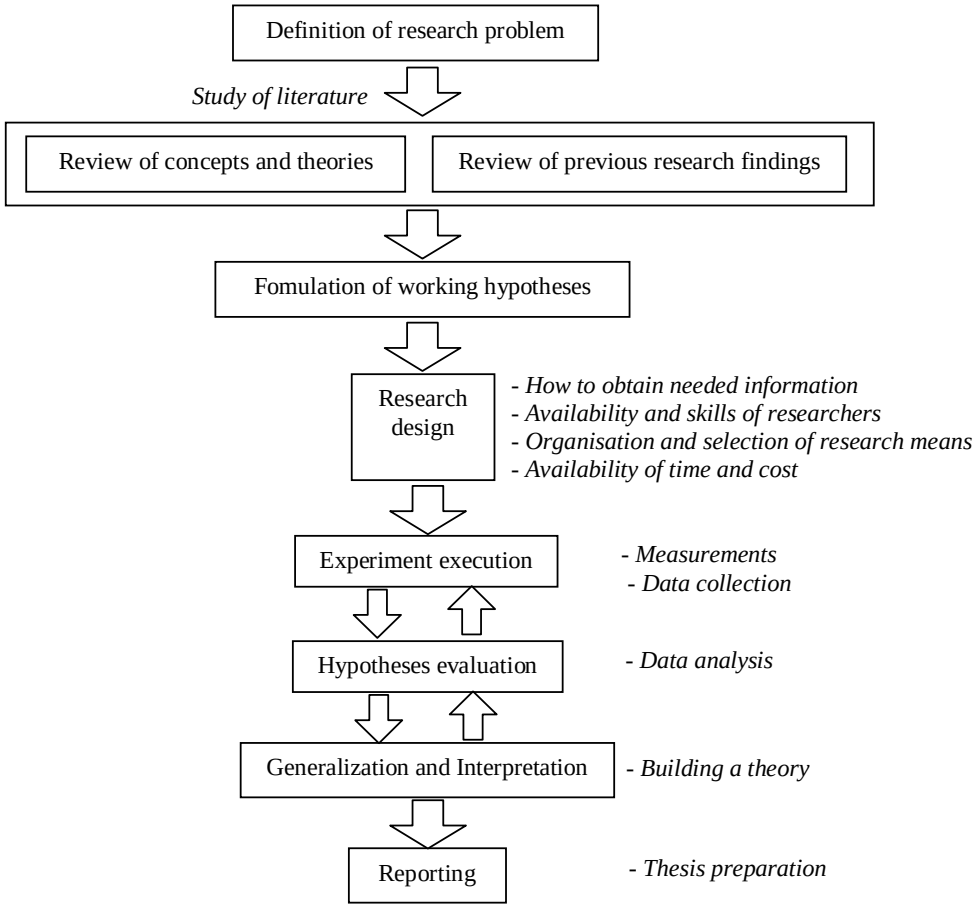

Fig.1. Flow diagram of research process.

a) [*X*, *R*, ?], which is known as *deduction*;
b) [?, *R*, Y], which is known as *abduction*;
c) [X, ?, Z], which is known as *induction*

For the problem a) and partially b) we are usually able to find exact solution. For the problem c) and partially b) only hypothetic problem solution is usually available. To give a trivial example, we could imagine the following triple [*X*, *R*, *Y*] where:

$$X = \{2\},\ R = \{\hat{}2\},\ Y = \{4\}.$$

Then we can imagine the following problem solutions:

a) For deduction: $x = 2$, $R = x\hat{}2 \rightarrow y = 4$;
b) For abduction: $y = 4$, $R = x\hat{}2 \rightarrow x = 2$; $x = -2$
c) For induction: $x = 2$, $y = 4 \rightarrow R = +2$; $R = *2$; $R = \hat{}2$; ...? (hypotheses)

Within examples of deductive problems we could mention finding response of the computer system (or any other technical, social or biological system) for a given input, running of particular computer program and so on. From the viewpoint of inferring one rule from the other deduction has a form of the rule known as Modus Ponens and notated in the form (3):

$$A, A \rightarrow B \vdash B \tag{3}$$

As a typical abduction problem we could mention the problem of technical or medical diagnostics, consultation expert systems and so on. Typical induction problems could be:

- Identification of a system;
- Searching for proof of a mathematical theorem;
- Design of computer program;
- Composition of a plan for robot movement/operation;
- Synthesis of a regulator based on certain input conditions, etc.

2.3 Objectives of research

To discuss different aspects of research process we may not omit the motivation in research. The possible motives for doing research may be different and classified (e.g. in accordance with [4]) to:

a) Desire to get a research degree along with its consequential benefits;
b) Desire to face the challenge in solving the unsolved problems, i.e., concern over practical problems initiates research;
c) Desire to get intellectual joy of doing some creative work;
d) Desire to be of service to society;
e) Desire to get respectability.

Obviously, the given list of hypotheses is not exhaustive – every researcher may have own internal motivation factors that drive him or her in the scientific work.

2.4 Hypothesis

One of the key concepts within the research process is the concept of *hypothesis*. A working hypothesis is a suggested tentative solution of explanations of a research problem which may or may not be the real solution. The task of research is to test and establish such hypotheses To formulate hypothesis also means to designate further steps of the research process – design of new theoretical models, new measurement and/or calculating approaches, simulation, practical experiments, observations etc. When talking about hypothesis we have an assumption in our mind which has a character of a proposition or a set of proposition whose validity may be either proved or rebutted. For example such a proposition may represent

the occurrence of a phenomenon either asserted merely as a provisional conjecture to guide some investigation or accepted as highly probable in the light of established facts.

At the moment when hypothesis is being formulated it is impossible to say whether it is true or not. From a lexical point of view, the hypothesis may be in one of the following forms:

a) IF proposition A is true THEN proposition B is also true … relationship between 2 variables;
b) I suppose that … declarative clause;
c) Question.

When a prediction or a hypothesised relationship is to be tested by scientific methods, it is called a *research hypothesis*. Computing increasingly employs experimental (scientific) methods to test hypotheses about complex information processes. The well-defined hypothesis must be objectively verifiable and testable and therefore it should:

a) Be clear and precise;
b) Be capable of being tested;
c) State relationship between variables (if applicable);
d) Be limited in scope, i.e. be sufficiently narrow to enable its testability;
e) Be understandable, i.e. stated as far as possible in most simple terms;
f) Be consistent with most known facts;
g) Be amenable to testing within a reasonable time;
h) Must actually explain what it claims to explain.

In most types of research, the development of working hypothesis plays an important role – to guide the researcher by delimiting the area of research and to keep him/her on the right track. Working hypotheses arise as a result of a-priori thinking about the subject, examination of the available data and material including related studies and the counsel of experts and interested parties. Working hypotheses are more useful when stated in precise and clearly defined terms.

Experimental phase, based on collecting data from models or real instruments, makes possible to obtain facts which either support the hypotheses or on the contrary refuse them. The hypotheses may be tested through the use of one or more tests, depending upon the nature and object of research inquiry. Hypothesis-testing will result in either accepting the hypothesis or rejecting it. Activities in academic (university) research often classify hypotheses as follows [8].

An early (initial) hypothesis

This kind of hypothesis is related to introductory study which is aimed at analysis of the problem and its background, mapping of the state-of-art, knowledge, importance of practical solution as well as partial objectives. It is a theoretical hypothesis since it is based on theoretical definitions. However, in fact it is not a right hypothesis because of its complex structure and dealing with partial problems only. It can be neither proved nor refuted. Its purpose is just to play a role of understanding the research problem. Understanding is associated with modelling, a key aspect of understanding. One cannot determine whether a system can be built or represented without the understanding needed to

pose hypotheses, theses, or formal requirements [9]. No research would start without early hypothesis despite its main disadvantage is a high level of generality and non-transparency. Mostly it has a character of deductive methods. For example, our initial hypothesis could be that there is a relation between the quality of the final software product and the quality of the models used to generate it, such as their consistency and completeness.

Working hypothesis

Introductory hypothesis should be elaborated and split into partial hypotheses which are called working hypothesis. A set of working hypotheses should be so concrete that it is possible to define direct relation to a set of techniques for collection of empirical data (e.g. observations, experiment, statistic data, questionnaire, practical realisation, etc.). Wrong transition from introductory to working hypotheses results in descriptive character of investigation and impossibility to identify the real nature of investigated phenomenon.

Statistic hypothesis

The statistic hypothesis can mostly be found in economic and pedagogical researches. Working hypotheses can be verified (refuted) on the vase of empirical data distribution characterising the investigated phenomenon. Not every working hypothesis can be simply transferred to statistic hypothesis; respectively not every problem to be solved can be investigated using statistic methods. Statistic hypotheses are a special case of empirical hypotheses, verifiable based on empiric material.

3. CONCLUSIONS

Good science requires relevance to the real world, measurements and experimental validation, testable hypotheses, and models with predictive power. Existence of a well-defined hypothesis is a key factor in the research process (more or less important depending on kind of research). Especially young scientists (PhD students) sometimes underestimate significance of hypothesis-based approach to their research activities which then brings misunderstandings and disappointment when reviewed achieved results.

4. ACKNOWLEDGEMENTS

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