SCITECH
RESEARCH ORGANISATIONS

Volume 8, Issue 2
Published online: August 20, 2018

Journal of Progressive Research in Social Sciences
www.scitecresearch.com

Statistical Probability in the Social Sciences. An Analysis on Methodical-Constructive Basis

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Abstract

The article analyzes the probability concept of the empirical social sciences. Basis of the study is the Methodical Constructivism. In particular the author asks whether the calculation of the statistical probability can be justified. The answer is: If references to the objects of science – colloquially "to reality" – are to be produced in the empirical social sciences, then it cannot be justified to calculate the statistical probability on the model of the natural sciences. According to the model, the use of the probability concept is based on mathematisation. "Mathematisation" means: The calculation of the statistical probability is favored at the expense of its empirical relevance. The article recommends investigating in the future what consequences it has when empirical educational research sets the course for individual CVs and social designs based on meaningless statements.

Keywords: Kolmogoroff's Probability Theory; Statistical Probability Theory in The Social Sciences; Methodical Constructivism; Logical Empiricism; Predication on Empirical Basis; Representation Theorem; Limits of Statistical Probability Theory; Mathematisation of Reality.

1. Introduction

It is hardly ever possible for scientists to rule out with certainty the fact that the findings of a study are already obsolete by the time they are first released. In that respect, empirical statements initially apply to the past. Accordingly, temporarily they are formulated in the past tense. For example, when skills in the subject of geography are tested in a secondary school, it is said: "The pupils were able to…". Only when the expectation of coming developments is justified can the past tense of the statement rightly be replaced by future-oriented phrases such as "The pupils can (in the future) …"

But how can statements on the past be provably projected into the future? The question as to the origin of answers to matters of the future has been addressed differently throughout history. In Ancient Greece, the oracle was supposed to provide indications of future events. In Delphi, a medium inspired by God gave answers to verbal or written questions. The information often claimed to have general validity beyond the individual case. Pronouncements were made on cultural, political and military matters, as well as on personal plights. In Ancient Rome, haruspices practised the interpretation of the future by examining entrails. The livers of the sacrificial animals were considered to be a microcosm that reflected the general state of the world. The teaching was recorded in detail in the literature. Haruspices were educated in part by the state. For a time, they were appointed by the Roman senate to make individual prophecies.

In the first third of the twentieth century, predictions have been passed to science through the theory of probability. Mathematical methods now aimed to calculate the occurrence of future events based on previous events. As statistical probability, the basic idea has found its way into the social sciences. In probability-based expectations of future developments, empiricists in modern times set the course for individual CVs and social designs.

This paper's question is posed with a view to the implications of the interventions in the areas of education, psychology and sociology. The aim below is to clarify whether the calculation of probability can be justified in the empirical social sciences.

Studying whether mathematics rightly forms the basis for social-scientific predictions is not unproblematic. Jürgen Mittelstraß (1992) declared the Renaissance artist, technician and architect Leonardo da Vinci to be the eponym of the mod-

ern world, in which mathematics shapes all thought and action. So regardless of the contemporary appreciation of mathematics, can the role it plays in one of its applications, the statistical probability, be analyzed?

The following study builds on Methodical Constructivism, an epistemological position that is characterised by two principles. First, the eponymous methodical principle and, second, the dialogical principle as developed further by Kuno Lorenz (2009).

2. Statistical Probability

In 1933 the Soviet mathematician Andrei Nikolajewitsch Kolmogoroff (1933, reprint 1973) presented the draft of an axiomatic probability theory. In the preface the scientist states that he was able to develop the theory after two important mathematical foundations became available. These were measure theory and functional analysis. The consequence of the foundation work is that the events to be predicted can be presented by means of set theory.

Below the concept of statistical probability is outlined, which was adapted from the classical theory of Kolmogoroff for application in the social sciences. The presentation follows the explanations in standard texts (Bortz 1993, Clauß and Ebner 1989, Wolf 1974) that were written for application in the fields of education, psychology and sociology.

The definition of the statistical probability theory presupposes several fundamental concepts. In line with the list by Wolf (1974, 297 – 307), these are:

- Event – the outcome of an experiment (e.g. a test survey);
- Experiment – the totality of conditions that lead to an event;
- Certain events – events that occur every time an experiment is conducted;
- Random event – the event may occur when an experiment is conducted, but not necessarily;
- Impossible event – an event that definitely cannot occur when an experiment is conducted;
- Random experiment – the experiment can be repeated at will, its events are random events;
- Set – the totality of similar objects in which one or more characteristics can be observed. Each object is called an "element of the set". In the parlance of Logical Empiricism, the subject matter of a study (in the case of statistical probability these are individuals or events) is called an object. Later in this account, the object concept will be compared with the concept of the entity (Gegenstand). In this manner the different steps in the constitution of the object area in Logical Empiricism and in the constitution of the entity area in Methodical Constructivism can be labelled more easily. Colloquially, the object area and the entity area could also be termed as "the reality";
- Event space – the set of all possible events from an experiment;
- Variable – a symbol for a set of characteristic values.

Three conditions must be met for statistical probability. These are:

1. The experiment in which A is a possible event is a random experiment;
2. h(A) is the relative frequency of the occurrence of A under

$$h(A) = \frac{k}{n} = \frac{\text{Number of experiments with outcome A}}{\text{Total number of experiments}};$$

3. With an increasing n, the relative frequency differs less and less from a fixed, real number, which is called the limit value of the sequence of numbers.

When these conditions are met, the fixed number mentioned in point 3 is defined as probability P (A). **Table 1** is intended to give an impression of the third condition.

Table 1: Illustration of condition 3 of the definition of statistical probability (excerpt of a table by Wolf 1974, 25). The results were registered by the British mathematician Karl Pearson (1857 – 1936) when tossing a coin.

Total number of tosses	Number of tosses with the result		h(Heads)
	"Heads"	"Tails"	
24000	12012	11988	0.5005

Details of the statistical probability concept are explained using a (fictional) example. A test is conducted with the aim of determining the geographical knowledge and skills of pupils in a secondary school. From a statistical perspective, this group of pupils is called a set, consisting of m pupils. Pupil 1 is called "Element 1", Pupil 2 is "Element 2", and so on, up to Pupil m. The characteristics studied are geographical knowledge and skills, measured by the points in a test. The characteristic is marked by a variable (X). Test value $x_1 = 5$ is produced by Pupil 1, test value $x_2 = 8$ by Pupil 2, and so on, up to $x_m = 15$.

The test values x_i (for i = 1, 2 …, m) of the variable X show the quantitative dimensions of the characteristic "geographical knowledge and skills" at each element of set M. Statistical probability – unlike classical probability – does not presuppose equally probable elementary events. The test values can vary from element to element, depending on influences that can be regarded as random. "The events are random" means: in each new test, a raw test value cannot be predicted exactly, but can probably be expected within certain limits. No test value can lie below 0, and none can exceed the highest amount of points that can be reached in the test. If, according to empirical accessibility, a distinction is made between manifest and latent variables, it can be assumed that some pupils would have been able to demonstrate greater geographical knowledge and skills, if only more difficult test tasks had been constructed. The same applies to the lower limit of the test. It can therefore be said that the statistical probability – in turn, in contrast to the classical concept of probability – does not presuppose any finite event space. Ultimately, statistical probabilities – in contrast to classical probabilities – can be gained only from the results of a conducted experiment (in this example, the test). For a pupil who attained k = 20 correct solutions from n = 40 test questions sample, the relative frequency is calculated according to $h(A) = \frac{k}{n} = \frac{20}{40} = \frac{1}{2}$. If the three aforementioned conditions are met, according to the conception, the relative frequency can be interpreted as probability P(A) = 0.50.

3. Predication on Empirical Basis

"Predication on empirical basis" is the name of a concept that was designed for the development of a methodical-constructive educational diagnostic (Krope 2000). Below, the two essential features of this concept, the predication and the reference to the empirical level, will be presented in preparation for an answer to the question posed in this paper.

The background of the presentation is an empirical study. In the years between 2013 and 2015, the Grundtvig project "Domestic Violence Met by Educated Women" (DVMEW) was conducted. The impulse-giver was the Istanbul Convention, an international treaty that bears the name "Council of Europe Convention on preventing and combating violence against women and domestic violence". The DVMEW project was carried out as an EU study in five countries. Women's organisations from Germany, Finland, Romania and Slovenia and an organisation from Sweden took part. The Zentrum für Konstruktive Erziehungswissenschaft at the University of Kiel (ZKE) made several contributions to the project. A report on the work of the ZKE was published by Krope and Petersen (2015).

One of the objectives of the DVMEW project was to examine empirically the experiences of female European academics with domestic violence. The developments presented by the Kiel team in this context include the explicit and unambiguous definition of violence, developed by Petersen (2015). The definition can be expanded by the term "experience$_2$" (Widerfahrnis). With reference to the term "experience$_2$" (Widerfahrnis) introduced by Kamlah (1973), experience is determined as a proficiency that presupposes an experience$_2$ (Widerfahrnis). This proficiency is the ability of secure orientation in familiar contexts of action and facts. This is the sense in which we refer to "people who have experienced violence". Experience on a pre-scientific level varies with the everyday situation.

With the definition, the first part of the task, the predication, should be completed successfully. Here, "predication" refers to a fundamental act of speech, with which elementary statements can be gained on the basis of Methodical Constructivism. Here, in simple actions, of which it is assumed that they are already understood, something is stated about an entity in that reference is made to it. In the process, words are allocated to the entities. These words are called "predicators". The process is called "predication". With a predicator, a distinction is made at the entity level.

According to Lorenzen (1987, 20 – 21, 41 – 42), predicators, such as the predicator "violence", are learned in empractical speech. "Empractical speech" means: verbal action is related to non-verbal action in such a manner that the former can be controlled by the latter. This action-related usage can be presented as if it would follow certain rules. This means it can also be said that the use of a predicator is correct when it complies with the rules, and incorrect when it is used in contradiction of these rules. In the first case, the corresponding statement is true, in the second it is false. The introduction of "true" and "false" necessitates explaining the use that should be made of the predicators in question by the introduction of rules that have been followed by the discussion participants until now, and which they wish to continue following. A predicator for which explicit rules have been agreed, as an element of a scientific language, is called a "term". If the phonological form of a term is ignored, and attention paid only to its standardised use, then we speak of a concept (Kamlah and Lorenzen 1973, 86). The definition provided by Petersen represents a system of concepts.

The elementary statement formed with predicators has the form $x \varepsilon Pr$, with Pr for "predicator", and the affirmative copula ε as a sign for attribution and the negative copula ε' for denial. Based on the statement by Lorenz (1995, 312) that the

copulae represent the connection of a piece of language with a piece of the world, the ZKE team could assert the claim that it has created, with its definition of violence, the relation between the presentation level and the entity level, or from another perspective, between the rational and empirical level. "Empirical study" is therefore the attempt to prove the claim to have rightly attributed the predicator.

Over the course of the project, conferences were staged in the EU countries involved. On these occasions, the ZKE organised meta-plan meetings, in which the participants were requested to give feedback, present their own view of problems, and suggest ideas for their solution. The objection was frequently raised that the Kiel team's definition of violence did not provide an insight into all dimensions of the individual experience of violence of each individual participant. This separation is problematic when it comes to constituting the relation to reality in speech and action. In the framework of the DVMEW project, the concepts of the definition of violence remain devoid of content as long as it cannot be demonstrated that pragmatic connections can be made with the entity level.

In this situation, the term "entity", which was already used above, takes on a special significance. "Entity" (E.) is "the most general predicator, and therefore no longer suitable for distinction: for each Predicator Pr, the conceptual determination $x \varepsilon Pr \Rightarrow x \varepsilon E$. (everything that is Pr is also E.) takes effect. This explanation is equivalent to naming everything that can be represented by a proper noun an 'entity' […]" (Lorenz 1980, 714/715; the letter "G" in the original is replaced by "E" and "P" by "Pr" in the quote, P.K.). If no predicators that have already been introduced are available, the speech development begins with the entity. Linguistically, the entity is then represented by a nominator (e.g. a proper noun), by an indicator, or by a designation, which in the statement form "$x \varepsilon Pr$" take the position of *x*.

In the DVMEW project, the entity was represented by participants by means of the following actions, among others:

- A female social education worker lists 45 cases of battered women.
- During a DVMEW conference, a banner with the picture and name of an abused migrant woman is shown.
- A doctor reports on her missions abroad to provide medical treatment to female victims of violence.
- A volunteer carer reports on her experience of violence in a Roma village.
- An employee describes the conditions in a women's shelter.
- The ZKE team refers to the novels "Effi Briest" by Theodor Fontane and "Anna Karenina" by Leo Tolstoy.

As long as the participants in the DVMEW project remain with their respective speech actions, they are fully "with their entity", but unable to say anything about that, since the entity is in each case only "their entity". The participants must make their experiences communicable, if they want to articulate them. According to Lorenz (2009), the entity level can be developed by means of phenomenological reduction. In a subsequent step, the implicit predicator rules of everyday language must then be explained. Finally, as soon as the abstraction process and the development of the predicator rules for the terms have been concluded, the definition can be shown at the presentation level. Against the background of the task which the DVMEW project set itself, this is a definition of violence. It has the form "Violence $\leftrightharpoons P_1 \wedge P_2 \wedge \ldots \wedge P_n$", with "$\leftrightharpoons$" as a definition sign, "$\wedge$" for "and", as well as "P_1" to "P_n" as predicator variables. The developments of the entity level and the presentation level are mutually dependent on each other. Statements about the experiences of the academics remained factually blind without the development of the entity level, and conceptually empty without the development of the presentation level, in one and the same development process.

Two principles are determinant for Methodical Constructivism. The methodical principle is responsible for the differentiation performed by predication. Thus, in the DVMEW project, a distinction can be made between "violence" and "non-violence", based on the definition by Petersen. Here, the dialogical principle, which was developed further by Kuno Lorenz, is the prerequisite for the applicability of the methodical principle: "Every distinction gained through the methodical principle is available collectively only" because it is acquired by the predicating persons "in a dialogical elementary situation of teaching and learning" (Lorenz 2009, 16). The DVMEW project is described elsewhere (Krope 2018) with a focus on the presentation of the dialogical principle.

4. The Representation Theorem

The constitution of the entity area on the basis of Methodical Constructivism is described above. Now we are concerned with the constitution of the object area, against the background of Logical Empiricism. For the sake of easier presentation, this paper distinguishes between "entity" (Gegenstand) and" object" and, accordingly, between the "entity area" and the "object area".

The set theory is of key significance when calculating statistical probability. A set is described by real numbers attributed to the objects. This means that the object area is the area to which the real numbers relate, and which therefore must be available, structured in countable units. The real numbers are contained in the presentation area.

In classical measurement theory, according to Suppes and Zinnes (1967), the relationships between the object area and the presentation area are shown in the representation theorem. Formally, an empirical relative is first described. Secondly, a numerical relative is defined. Under certain conditions, the empirical relative can be illustrated in the numerical relative. Measurement theory is concerned with naming rules that must be met in the empirical relative in order for it to be illustrated in the numerical relative. The representation theorem performs this task.

For empirical studies in the social sciences, the theory of measurement can be translated into a definition of measurement, which stems from work by the physicist and philosopher Campbell (1938). According to Campbell measurement consists – put simply – of the allocation of numbers to objects, whereby relations between the objects reflect analogous relations between the allocated numbers.

Guilford (1954, 11) describes the relations between the real numbers that are significant in the empirical social sciences in nine axioms. These are three axioms of identity, two axioms or sequence, and four axioms of additivity. The decision as to which statistical calculations can be carried out depends, among other things, on which of the axioms apply. If the nine axioms are simplified into four characteristics of real numbers, the calculation possibilities can be compiled into four categories called "measurement levels" **(cf. Table 2).** According to the terminology introduced by Stevens (1946), measurements are taken at different measurement levels, and then allow different statistical operations, depending on which axioms come into question for the numbers. The measurements are divided hierarchically from the (simplest) nominal level, in which only equality or inequality play a role, to the (in ascending order) ordinal, interval, and ratio level. The nominal level is determined only by the equality-inequality ratio. In all other measurement levels, more and more axioms, in ascending order, must be fulfilled, in order for the respective statistical operations to be carried out correctly. As an example of the dependency, the calculability of the central tendency is shown in **Table 2.** At the nominal level, it is only allowed by method to calculate the mode as a measure of the central tendency. At the ordinal level, the calculation of the median is permitted in addition, and so on. At the ratio level, all of the subordinate parameters in the hierarchy, as well as the geometric and harmonic mean, may be calculated.

Table 2: Measurement levels according to Stevens (1946) and calculation possibilities of the central tendency, depending on the respectively valid characteristics of the real numbers.

Measurement level	Characteristics of real numbers	Calculation of the central tendency
Nominal	1. Equality and inequality, e.g.: 4 = 4 and 4 ≠ 5.	Mode
Interval	1. Equality and inequality, 2. Order, e.g.: 4 < 5 and 5 > 4.	Median
Ordinal	1. Equality and inequality, 2. Order, 3. Equality of differences, e.g.: 45 – 40 = 24 – 19.	Arithmetic mean
Ratio	1. Equality and inequality, 2. Order, 3. Equality of differences, 4. Equality of quotients, e.g.: $\frac{80}{10} = \frac{-24}{-3}$.	Geometric and harmonic mean

According to the concept of Logical Empiricism, the scientist's task is to test which of the characteristics (axioms), which are valid for the real numbers, are also valid for the objects. Using the example of performance assessment in a high school class in geography, Wolf (1974, 56/57) presents this examination procedure for grades in the German school system as follows:

"We expect the following:

1. If two equal measurement results arise in this class, it means that two pupils receive the same score in the subject of geography, and thus these pupils have also shown the same performance. The equality of the numbers has empirical significance.
2. If one measurement result is greater than the second (e.g. 4 greater than 2), the first pupil has a lower performance than the second. The order of numbers has empirical significance […]".

In points 3 and 4 Wolf treats the interval and the ratio levels in the same way as the nominal and ordinal levels.

The procedure in this example can be explained as follows. The educationalist translates statements of a pre-scientific language, with which an everyday situation is illustrated, directly (without any intermediate methodical steps) into terms of a scientific language. That is the language of mathematics at the presentation level. The question remains open: How, in a confrontation, can a judgement expressed in everyday language on the allocation of numbers to objects be replaced by a situation-independent decision-making process?

With its dichotomy, the procedure in the case of the performance measurement in the secondary school class recalls the two-step model from the tradition of Logical Empiricism. According to the model, developed by Rudolf Carnap (1959), the observation language belonging to the pre-scientific observation should be differentiated from the theoretical language of a theory to be controlled empirically. Among the critics of the model was Wolfgang Stegmüller (1970), whose analysis suggests that the model failed for logical reasons.

The measurement theory described by the representation theorem is concerned with naming rules that must be met in the empirical relative, so that it can be illustrated in the numerical relative. After the failure of Carnap's attempt to introduce empirical content to mathematics, the object area is constituted from the presentation area, in accordance with the axioms that apply for the real numbers. A criterium that is independent of the axiomatic is not evident.

Therefore, the use of the probability concept, against the background of Logical Empiricism, is based on a mathematisation. We speak of the mathematisation of the object of a study when the calculability of the statistical probability is favoured at the expense of its empirical relevance.

According to Krope (2000, 51/52), a statement that presents the multiplicity of same facts is called a "quantitative statement". The prerequisite for quantification is a statement that presents the facts as equal or unequal, and which is called a "qualitative statement". The possibility to formulate qualitative statements is based on the differentiation performed by predication. The formulation of quantitative statements on a methodical-constructive basis should not be confused with a mathematisation.

5. Conclusions

It was shown above how statistical probability is calculated in Logical Empiricism. However, if the key question of this paper is to be answered on the basis of the same position on which the calculation takes place, an answer could be given only within a limited framework. For a statement formulated using the means of Logical Empiricism is a statement within this position, but not a statement about it. For this reason, a second position was introduced above, to allow an observation from outside: Methodical Constructivism.

As an example of the latter, the methodical-constructive study was described in which academic women in Europe who had experienced domestic violence were surveyed. The entity level was developed according to the procedural rules of phenomenological reduction, the presentation level was developed under the procedural rules of predication. Both levels are mutually dependent on each other. For statements about experiences, the syntax and semantics of scientific language are made available in Methodical Constructivism as interpreted formal language.

As an example for a procedure in the context of Logical Empiricism, the performance evaluation of secondary school pupils during a geography lesson was chosen. The relation between presentation level and object level in this process was examined above with three different accentuations. First, the set-theoretical foundations of probability theory described by Kolmogoroff (1973), the consequence of which Seiffert (1973, 15) summarises as follows: "Mathematical set theory understands the set as the result of a process of an abstraction from *formulae* […]". Secondly it was indicated that Carnap's (1959) attempt to introduce empirical content into mathematics by means of the differentiation of observation and theoretical language failed after the verdict by Stegmüller (1970). Thirdly, it was pointed out that the rules demanded in the representation theorem of Suppes and Zinnes (1967) for the empirical relative (the object level) are not explicitly available. In Logical Empiricism, a scientific language with a high degree of formalisation is made available for statements about experiences in a closed formal system without any content-related reference to its objects.

In conclusion, the opening question of this paper must be answered. To answer the question of justification, the "if A, then B" combination of deontic modal logic (Krope et al. 2013, 30 – 39) is used. The answer is: If, in the empirical social sciences, connections are made to the objects of science – colloquially, "to reality" – and experiences are to be presented in a methodically understandable manner, it cannot be justified to calculate statistical probability on the basis of Logical Empiricism.

Ignoring content-related references in favour of calculability has been termed above as the "mathematisation of the object". Mathematisation is no exception in empirical education research in the Federal Republic. PISA studies, for example, are conducted on the basis of probabilistic test theory. This theory has the theoretical deficits described above for the calculation of statistical probability. Furthermore, its calculation methods presuppose irregular transformations insofar as

the axioms from the concept of the measurement level are violated. It is reserved for future research to study the consequences of mathematisation in the empirical social sciences for learners and teachers.

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