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Review Article

Two Dimensions of the Progressiveness of Scientific Problems

Zhen Dong Shen*

School of Marxism, Jiangsu Second Normal University, China

Corresponding author: Zhen Dong shen, School of Marxism, Jiangsu Second Normal University, Nanjing, Jiangsu 210013, China.

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Abstract

How to characterize the progressiveness of scientific problems from a logical perspective? This article attempts to characterize the progressiveness of scientific problems by introducing the concepts of rank and moment of scientific problems:

I. defines two dimensions of the information domain of scientific problems - rank and moment;

II. resolves the comparison of progressiveness between different and related scientific problems by comparing their ranks and moments.

Keywords: Scientific problems; Rank of information domain; Moment of information domain; Progressiveness of scientific problems

Introduction

We know that problems serve as the precursor to theoretical development. The formulation of a good scientific problem not only reflects the comprehensiveness, depth, and progressiveness of the background knowledge associated with the problem, but also to some extent determines the direction of theoretical advancement. So, what are the criteria for a good scientific problem? In other words, what are the standards for measuring the progressiveness of a scientific problem? This article discusses these issues from two dimensions: the vertical dimension, which can be characterized by the rank of the information domain defined in this article, and the horizontal dimension, which can be characterized by the moment defined in this article.

Rank of the information domain

Let's consider the existence of two sets of correlated variable groups: $p_1, p_2, \ldots p_m$ * MERGEFORMAT ; $q_1, q_2, \ldots q_n$ * MERGEFORMAT. According to the classification criteria of species concepts, $p_1, p_2, \ldots p_m$ * MERGEFORMAT and $q_1, q_2, \ldots q_n$ * MERGEFORMAT belong to different species concepts. If we can logically deduce that if set Π_1 * MERGEFORMAT(formed by variables in group $p_1, p_2, \ldots p_m$ * MERGEFORMAT) exists, then set Π_2 * MERGEFORMAT(formed by variables in group $q_1, q_2, \ldots q_n$ * MERGEFORMAT) also exists, we can say that the information content of set Π_1 * MERGEFORMAT is more profound than that of set Π_2 * MERGEFORMAT , indicating that the rank of set A is greater than the rank of set B. This relationship is denoted as $|\Pi_1| \succ |\Pi_2|$ * MERGEFORMAT .

The rank of the information domain is a conceptual classification of the information within the domain, reflecting the hierarchy and depth of the information. Correlated variables with the same rank belong to the same level of correlated variable sets, while correlated variables with different ranks belong to different levels of correlated variable sets. Lower-rank correlated variables are subordinate concepts to higher-rank correlated variable sets, while higher-rank correlated variables are species concepts to lower-rank correlated variable sets.

For example, ||{prime numbers, composite numbers}|| $\succ$ * MERGEFORMAT||{integers, fractions}||. Here, integers are the subordinate concept to both prime numbers and composite numbers, while prime numbers and composite numbers are species concepts of integers. From the perspective of cognitive science, higher-rank correlated variables are based on lower-rank correlated variables. For example, without the concept of integers, we cannot define the concepts of prime numbers and composite numbers. However, having the concept of integers does not necessarily lead to the concepts of prime numbers and composite numbers. In other words, once we have the concepts of prime numbers and composite numbers, we can logically conclude that integers are already defined concepts, and integers and fractions belong to the same level as subordinate concepts.

Another example is ||{Is God all-powerful?}|| $\succ$ * MERGEFORMAT||{Does God exist?}|| ,because regardless of the answer to "Is God all-powerful?"—whether it is yes, no, or meaningless—it logically entails its predecessor question, "Does God exist?" We can also say that a problem with a higher rank in the information domain is a subsequent problem to a problem with a lower rank, and a problem with a lower rank is a predecessor problem to a problem with a higher rank. The higher the rank of the information domain, the deeper the information reflected by that domain.

Moment of the information domain

According to the classification criteria of subgenus concepts, if two correlated variable sets, Π_1 * MERGEFORMATand Π_2 * MERGEFORMATdenoted as belong to the same-rank correlated variable set, and Π_1 * MERGEFORMAT is a proper subset of Π_2 * MERGEFORMAT, then we say that the moment of is greater than the moment of Π_1 * MERGEFORMAT, denoted as $|\Pi_2| \succ |\Pi_1|$ * MERGEFORMAT.

The moment of the information domain is a concept that characterizes the comprehensiveness of information at the same level within the information domain. For example, when examining the possible outcomes of flipping a coin, based on common background knowledge, we can construct a result set Π_1 * MERGEFORMAT= {heads, tails}. However, if the background knowledge changes, such as learning that the material used to make the coin is very fragile, we can then construct a new result set Π_2 * MERGEFORMAT= {heads, tails, shattered}. Furthermore, if the background knowledge includes the belief that the coin is in a state of complete weightlessness when it is flipped, we can further construct a result set Π_3 * MERGEFORMAT= {heads, tails, shattered, not landing} ... As the background knowledge continues to expand, the constructed information sets become increasingly comprehensive, i.e.,$|\Pi_{i+1}| \succ |\Pi_i|$ * MERGEFORMAT. The moment of the information domain increases gradually as the background knowledge becomes more complete. Therefore, the moment of the information domain reflects the strength of human cognitive ability. The larger the moment, the more comprehensive the constructed information domain, and thus the more comprehensive the solution space of a scientific problem. In the extreme case, when all logical possibilities are taken into account, a closed solution space for a scientific problem can be constructed.

Minimum information set of a scientific problem

Let's consider a scientific problem P that involves different predicates $\alpha_i, \beta_j, \gamma_k, \ldots$ * MERGEFORMAT, where $\alpha_i \in \alpha, \beta_j \in \beta, \gamma_k \in \gamma, \ldots$ * MERGEFORMAT. Here, $\alpha, \beta, \gamma, \ldots$ * MERGEFORMAT are correlated variable sets consisting of all correlated variables with the same rank as $\alpha_i, \beta_j, \gamma_k, \ldots$ * MERGEFORMAT , respectively. The information set Q composed of $\alpha, \beta, \gamma, \ldots$ * MERGEFORMAT is referred to as the minimum information set of the scientific problem P.

In general, for two sequentially related sets of correlated variables in terms of logic, the set of correlated variables with a lower rank is also a set of correlated variables within the higher-rank information domain. However, within the higher-rank information domain, there exists a set of correlated variables that is not a part of the set of correlated variables within the lower-rank information domain. This set of correlated variables is considered the minimum information set of the higher-rank information domain, while the lower-rank information domain can be seen as a presupposition of this minimum information set. The concept of the minimum information set reflects the possibilities of the response domain, the construction of the solution space, and the level of completeness of a scientific problem.

Scientific problem progressiveness principles

Principle of the profundity of scientific problems

Let's consider two scientific problems, P and P', which are based on the same subordinate question. If the minimum information set of scientific problem P is denoted as Q, and the minimum information set of P' is denoted as Q', then if $\| Q' | \succ | Q |$ * MERGEFORMAT, problem P' is considered more profound than problem P.

The principle of the profundity of scientific problems states that if any set of correlated variables $q_1, q_2, \ldots q_n$ * MERGEFORMAT in Q is also a valid set of correlated variables in Q', and Q' contains a set of correlated variables $q_1, q_2, \ldots q_n$ * MERGEFORMATthat are not present in Q, then problem P' is more profound than problem P. In other words, the relationship between the information domains of higher and lower rank is as follows: if the former is a set composed of a group of concepts, then the latter is a set composed of the hierarchical concepts that the concepts in the former belong to.

Example 1: Regarding the same subordinate question "the carrier of genetic information."

In the pre-Mendelian era:

P_1 * MERGEFORMAT : Is the carrier of genetic information a "certain fluid" resulting from the mixture of maternal egg cells and paternal sperm cells?

During the Mendelian era:

P_2 * MERGEFORMAT : Is the carrier of genetic information a unitary particle-like substance (later referred to as a gene) that does not interact in a heterozygous state but is faithfully segregated during gamete formation?

American geneticist Sutton:

P_3 * MERGEFORMAT : Is the carrier of genetic information located on the chromosomes inside the cell?

Canadian scientist Avery:

P_4 * MERGEFORMAT : Is the carrier of genetic information a biochemical substance known as deoxyribonucleic acid (DNA) found within the chromosomes?

Watson and Crick:

P_5 * MERGEFORMAT: Does the double helix structure of DNA and its sequence provide crucial genetic instructions?

Clearly, P5 is more profound than P_4 * MERGEFORMAT, P_4 * MERGEFORMAT is more profound than P_3 * MERGEFORMAT, P_3 * MERGEFORMAT is more profound than P_2 * MERGEFORMAT, and P_2 * MERGEFORMATis more profound than P_1 * MERGEFORMAT. The reason P_{i+1} * MERGEFORMAT is considered more profound than P_i * MERGEFORMAT is that the information content of P_{i+1} * MERGEFORMATexceeds that of P_i * MERGEFORMAT, i.e. $\| P_{i+1} | \succ | P_i |$ * MERGEFORMAT. For example, the chromosome mentioned in P_3 * MERGEFORMAT is also present in P_4 * MERGEFORMAT, but the DNA mentioned in P_4 * MERGEFORMAT is not part of P_3 * MERGEFORMAT's information. Furthermore, we can say that P_{i+1} * MERGEFORMAT represents further progress compared to P_i * MERGEFORMAT.

Example 2: When a glass rod rubbed with silk is brought near a rubber rod rubbed with fur, the following questions are raised: P_1 * MERGEFORMAT: Will they experience relative motion? P_2 * MERGEFORMAT: Will their states of motion be towards each other? P_3 * MERGEFORMAT: Are they accelerating towards each other? Clearly, P_2 * MERGEFORMAT is deeper than P_1 * MERGEFORMAT, and P_3 * MERGEFORMATis the deepest. This is because answering the latter question requires not only addressing the former question but also considering additional information at a deeper level that was not involved in the former.

Principle of Completeness of Scientific Questions.

For scientific questions P and P' formulated based on the same sub question, the minimal information set for question P is Q, and the minimal information set for question P' is Q'. If $|Q'| \succ |Q|$ * MERGEFORMAT, then question P' is more comprehensive than question P.

When the background information contained in a question is broader at the same level, although the uncertainty in answering the question may be greater, the distribution of the possible space of answers to the scientific question will be more complete.

Example 3: In an experiment of flipping a coin, the following questions are raised: P_1 * MERGEFORMAT: Will it land heads up or tails up? P_2 * MERGEFORMAT : Will it land heads up, tails up, or get shattered? P_3 * MERGEFORMAT :For the flipped coin, will the final outcome be heads up, tails up, shattered, or not landing at all? For the successive appearance of P_1 * MERGEFORMAT, P_2 * MERGEFORMAT, and P_3 * MERGEFORMAT, the answer set of the preceding question is a proper subset of the solution space of the subsequent question. The latter expands the solution space of the former by introducing more background knowledge or assumptions, thereby gradually enhancing the scientific completeness. For example, P_2 * MERGEFORMAT considers the material composition of the coin in addition to P1, while P_3 * MERGEFORMATfurther addresses the issue of gravitational effects.

Based on the aforementioned definitions of rank and matrix in the information domain, as well as the two principles mentioned above, we can further derive a general principle for the progress of scientific questions.

Principle of Two-Dimensional Criteria for the Progress of Scientific Questions.

For two related scientific questions P and P', with Π_1 * MERGEFORMAT and Π_2 * MERGEFORMAT being their respective minimal information sets, if any of the following conditions is satisfied: (1) $\| \Pi_2 | \succ | \Pi_1 |$ * MERGEFORMAT; (2) $|\Pi_2| \succ |\Pi_1|$ * MERGEFORMAT; (3) $\| \Pi_2 | \succ | \Pi_1 |$ * MERGEFORMATand $|\Pi_2| \succ |\Pi_1|$ * MERGEFORMAT, then P' represents progress compared to P.

Conclusion

As an important research area in the philosophy of science, the study of scientific questions involves many concepts that require clarification and solidification. In this paper, the author has attempted to address some of the core issues by introducing the concepts of rank and matrix for scientific questions, thereby providing a practical method for comparing the progress of scientific questions. However, due to its innovative nature, the arguments proposed in this paper still require careful consideration and further scrutiny. Additionally, there are other follow-up questions that need to be discussed, such as exploring various logical relationships among scientific questions based on the concepts of rank and distance (e.g., equivalence of scientific questions, inclusion of scientific questions, composite questions, atomic questions, question sequences, and logical implications between questions). These topics will be addressed in future discussions.

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Conflict of Interest

No conflict of interest.

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