



THE CONCEPT OF EMPIRICAL METHOD IN MEDIEVAL CENTRAL ASIAN SCIENTIFIC THOUGHT

Sharof Rashidov Samarkand State University
Doctoral Student of the Department of “History of
Uzbekistan”,

Acting Associate Professor at Oriental University, PhD

Turdaliyev Jahongir Rustam ogli

Tel.: +99894 280-03-70; E-mail:

jahongirturdaliyev1991@gmail.com

ORCID: <https://orcid.org/0009-0002-2186-7765>

Abstract. *This article examines the formation and conceptual structure of the empirical method in medieval Central Asian scientific thought. The empirical method is interpreted not merely as laboratory experimentation in the modern sense, but as a system of observation, experience, measurement, calculation, comparative evidence, verification, and instrumental accuracy. On the basis of the intellectual legacy of al-Biruni, Ibn Sina, Ulugh Beg, al-Khwarizmi, and al-Farabi, the study shows that scientific reasoning in the region did not rely solely on texts and authority, but also on the examination of natural phenomena, the human body, celestial bodies, geographical distances, minerals, and social evidence. The article concludes that the unity of theory and practice constituted the core feature of empirical method in medieval Central Asian science.*

Keywords: *empirical method, Central Asia, al-Biruni, Ibn Sina, Ulugh Beg, al-Khwarizmi, observation, experiment, measurement, scientific reasoning*

Annotatsiya. *Mazkur maqolada o'rta asr Markaziy Osiyo ilmiy tafakkurida empirik metod tushunchasining shakllanishi va mazmuni tahlil qilinadi. Tadqiqotda empirik metod zamonaviy laboratoriya tajribasi bilan cheklanmay, kuzatuv, tajriba, o'lchov, hisob-kitob, qiyosiy dalil, verifikatsiya va asbobli aniqlik tizimi sifatida talqin qilindi. Beruniy, Ibn Sino, Ulug'bek, Xorazmiy va Forobiy merosi orqali ilmiy bilishda matn va avtoritet bilan bir qatorda tabiat, inson organizmi, osmon jismlari, geografik masofa, mineral va ijtimoiy dalillarni tekshirish muhim o'rin egallagani*

ko'rsatildi. Natijada Markaziy Osiyo ilmiy an'anasida nazariya va amaliyot o'rtasidagi bog'liqlik empirik metodning markaziy belgisi sifatida asoslandi.

***Kalit so'zlar:** empirik metod, Markaziy Osiyo, Beruniy, Ibn Sino, Ulug'bek, Xorazmiy, kuzatuv, tajriba, o'lchov, ilmiy tafakkur*

***Аннотация.** В статье анализируется формирование и содержание понятия эмпирического метода в средневековой научной мысли Центральной Азии. Эмпирический метод рассматривается не только как лабораторный эксперимент в современном смысле, но как система наблюдения, опыта, измерения, вычисления, сравнительного доказательства, проверки и инструментальной точности. На материале наследия Бируни, Ибн Сины, Улугбека, Хорезми и Фараби показано, что научное познание в регионе опиралось не только на текст и авторитет, но и на проверку природных явлений, человеческого организма, небесных тел, географических расстояний, минералов и социальных фактов. Делается вывод, что связь теории и практики была ключевым признаком эмпирического метода в центральноазиатской научной традиции.*

***Ключевые слова:** эмпирический метод, Центральная Азия, Бируни, Ибн Сина, Улугбек, Хорезми, наблюдение, опыт, измерение, научное мышление*

INTRODUCTION. The problem of empirical method in medieval Central Asian scientific thought requires a more careful interpretation than the simple opposition between “traditional” and “modern” science. In the intellectual world of Khwarazm, Bukhara, Samarkand, Farghana, and the wider Islamic East, scientific reasoning was not limited to inherited textual authority. The scholar could cite Aristotle, Ptolemy, Galen, or earlier Muslim authors, yet the authority of such texts was repeatedly tested through observation, calculation, comparison, and practical verification. In this context, empirical method meant not only controlled experiment in a narrow laboratory sense, but a broader epistemic discipline: to observe a phenomenon, to measure it when possible, to compare data obtained from different

sources, to repeat or verify the result, and to connect the conclusion with a coherent theoretical explanation.

This approach is especially visible in the works and intellectual profiles of Abu Rayhan al-Biruni, Ibn Sina, Mirzo Ulugh Beg, Muhammad al-Khwarizmi, and Abu Nasr al-Farabi. Al-Biruni's scholarly practice combined astronomy, geography, mineralogy, history, and anthropology. Ibn Sina developed a sophisticated understanding of experience, especially in medicine and logic. Ulugh Beg and the Samarkand astronomical school transformed observation into numerical precision through observatory-based measurement. Al-Khwarizmi used mathematical modelling to connect abstract algebraic procedure with geometrical demonstration. Al-Farabi, while usually read as a philosopher of logic and metaphysics, also treated knowledge as a movement from sensory perception toward rational demonstration [Masykur, 2025, p. 95–96].

The relevance of the topic lies in the need to move beyond the one-sided view that medieval Central Asian thought was predominantly textual, speculative, or theological. Certainly, religious and philosophical frameworks shaped the language of science, but they did not eliminate empirical practice. Recent studies on the historical formation of Central Asian Islamic civilization also show that intellectual life developed within a complex socio-cultural environment where local, Islamic, and transregional traditions interacted [Ungalov, 2025, p. 75–88]. The research problem of this article may therefore be formulated as follows: what conceptual content did the empirical method acquire in medieval Central Asian scientific thought, and through which practices was it realized? The purpose of the article is to identify the main components of that method and to show their interconnection in observation, experiment, measurement, and theoretical verification.

METHODS. The study was conducted on the basis of historical-analytical, comparative, source-critical, and conceptual methods. The historical-analytical approach made it possible to examine empirical practices within their own intellectual context, without mechanically projecting the modern concept of

experimental science onto the medieval period. The comparative method was used to distinguish several types of empirical procedure: natural observation, medical experience, mathematical modelling, instrument-based measurement, and comparative source verification. The source-critical method was necessary because some modern discussions of medieval science may either exaggerate continuity with modern science or underestimate the evidentiary value of medieval observation.

The analytical units of the study were the following concepts: observation, experiment, measurement, verification, instrumental accuracy, quantification, and comparative evidence. “Observation” was taken to mean the direct or systematic registration of natural, medical, astronomical, geographical, or social phenomena. “Experiment” was understood as purposeful testing under defined conditions, especially in medicine, pharmacology, and mineralogical measurement. “Measurement” referred to numerical determination through mathematical, geometrical, or instrumental procedures. “Verification” denoted the comparison of a theoretical statement with observed or measured reality.

The source base was selected according to thematic relevance, bibliographic clarity, and the availability of page references. Special caution was applied to page accuracy: sources with unclear pages were not used as central evidence. Where the available literature offered precise pages, the citation was given directly in square brackets. The article relies primarily on studies dealing with al-Biruni’s historical and empirical method, Ibn Sina’s medical and logical theory of experience, Ulugh Beg’s astronomical observations, al-Khwarizmi’s mathematical demonstrations, and al-Farabi’s epistemological framework.

RESULTS. The first result of the study is that empirical method in medieval Central Asian thought emerged as a composite system rather than as a single technique. It included at least three interrelated levels: natural observation, experimental verification, and mathematical-instrumental measurement. These levels did not exist separately. Observation supplied the initial data; experiment or

comparison tested the reliability of the data; measurement transformed the data into a reproducible form; and theory gave the result intellectual coherence.

Al-Biruni's scholarship provides one of the clearest examples of this structure. In the study of India, he did not rely solely on inherited narratives. The examined literature shows that he combined written sources, oral information, and field observation; this combination corresponds to what modern methodology calls data triangulation [Putri, Yasmin, 2026, p. 394]. His historical writing therefore was not merely descriptive. It was based on source criticism, direct observation, and comparative analysis, especially when he interpreted Indian religion, culture, geography, and scientific knowledge [Putri, Yasmin, 2026, p. 395]. The same methodological pattern is visible in the assessment that al-Biruni's approach anticipated the principle of checking data through multiple independent evidentiary channels [Putri, Yasmin, 2026, p. 400].

In the natural sciences, al-Biruni's empirical method was even more strongly connected with measurement. His work on metals and precious stones shows that he did not accept ancient statements about weight and volume without verification. He experimentally tested the relative weights of metals and minerals and recorded results in tabular form; modern comparisons have noted that his calculations were remarkably close to values obtained by later precise instruments [Kuranbaeva, 2023, p. 34]. The device associated with his measurement of density, sometimes described as the "Biruni vessel," demonstrates that empirical method also required the construction and documentation of instruments [Kuranbaeva, 2023, p. 35–36]. A recent technical discussion of density determination also connects al-Biruni's hydrostatic method with the use of a conical instrument and controlled overflow measurement for determining the density of natural stones [Loizidou, Deepshikha, Zeinalipour-Yazdi, 2025, p. 14–15]. Thus, in al-Biruni's case, empirical knowledge was not passive observation but an organized procedure of instrument, measurement, comparison, and numerical result.

Ibn Sina's contribution lies in the conceptual clarification of experience. He distinguished between mere induction and methodical experience. The problem was not whether repeated observation was useful, but whether it could yield certainty without proper conditions. In his logical discussion, Ibn Sina treated experience as a source that can produce confidence only when the relation between cause and effect is carefully examined; the example of scammony shows that an observed medicinal effect was valid only when no obstructing condition interfered with the result [Erlwein, 2025, p. 45–48]. In medical practice this caution became a methodological principle. Modern studies of the Canon of Medicine show that Ibn Sina formulated rules for assessing the effects of drugs and connected pharmacological judgment with controlled comparison [Nasser, Tibi, Savage-Smith, 2009, p. 78–80]. The later medical literature also notes that Ibn Sina rejected anecdotal treatments when they were not confirmed through controlled trials and clinical experience [Elahi, 2025, p. 3]. His medical empiricism therefore did not mean simple trial-and-error; it meant disciplined experience governed by conditions, diagnosis, comparison, and repeated observation.

The case of Ulugh Beg shows another dimension of empirical method: observatory-based quantification. The Samarkand observatory became a space where astronomical knowledge was produced through repeated observation and mathematical refinement. The available evidence indicates that Ulugh Beg's astronomical school compiled a catalogue of 1018 stars and calculated the length of the astronomical year as 365 days, 6 hours, 10 minutes, and 8 seconds, with an error of less than one minute in comparison with modern values [Sharipova, Abilqasimova, 2024, p. 467–468]. Such a result could not be obtained by speculative reasoning alone. It presupposed instruments, observational discipline, mathematical tables, and collective scholarly work. The zij tradition itself represented a form of empirical mathematics, because astronomical tables were not merely theoretical schemes; they were tools for predicting and checking celestial events [Kennedy, 1956, p. 123–177].

Al-Khwarizmi's mathematical practice demonstrates that empirical method in the medieval context could also appear as geometrical verification. His solution of quadratic equations through geometrical models, including the well-known case of $x^2 + 10x = 39$, connected abstract algebraic reasoning with visual and spatial demonstration [Baki, 1992, p. 226–227]. He also recognized the approximate character of certain calculations, including the circumference of a circle, which shows awareness of the limits of numerical precision [Baki, 1992, p. 226]. This is significant because empirical method is not only the collection of sensory data; it also includes recognition of approximation, error, and the boundary between exact knowledge and practical computation.

Al-Farabi's epistemology adds a theoretical frame to this empirical culture. He described knowledge as a hierarchical movement from the sensory world toward active intellect, thereby preserving the role of sensation while subordinating it to rational demonstration [Masykur, 2025, p. 95]. His concept of *burhan*, or demonstrative proof, indicates that empirical evidence alone was not considered sufficient unless it could be integrated into a valid structure of reasoning [Masykur, 2025, p. 96]. Therefore, medieval Central Asian empirical method was not anti-theoretical. It was a form of scientific reasoning in which experience and demonstration supported one another.

DISCUSSION. The results indicate that medieval Central Asian scientific thought cannot be reduced to a purely textual or authority-based tradition. Texts mattered, but they functioned within a broader regime of verification. A scholar could begin from inherited knowledge, yet the credibility of that knowledge was strengthened or weakened by observation, comparison, measurement, and practical testing. This is especially clear in al-Biruni's treatment of historical and cultural material. His use of written, oral, and observed evidence shows that empirical reasoning was not limited to astronomy or medicine; it also entered the human sciences [Putri, Yasmin, 2026, p. 394–400].

At the same time, it would be inaccurate to identify medieval empirical method with modern experimental science in a simple or direct way. Medieval scholars did not possess modern laboratories, statistical protocols, or institutional peer review. Their language of causality was often shaped by Aristotelian, Galenic, Islamic, and philosophical categories. Nevertheless, they developed intellectual practices that performed many functions later associated with scientific method: checking statements against reality, comparing evidence, making measurements, constructing instruments, testing medicines, and recognizing error. Ibn Sina's rules for drug assessment, for example, should not be called a modern randomized clinical trial, yet they clearly show an attempt to control conditions and distinguish reliable experience from anecdotal report [Nasser, Tibi, Savage-Smith, 2009, p. 78–80].

The first level of the empirical method was natural observation. It included celestial observation, geographical description, clinical observation, and social-anthropological observation. In al-Biruni's scholarship, observation was inseparable from comparison: a fact became stronger when it was confirmed by different types of evidence. The second level was experimental verification. This is visible in Ibn Sina's pharmacology and in al-Biruni's density measurements. Experiment in this context meant a purposeful test, not necessarily a modern laboratory procedure. The third level was mathematical and instrumental measurement. Ulugh Beg's star catalogue and al-Biruni's mineralogical work show that measurement transformed experience into a stable scientific record.

The most important feature of this tradition was the unity of these three levels. Observation without measurement remained incomplete; measurement without theory remained mechanical; theory without verification risked becoming speculative. Medieval Central Asian scholars therefore did not simply "observe" the world. They organized observation through mathematical, logical, and instrumental frameworks. In this sense, the empirical method served as a bridge between theory and practice. It allowed astronomy to produce tables, medicine to judge the effect of

drugs, geography to calculate distances and coordinates, mineralogy to determine density, and history to distinguish report from evidence.

This methodological culture also connects Central Asian science with the broader history of the Muslim East and world science. Al-Biruni worked within a transregional scholarly world that connected Khwarazm, Ghazna, India, and the Arabic-Persian intellectual tradition. Ibn Sina's works circulated widely in Islamic and later Latin medical culture. Ulugh Beg's observatory represented one of the high points of mathematical astronomy before the early modern period. Al-Khwarizmi's algebra became foundational for later mathematical traditions. The empirical method in Central Asia, therefore, was not an isolated regional curiosity; it was part of a larger historical process in which observation, calculation, and verification gradually became central to scientific authority.

CONCLUSION. The analysis yields several connected conclusions. The empirical method in medieval Central Asian scientific thought was a composite epistemic system resting on observation, experience, measurement, comparison, and verification, and for that reason it cannot be reduced either to the modern laboratory experiment or to passive sensory perception. Its broadest application is found in al-Biruni's scholarship: in history and anthropology he drew on comparative evidence and field observation, while in mineralogy and geography he relied on instruments, measurement, and numerical comparison, showing that empirical reasoning suited both natural and social phenomena. Ibn Sina, in turn, transformed experience into a controlled intellectual procedure, questioning the limits of induction in logic and treating diagnosis, drug testing, and clinical observation in medicine as conditions of reliable knowledge – a clear movement from anecdotal experience toward methodical verification. Ulugh Beg and the Samarkand astronomical school represent the mathematical-instrumental form of the method, their star catalogue and calculation of the year illustrating how repeated observation, instruments, and numerical tables produced high precision. Al-Khwarizmi and al-Farabi, meanwhile, show that the method did not stand outside theory: mathematical modelling,

geometrical demonstration, and logical proof gave empirical data a rational structure. Medieval Central Asian science thus advanced not by rejecting theory but by testing and strengthening it through measured reality. Future research may examine specific manuscripts, instruments, and numerical tables more closely, especially the relation between the region's observatories, medical texts, and practical sciences such as geodesy, mineralogy, and pharmacology.

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