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of the MMIT'25 International Conference

TA'LIMNING ZAMONAVIY USULLARI VA
INNOVATSION TEXNOLOGIYALAR

MODERN METHODS AND INNOVATION
TECHNOLOGIES IN EDUCATION

СОВРЕМЕННЫЕ МЕТОДЫ И
ИННОВАЦИОННЫЕ ТЕХНОЛОГИИ
В ОБРАЗОВАНИИ

29 May 2025, Tashkent, Uzbekistan

MAQOLALAR TO'PLAMI
СБОРНИК СТАТЕЙ



Tashkent International University of Education

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Modern methods and innovation technologies in education

**Современные методы и инновационные технологии в
образовании**

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MATHEMATICS IN THE TREATISE BY BAHAD-DIN AL-AMILI “THE ESSENCE OF ARITHMETIC”, HIS CONTEMPORARIES AND FOLLOWERS

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Abstract. The article is a commented translation from Arabic of the essay by the greatest mathematician of the 16th century Baha ad-Din al Amili “The Essence of Arithmetic”. The paper also provides a historical and comparative analysis of the mathematical chapters of encyclopedias of that period using various sources.

Keywords: *treatise, manuscript, medieval, algebra, arithmetic, geometry, trigonometry, number theory, equations, cubic equations, the rule of “two false positions”.*

Introduction

The growing role of science, including mathematics, in the life of modern society requires an ever more careful study of the historical paths of its development. A holistic picture of the development of mathematics in the world cannot be created without a detailed study of the history of the origin and development of mathematical knowledge in certain regions of the planet. As a part of the history of mathematics, the history of the emergence and formation of mathematical crafts and science in each region has its own special features that must be studied and disclosed. This will make it possible to assess the contribution of each nation to the development of mathematical science and, at the same time, will contribute to the disclosure of the patterns of development of mathematics in a particular region. In this regard, the study and generalization of the historical aspects of the formation and development of mathematics in Central Asia is relevant.

Literature review and methodology

Arabic primary sources, primarily handwritten ones, were used when writing the article. The main attention is paid to the mathematical encyclopedia of the 16th-17th centuries, the treatise “The Essence of Arithmetic” (Khulosat al-Khisab) by Baha ad-Din al-Amili (1547-1622). One of the authors took part in the translation of this source into Russian and its commenting. The works of scholars of the Muslim Middle Ages have been investigated on the basis of commented translations from Arabic and Persian into Russian, and a comparative analysis of these works with the treatise “The Essence of Arithmetic” by al-Amili has been carried out. This makes it possible to establish the origin of scientific ideas in that important period when the foundation of modern exact sciences was laid. The novelty of the studied material also lies in the fact that the authors of the work for the first time studied and described most of the manuscripts, which are encyclopedias or works of an encyclopedic nature.

The study of the history of physical and mathematical sciences in the medieval Near and Middle East is carried out in several directions, problems are consistently solved that are quite diverse in nature.

Mathematics is no longer what it was two hundred or even fifty years ago. Her subject matter becomes much broader, and the tasks she has to face become more difficult and varied. These changes had a significant impact on the volume and content of the school mathematics course. Life is making amendments to the teaching methodology; ways are being looked for that would help to intensify the process of mastering the educational material.

Practice has shown that the introduction of historicism elements in the teaching of mathematics at school can be of great benefit. Using information on the history of science, the teacher can make it easier for students to assimilate the main program, revitalize the learning process.

The history of mathematics is primarily the history of the development of mathematical ideas. However, the bearers of these ideas in every epoch were outstanding scientists whom we call the classics of science. Studying their heritage, we get the opportunity to show the general course of development of mathematics, using specific examples, to clearly show the connection between mathematics and life at different stages of history. This connection is manifested both in the tasks that the scientist solved, and in the scientific language in which he speaks with us. That is why Academician S.I. Vavilov wrote: "The history of science cannot be limited to the history of ideas - it should equally concern living ideas with characteristics, talents, dependence on social conditions, country and era."

"The Essence of Arithmetic" (Khulosat al-Hisab) by the famous scientist Baha ad-Din Amili belongs to a later time, namely the 16th century and the beginning of the 17th century, it received the greatest popularity during this period in Central Asia, Iran, Turkey, India. It outlines the arithmetic of integers and fractional numbers, provides the basic concepts and computational rules of geometry, and explains the beginnings of algebra (al-Jabr wa-l-Muqabala) in the tradition leading from Muhammad ibn Musa al-Khwarizmi.

"The essence of arithmetic" has been preserved in numerous manuscripts and was published more than once in the 19th and early 20th centuries. lithographed in Tehran, Cairo, Bombay, Istanbul and other cities of the East. In 1812, the Indian scientist Rushen Ali organized in Calcutta the scientific publication of the Arabic text of the work, accompanied by its translation into Persian [1]. After this, the treatise of Baha ad-Din Amili attracted the attention of European historians of mathematics.

In 1843, G. Nesselmann published the Arabic text "Essence of Arithmetic" together with a translation into German [2], and in 1846, A. Marr published its French translation [3]. Jalal Shawki produced a new edition of the treatise with substantial commentaries in Arabic, it was published in 1976 in Aleppo [4]. In 1992, the commented Russian translation of "The Essence of Arithmetic" was made by G.P. Matvievsckaya, J.H. Ibadov and Z.I. Sadritdinova from the text published by G. Nesselman and J. Shavka, with the involvement of some manuscripts stored in Tashkent (Institute of Oriental Studies named after Abu Raikhan Beruni of the Academy of Sciences of Uzbekistan and the Library of the Spiritual Administration of Muslims of Central Asia and Kazakhstan) [5]. The illustrations were borrowed from the manuscript of the Institute of Oriental Studies of the Russian Academy of Sciences (St. Petersburg), stored under the code B 841 (643).

The following research methods are used in the paper:

Historical and scientific analysis used in the history of mathematics;

Source study analysis that meets the requirements of oriental studies.

The work has the practical value:

for further research on historical and mathematical source studies, history of exact sciences of the Near and Middle East;

when compiling textbooks on the exact sciences and their history;

when developing the relevant sections of lecture cycles, books on the history of culture and science of Central Asia;

during additional classes for students of higher and secondary specialized educational institutions;

in the preparation and conduct of student scientific conferences of higher educational institutions, in optional classes for students of lyceums, senior secondary schools and vocational schools;

when compiling problems of republican, regional and city Olympiads in mathematics for students of senior classes of secondary schools, lyceums, colleges, as well as in teaching the history of mathematics.

Results and discussion

Baha ad-Din Muhammad ibn al-Hussein al-Amili was born in Baalba (Syria) in 1546 (953 AH) in the family of the famous Shiite leader Sheikh Hussein. At the age of 13, having lost his mother, he and his father moved to Iran, where, during the reign of the Safavids, the rise of spiritual life and the flourishing of sciences began.

Baha ad-Din Amili received an excellent education. At first he was taught by his father, and then by prominent scientists of Qazvini and Khorasan, from whom he learned philosophy and theology, physics and medicine, mathematics and astronomy. Starting an independent activity, al-Amili soon gained universal recognition as a theologian and became the largest religious authority in the country – Sheikh-ul-Islam of Isfahan, the city that was the capital of the Safavid Shah Abbas 1, who ruled from 1587 to 1629. He died in 1622 (1030 AH) in Isfahan, where he was buried.

Baha ad-Din owns many works in Persian and Arabic, both religious and purely scientific. Researchers see him as the last universal thinker in the countries of Islam. Not all of the works of Baha ad-Din Amili are now known, and some of them have not yet been studied.

The treatise “The Essence of Arithmetic” was very popular as a textbook of arithmetic in the countries of the Near and Middle East.

Now the treatise is now known in numerous manuscripts [6, Vol. 2, 579-584].

A brief description of the manuscripts and printed editions of “The Essence of Arithmetic” by Amili, stored in the libraries of Tashkent city and comments to this treatise, was given by J. Ibadov [5, p.86]. The text of each manuscript was compared with the Bombay edition in 1882.

24 manuscripts of “The Essence of Arithmetic” by Baha ad-Din al Amili and 6 manuscripts – commentaries on this treatise are kept at the Institute of Oriental Studies named after Beruni of the Academy of Sciences of the Republic of Uzbekistan. In addition, there are 26 prints of the essay.

The extraordinary prevalence of the manuscripts “The Essence of Arithmetic” in Central Asia made the scientists of Uzbekistan and Tajikistan pay special attention to this work.

A significant part of these manuscripts is described in the multivolume catalog “Collection of Oriental Manuscripts” of the Academy of Sciences of Uzbekistan, which began to appear in 1952.

It is possible to determine the meaning of Baha ad-Din Amili’s treatise only if its content is compared with works of a similar genre written by predecessors, which were in the nature of mathematical encyclopedias.

In a short preface, the author, after the traditional introduction with praise to Allah and the Prophet Muhammad, gives a characterization of his work. He notes the importance of the treatise, which, in his words, contains all the basic rules of “the great science of arithmetic, which is necessary for many other sciences”. In “The Essence of Arithmetic”, as Baha ad-Din confirms, the results of the works of scientists living before him are summarized. Abu Ghalib Bahadirkhan, who lived at the end of the 16th century, is named the initiator of its writing.

The treatise consists of three sections, the first of which is devoted to the arithmetic of integers and fractions, the second to planimetry and stereometry, and the third to algebra. This tradition originates from the “Book of Algebra and Al-Muqabala” by Muhammad ibn Musa al Khwarizmi [7], which defined in the 9th century the main form of the branch mathematical encyclopedia.

In the introduction, Baha ad Din gives the usual definition of arithmetic as “the science from which one learns how to find unknown numbers from some known ones.” The concepts of integer, fractional, rational and irrational numbers are introduced. The latter is important from the point of view of the history of the number concept: usually irrational quantities appear in the arguments, and not numbers in accordance with the “Principles” of Euclid [8].

Further, perfect numbers (i.e., numbers equal to the sum of their improper divisors ($\sigma(n) = n$)), abundant numbers ($n < \sigma(n)$) and deficient numbers ($n > \sigma(n)$) are considered.

In the first chapter (“On computation with integers”), the rules of addition, doubling, subtraction, multiplication, division, and root extraction are formulated and explained using examples [9].

The division is carried out according to the scheme, which was previously described in detail in the treatises of an-Nasawi [10, p. 393] and al-Kashi [11, p. 23-24].

The standard rule is also applied for approximate square root: if $b = a^2 + m$, where a^2 is the largest square contained in b , then $\sqrt{b} = \sqrt{a^2 + m} = a + \frac{m}{2a+1}$.

Baha ad-Din Amili confines himself to this rule and does not give a general method for extracting the n -th root [9, p. 144 – 151], which was well known from the writings of an-Nasawi [10], at-Tusi [12, 13], and al-Kashi [11].

The second chapter (“On the arithmetic of fractions”) has three introductions, in which the concepts of the theory of fractions are introduced. Baha ad-Din Amili basically repeats the reasoning from the corresponding sections of the “Key of Arithmetic” by al-Kashi. However, unlike the latter, he gives some information from the Old Arabic arithmetic of fractions, but does not mention not only decimal fractions, which were first introduced and applied by al-Kashi, but also about the “calculus of astronomy” – the theory of sexagesimal fractions [11, p. 73-101].

Six sections of this chapter explain the rules for arithmetic with ordinary fractions, including the rule for extracting the square root of a fraction.

In the next three chapters, Baha ad-Din Amili gives some practical techniques for solving arithmetic problems and, above all, the “rule of finding unknowns from proportion (the “triple rule”) and “the rule of two errors” (“the rule of two false positions”), which were popular in the Middle Ages.

The sixth chapter, consisting of an introduction and three sections, is devoted to geometry. The presentation of the material corresponds to the tradition laid down by Muhammad ibn Musa al-Khwarizmi in the “Chapter on Measurement” of his algebraic treatise [7, p. 46-53]. This tradition was developed by al-Karadzhi [14], al-Naysaburi [15], al-Kashi [11], etc.

In the seventh chapter, examples are given of the application of geometry to solving practical problems. He borrowed these examples from his predecessors: similar problems were solved before him by Abu Raikhan Beruni and Abu-l-Fath Abd ar-Rahman al-Mansur al-Khazini (12th century).

The eighth chapter (“On finding unknowns by the method of Algebra and Al-Muqabala”) consists of two sections. In the first section, the concepts of the unknown and its powers are introduced, in the second one, quadratic equations of six canonical types are solved in full accordance with the scheme established by Muhammad ibn Musa al-Khwarizmi. Algebra is presented in this way in the writings of al-Khububi and al-Sijawandi [16], al-Karadzhi [14], Imad ad-Din al-Baghdadi [17], and ali-Kushchi [18].

In the ninth chapter (“On noble rules and subtle advantages that cannot be avoided by the one who solves, and which he needs”), some rules of theoretical arithmetic are given.

Similar sections are in other works, which are in the nature of mathematical encyclopedias. In some of them, for example, in the treatise of al-Karadzhi and in the “Heart of the Account” by al-Wusudi [19], the material is presented in more detail.

Baha ad-Din Amili gives the rules for summing number sequences:

$$1) \quad n * \sum_{k=1}^n k = \frac{n^2(n+1)}{2}$$

$$2) \quad \sum_{k=1}^n (2k-1) = n^2$$

$$3) \sum_{k=1}^n (2k) = n(n+1)$$

$$4) \sum_{k=1}^n k^2 = \frac{2n+1}{3} \sum_{k=1}^n k$$

$$5) \sum_{k=1}^n k^3 = \left(\sum_{k=1}^n k \right)^2$$

Some algebraic rules are given:

$$\sqrt{a} * \sqrt{b} = \sqrt{a*b}$$

$$\frac{\sqrt{a}}{\sqrt{b}} = \sqrt{\frac{a}{b}}$$

$$\begin{cases} \frac{x^2}{x} = \frac{a}{b} \\ x^2 = \left(\frac{a}{b} \right)^2 \end{cases}$$

$$ab \frac{a}{b} = a^2$$

$$a^2 - b^2 = (a+b)(a-b)$$

$$\frac{a}{b} * \frac{b}{a} = 1$$

And finally, the definition of a perfect number is given according to Euclid, after which the number

$$28 = 1 + 2 + 4 + 7 + 14$$

is given as an example.

In the tenth chapter, seven problems are solved “in various ways that sharpen the mind of the student and consolidate it in finding what he is looking for”. Baha ad-Din says that they relate to the most difficult questions, in which “obscurity that defies any mind” was discovered even in antiquity.

Along with unsolved problems, he lists those whose solutions are negative or irrational numbers. Conditions can be written as follows:

$$1. (x + \sqrt{x})(10 - x + \sqrt{10 - x}) = 10;$$

$$2. x^2 + 10 = y^2, \quad x^2 - 10 = z^2;$$

$$3. x^2 + y = 10, \quad y^2 + x = 5;$$

$$4. x^3 = y^3 + z^3;$$

$$5. x + y = 10, \quad \frac{x}{y} + \frac{y}{x} = x \text{ or } \frac{x}{y} + \frac{y}{x} = y;$$

$$6. \frac{x^2}{y^2} = \frac{y^2}{z^2}, \quad x^2 + y^2 + z^2 = w^2;$$

$$7. x^2 + x + 2 = y, \quad x^2 - x - 2 = z^2$$

The fourth problem is of greatest interest. This is a special case of the so-called Great Fermat's theorem (at $n = 3$): find a solution to the indefinite equation

$$x^n + y^n = z^n, \quad n \geq 1.$$

The proof of the impossibility for this particular case was given in the 17th century by L. Euler.

Today every educated person knows the name of Muhammad ibn Musa al-Khwarizmi, immortalized in the term “algorithm”, and the science Algebra founded by him. Before al-Khwarizmi, Mathematics meant mainly geometry with some part of number theory.

The work of the scientist “Al-Kitāb al-mukhtaṣar fī ḥisāb al-jabr wa-l-muqābala” (“A Brief Book of Replenishment and Opposition”) became, along with Euclid’s book “Beginnings”, the foundation, on which the building of modern mathematics rests. It was rewritten many times in the original language and in translation into Latin, as a result of which its name was shortened to the word “aljabra” – “algebra”.

Al-Khwarizmi emphasized in his book two operations – “aljabr” and “al-muqabala”, which, unlike arithmetic, allow performing four arithmetic operations on expressions containing an unknown. It was a really brilliant idea. Unfortunately, his immediate followers, who set themselves the goal of solving cubic equations, began to understand algebra as the science of equations. This was a deviation from the main idea of the scientist, who considered algebra as the science of algebraic operations and algebraic calculus. This interpretation of the term lasted until the middle of the 19th century.

One involuntarily amazes at how far-sighted al-Khorezmi was, having included in the title of his treatise not the concept of an equation, but precisely the name of a pair of operations! In the future, more and more new types of algebras have been introduced. It is pleasant to note that one of them – topological Boolean algebras – was developed in Tashkent by mathematicians of Uzbekistan headed by Academician Tashmukhamed Alievich Sarymsakov. The monograph, written by him together with his colleagues, was republished in the United States in translation into English, then awarded the State Prize named after Abu Raikhan Beruni.

At present, the indicated direction of mathematics, founded by this great scientist, has been intensively developed within the framework of the scientific school founded by T.A. Sarymsakov and now headed by Academician Shavkat Abdullaevich Ayupov. Research cycle by Sh.A. Ayupov, K.K. Kudaibergenov, B.A. Omirov, and U.A. Rozikov “Development of the theory of non-associative algebras, differentiations and nonlinear dynamical systems” was awarded the State Prize of the Republic of Uzbekistan. The results obtained by Sh.A. Ayupov, together with his followers, have already received worldwide recognition. Moreover, a kind of “branches” of the Tashkent school of non-associative algebras and the theory of generalized differentiations managed to emerge in Seville (Spain), Kuala Lumpur (Malaysia), Berkeley (USA) and Nukus (Uzbekistan). Scientific centers of China, South Korea, France and other countries are showing interest in the research of Uzbek scientists.

Conclusions

The treatise “The Essence of Arithmetic” by al-Amili, which was written by al-Amili in the spirit of al-Khwarizmi, served as the main textbook on mathematics in the countries of the East. This is evidence that al-Amili was a worthy successor to the cause of al-Khwarizmi.

It is often believed that the original mathematical creation in the Near and Middle East ended in the 15th century with the activities of the scientists of the Ulugbek school. The works of Baha ad-Din Amili and his disciples Muhammad Najim ad-Din and al-Yazdi show that this was not so, it was continued, and not without success in the 16th and even in the 17th centuries.

One can express confidence that Uzbek mathematics will continue to develop. And the followers of the scientific school of Academician T.A. Sarymsakov will continue to adequately represent Uzbek science at the world level. The recognition of this fact was the election of the scientist as a full member of the World Academy of Sciences (TWAS), as well as an international conference organized in connection with the 100th anniversary of the birth of T.A. Sarymsakov in Tashkent in 2015. The importance of the researches, which is carried out by Uzbek mathematicians was noted by all its participants, including the winner of the Fields Medal Efim Zelmanov, who then invited Sh.A. Ayupov to the University of California (San Diego) to familiarize American scientists with him.

The data that have appeared in the scientific literature of recent years show that many handwritten medieval mathematical works, which still remain unexplored, contain important results on the history of algebra. Therefore, it is necessary to pay attention to the study of these sources.

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An abstract graphic featuring a complex network of interconnected nodes and lines, resembling a molecular structure or a digital network, set against a dark blue background. The nodes are represented by circles of varying sizes, and the lines are thin, light blue, creating a web-like pattern that fills the upper two-thirds of the page.

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