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THE FORMATION OF EMPIRICAL METHODS AND EXPERIMENTAL METHODS IN THE SCIENTIFIC HERITAGE OF CENTRAL ASIAN SCIENTISTS IN THE 9TH–12TH CENTURIES

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Abstract

Within the framework of the Islamic Golden Age of the 9th-12th centuries, scholars of Central Asia (Movarounnahr and Khorezm) played an important role in the development of the empirical style and methods of experience in scientific thought. During this period, thinkers such as Abu Rayhan Beruni (973-1048) and Abu Ali ibn Sina (980-1037) enriched the theoretical approaches derived from Aristotle's philosophy with practical observations and experiments. When measuring the Earth's radius, Beruni used trigonometry and empirical experiments on the mountain horizon, developed experimental methods based on equilibrium and water volume to determine the density of matter, and also analyzed astronomical phenomena through precise observations. In his work "The Canon of Medicine" (Al-Qanun fi at-tibb), Ibn Sina systematized the principles of experimentation (tajribah) for evaluating the efficacy of medicinal substances. By combining analogy with experimental trials, he emphasized the necessity of considering factors such as age, gender, dosage, and the state of the illness when determining a drug's potency. These approaches solidified the roots of empiricism in medieval Eastern science and later formed the basis for the European scientific revolution. This article compares the legacies of these scholars, illuminating the mechanisms behind the formation of the empirical method and its place in the history of dunyo science.

Keywords

XI th-XII th centuries, Central Asian scholars, empirical method, experimental method, Abu Rayhan Beruni, Abu Ali ibn Sina, scientific methodology, Eastern Renaissance, dunyo history of science.

Introduction

The 9th–12th centuries are referred to as the “Golden Age” of the Islamic world or the Eastern Renaissance, during which Central Asia (Movarounnahr and Khorezm) became one of the major centers of science. Scientific institutions such as the Ma'mun Academy were established, and encyclopedic scholars such as Abu Rayhan Beruni (973–1048) and Abu Ali ibn Sina (980–1037) were active. These scholars not only preserved Greek, Indian, and Persian heritage through translation but also critically analyzed it and significantly developed empirical methods and experimental approaches. The fundamental elements of the modern scientific method—observation, experimentation, and evidence-based reasoning—began to take shape during this period.

Abu Rayhan Beruni is considered one of the most prominent representatives of the empirical method. In measuring the Earth’s radius, he relied on trigonometry and observations of the horizon from mountain peaks, and he determined the density of substances through experiments based on balance and water volume. In his works such as *“Qanun al-Mas‘udi”*, *“India”*, and *“Mineralogy”*, he confirmed astronomical, geodetic, and natural phenomena through precise observation and mathematical calculations. Beruni regarded experimentation as

"the only means of verifying the truth of knowledge" and insisted that theoretical conclusions must always be tested through practical experiments.

Abu Ali ibn Sina, on the other hand, systematized the empirical method in medicine and philosophy. In his work *"The Canon of Medicine" (Al-Qanun fi al-Tibb)*, he described in detail the rules of experimentation for evaluating the effects of medicinal substances. Ibn Sina combined analogy with experimental testing and emphasized the need to consider factors such as age, gender, dosage, disease condition, and climate when determining the effectiveness of drugs. He viewed experimentation as the primary means of validating theory and introduced observation-based methods in diagnosis and treatment.

This article examines the formation of empirical methods and experimental approaches in the scientific heritage of Central Asian scholars during the 9th–12th centuries. The main focus is on the works of Beruni and Ibn Sina, comparing their experimental approaches and highlighting their place in the history of world science. The relevance of this study lies in the fact that the origins of the modern scientific method are often associated with the European Renaissance, while the contributions of Central Asian scholars during the Eastern Renaissance have not yet been fully appreciated. This work aims to reveal the significance of this heritage and reconsider the history of science from a global perspective.

Main Part

The formation of empirical methods and experimental approaches in the scientific activity of Central Asian scholars during the 9th–12th centuries is one of the most significant achievements of the Eastern Renaissance. This process represents a transition from the theoretical dominance of Aristotelian philosophy to a practical, experimental approach. During this period, empiricism (knowledge based on experience) and the experimental method (verification through testing) became the main principles of scientific research. These changes laid the foundation not only for local scientific development but also for the formation of global scientific methodology.

Abu Rayhan Beruni (973–1048) is recognized as the most consistent and prominent representative of the empirical method. In his works, experimentation is regarded not only as a tool of observation but also as the only reliable mechanism for confirming or refuting theoretical conclusions. Beruni's method of determining the Earth's radius is a classical example of this approach. From a mountain peak in Nandana (present-day Pakistan), he measured the dip angle of the horizon and calculated the Earth's radius using trigonometric principles, arriving at a value of 6339.6 km. Compared to the modern average radius (6371 km), this result has an error of less than 0.5%. The essence of the method lies in the fact that due to the Earth's curvature, the horizon appears lower when viewed from a mountain peak. Beruni measured this angle using an astrolabe and calculated the radius through geometric relationships of triangles. This experiment combined direct measurement with mathematical modeling, distinguishing it from purely theoretical approaches.

(Figure 1: Diagram of Beruni's measurement of the Earth's radius)

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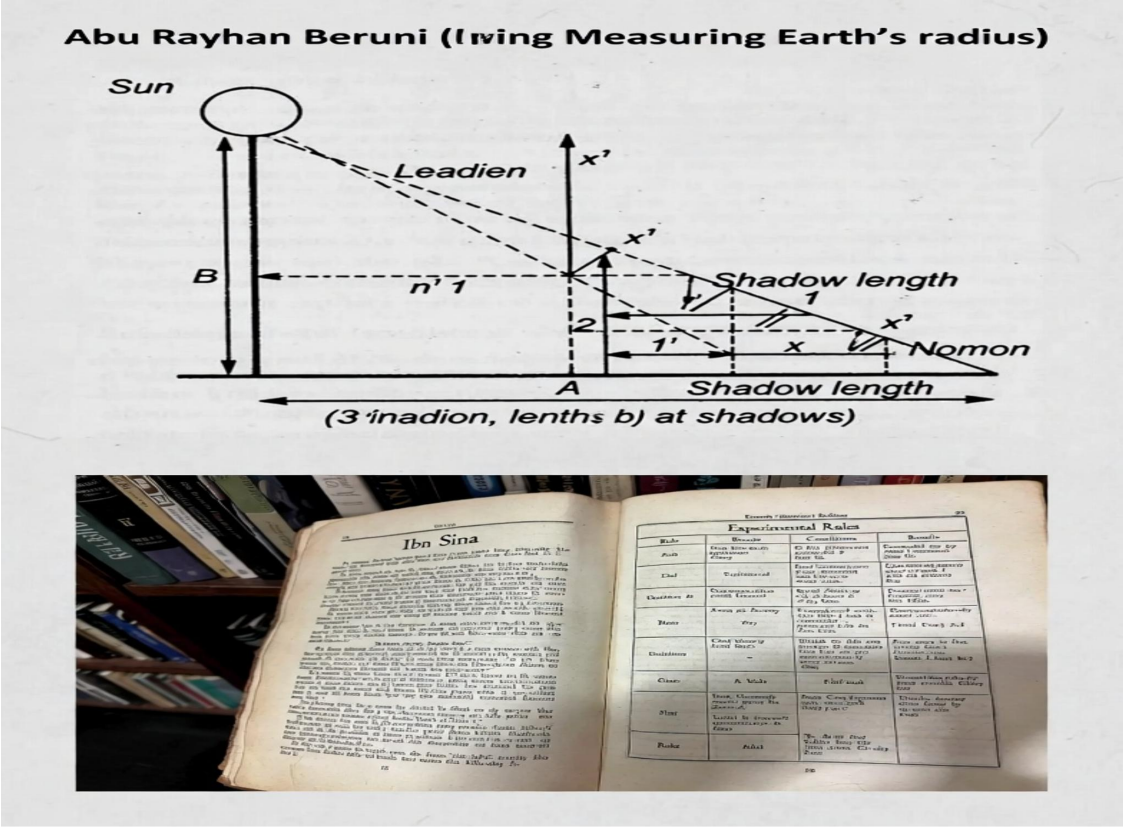

Beruni's experiments on determining the density of substances also played a crucial role in the development of the empirical method. Using hydrostatic balance, he calculated density by comparing the weight and volume of substances in water. This method is based on Archimedes' principle and was applied by Beruni to various minerals and metals. In his work *"Kitab al-Jawahir" (The Book of Precious Stones)*, he emphasized the importance of repeated experiments and controlled conditions to minimize error. His approach is close to the inductive method: moving from individual observations to general conclusions and continuously testing theory through experimentation.

Abu Ali ibn Sina (980–1037) systematically applied the empirical method in medicine and philosophy. In the second book of *"Al-Qanun fi al-Tibb" (The Canon of Medicine)*, he outlined detailed rules for experimentation (tajribah) in evaluating medicinal substances. He distinguished two methods for determining drug potency: analogy (qiyas) and experimentation. For experimental results to be reliable, he established seven conditions:

1. The experiment must be conducted on organisms in similar conditions;
2. The substance must be pure and not mixed;
3. The test must be repeated, not performed only once;
4. Results must be evaluated independently of external factors (age, gender, climate, disease condition);
5. Experiments should be conducted on humans (results from animals may not fully apply);
6. Dosage and duration must be strictly controlled;
7. Negative effects (toxicity, side effects) must be separately observed.

These rules represent a prototype of modern clinical trials. Ibn Sina considered experimentation superior to theory, stating that "experiment is the only way to confirm theory." He critically analyzed the works of Galen and other Greek scholars, prioritizing empirical evidence. For example, he used analogy only as a preliminary hypothesis, requiring final

conclusions to be confirmed through experimental testing.

(Table: Ibn Sina's rules of experimentation from "The Canon of Medicine," Book II)

No.	Experimental Rule	Description
1	Uniform conditions	The experiment must be conducted on organisms under similar conditions.
2	Purity of substance	The medicinal substance must be pure and not mixed with other substances.
3	Repetition of experiment	The test must be repeated multiple times, not conducted only once.
4	Control of external factors	Results must be evaluated independently of external factors such as age, gender, climate, and disease condition.
5	Human testing	Experiments should be conducted on humans, as results from animals may not fully apply.
6	Dosage and duration control	The dosage and duration of the drug's effect must be precisely controlled.
7	Observation of side effects	Negative effects such as toxicity and side effects must be carefully monitored.

A comparison of Beruni and Ibn Sina reveals shared characteristics of the empirical method: observation-based induction, repeated testing, error reduction, and practical verification of theory. However, Beruni relied more on mathematical and trigonometrical models in physics and natural sciences, while Ibn Sina developed systematic rules considering biological and clinical factors in medicine. Both scholars established experimentation as the main criterion of scientific knowledge and directly influenced later European thinkers such as Roger Bacon, Francis Bacon, and Galileo.

(Figure 2: Ibn Sina's experimental rules and Beruni's hydrostatic apparatus – schematic composition)

Thus, the empirical method and experimental approaches developed in the scientific heritage of Central Asian scholars during the 9th–12th centuries represent not only the achievements of the Eastern Renaissance but also a turning point in the history of world science. These approaches facilitated the transition from speculative philosophy to empirical scientific research and laid the foundations of the modern scientific method.

Conclusion

The formation of empirical methods and experimental approaches in the scientific heritage of Central Asian scholars during the 9th–12th centuries was one of the most significant achievements of the Eastern Renaissance. Thinkers such as Abu Rayhan Beruni and Abu Ali ibn Sina ensured the transition from purely theoretical approaches to research based on observation and experimentation, bringing fundamental changes to scientific methodology.

Beruni's determination of the Earth's radius using trigonometry and horizon measurements, as well as his evaluation of substance density through hydrostatic balance, demonstrated the precision and repeatability of the empirical method. Ibn Sina, in *"The Canon of Medicine,"* systematized seven experimental conditions and used analogy only as an initial hypothesis, requiring final conclusions to be supported by empirical evidence. These principles form the prototype of modern clinical trials.

Both scholars' approaches were based on common principles—inductive reasoning, controlled conditions, and the use of experimentation as a verification mechanism—and later influenced European scientists such as Roger Bacon and Galileo. As a result, the roots of the modern scientific method lie not only in the European Renaissance but also in the scientific

tradition of Central Asia during the 9th–12th centuries. This heritage represents a crucial turning point in the history of science, and highlighting the "forgotten" contributions of the East remains an important task today. The development of the empirical method stands as a key factor ensuring continuity in the scientific progress of human civilization.

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