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16TH CENTURY OTTOMAN MATHEMATICS VISIBLE FEATURES

İrem ASLAN

Özet

XVI. yüzyıl Osmanlı biliminin altın çağıdır. Bu yargı matematik alanı için de geçerlidir. XVI. yüzyılda Osmanlı Devleti'nde diğer çağlardan çok daha fazla çeviri yapılmış ve özgün eser yazılmıştır. Osmanlıca metinlerin henüz hepsi günümüz Türkçesine çevrilmediği ve incelenmediği için Osmanlı matematiğinin genel karakteri ile ilgili varılacak her yargı eksik kalacaktır. Ancak mevcut eserleri dönemsel olarak kıyaslandığımızda, XVI. yüzyılın genel karakteri ile ilgili bazı yargılara varmak mümkündür. Bu makalede literatür taranarak, XVI. yüzyılda Osmanlılarda yazılmış aritmetik, cebir, geometri, analitik geometri gibi matematiğin çeşitli dallarındaki eserler ve bunların yazarlarına ilişkin genel bir sunum ve değerlendirme yapılacaktır

Anahtar Kelimeler: 16. yüzyıl, Altın Çağ, Osmanlı Matematiği, Osmanlı Geometrisi, Osmanlı Aritmetiği, Osmanlı Cebri, Takîyuddîn, el-Magrîbî.

Abstract

16th century is the golden era of the Ottoman science. That broad conclusion is also valid for mathematics. In that century Ottomans produced original treaties and commentaries more than ever. Unfortunately, all the Ottoman texts has not translated and examined yet. So all the conclusions and the evaluations about the general characteristics of the Ottoman mathematics, will be in inadequate and

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insufficient. Nevertheless, when the 16th century compared with all periods, it is possible to revise an acceptable conclusion.

Keywords: 16th century, Golden Era, Ottoman Mathematics, Ottoman Algebra, Ottoman Geometry, Ottoman Arithmetic, Taqi al-Dîn, al-Maghrîbî.

16th Century was a Renaissance era for the West was also the golden era for the Ottomans in science. The basic sense of science was the pragmatism in Ottomans. Sciences which can be used in daily life, for daily needs had major priority in Ottomans. That is the reason of the medicine and engineering schools were established before the fundamental sciences schools. Mathematic had the attention because of its applications in daily life were needed, but the interest towards natural sciences waited until the Republic time which is after 1923. As well as astronomy, engineering, war technology and architecture, the mathematic knowledge was also needed in the merchandise, trades, and legacy (as they called feraiz, share of heritage). So mathematics has gained the attention it deserves from the Ottoman scholars. But Ottoman scholars "used" the "needed knowledge" which they've learned from Medieval Islamic scholars, and they haven't tried to make a new progresses on it. That pragmatic approach can easily be understood by a glance at the book topics. The major percentages of the books written in 16th century was on arithmetic, accounting and share of heritage. While in the second raw the Geometry books are taking a part, the algebra books which are closer to the pure mathematics are the less interested ones in comparison with the other ones. Books are mostly written in Arabic. That shows us like in Islamic tradition, in Ottomans language of science was also Arabic. Another interesting point is the books ordered by Sultans was in Persian which was the literature language of the mentioned time.

Ottoman mathematicians were using two kinds of calculation systems. One of them was called "Indian-Arabic System" that was a decimal system and other was the sexagesimal "Astrologer System".

I would like to inform you that not all Ottoman texts investigated and translated yet. So all those comments and conclusions in this article will be made under those circumstances. My references will be the knowledge which has uncovered already. So none of that is one hundred percent definite, in order to obtain certain results we should have first investigate each and every text exists. But yet my comments and statistics in this article, will try to provide the general out look towards Ottoman mathematics and geometry.

I told the basic sense of science was the pragmatism in Ottomans yet that doesn't mean there weren't any original contributions. Bright scientists may appear in anytime anyplace. So in 16th century Ottoman empire there were also brilliant scholars one and the primary of them is Taqi al-Dîn (932/1526-993/1585).

Taqi al-Dîn ibn al-Marûf

Taqi al-Dîn Muhammed b. al-Maruf b. Ahmet Muhammed b. Muhammed b. Ahmet b. Yusuf b. al-Emîr Humartegin, was born in Damascus in June 1526. He received his education from various scholars about tafsir (interpret or comment), fıkıh (Islamic jurisprudence), astronomy, mathematics and medicine in Egypt and Damascus. After this education he become qadı (a judge in sharia law) and muderris (teacher in medrese) in different cities. One of these cities that he worked was Cairo. While he was a qadı in Cairo he accelerate his studies about mathematics and astronomy. His main interests were astronomy, mathematics and physics. He returned Istanbul in 1570 and he become the chief astrologer[1] of the Sultan 2nd Selim. In 1575 Taqi al-Dîn established an observatory some place around Tophane and he made astronomical observations. The instruments which has used in Taqi al-Dîn's observatory has resemblances to the instruments which has used in of Uranienborg (sky land castle) observatory by his contemporary Tyco Brahe (1546-1601). But we should emphasize that chronologically Taqi al-Dîn was before Tyco Brahe (Tekeli, 2005). Taqi al-Dîn used the observational clocks indicating minutes and seconds. that allows him to make more accurate calculations. So his zijs deviate less than one minute. In those zijes he proposed and used decimal system in order to sexagessimal system. He stressed that will which provide easier and more accurate calculations for the first time in history (Demir, 1999). Unfortunately although its tremendous successes the observatory demolished by encouragements of sheik al-Islam Ahmet Şemseddin Efendi in 1580 (Unat, 1999: 483-484).[2]

I am not going to dwell his astronomical dissertations since our topic is a general features of mathematics in Ottomans but since his studies indicates original mathematical ideas I would like to mention briefly.

Taqi al-Dîn has tree zijes: *Sidre Müntehâ al-Efkâr fî Melekût al-Felek al-Devvâr (the limits of the Sky knowledge), Teshîl Zîj al-A'şârî al-Şehinşâhî Sânî Aşara fî Devle al-Osmâniyye al-Murâdiyye (The Decimal Zijes of Sultan), Cerîde al-Dürer va Harîde al- Fikrer (The Collection of the Pearls and the Pearl of the Views)*[3]. These zijes has prepared with regard to his studies in Istanbul Observatory. These are crucial zijes about both history of mathematics and history of interpolation[4]. The third zij has studied and translated by Prof. Dr. Remzi Demir in 1992 in his doctorate dissertation (Demir, 1999).

---

1 When Taqi al-Dîn died Kepler was 14. and later he wrote a book named *The Reliable Foundations of Astrology* in 1601.

2 He said the comet in 1577 November was a sign of God and plague in 1578 has started because of the people interfere God's job.

3 Here he means "The collection of the important knowledges, and the most important knowledge among all others".

4 Finding one functions value by using another.

The Number System of Taqi al-Dîn

The Indian numbers causes many problems to the Islamic scholars. The language of science was Arabic which's letter were written right to left, but the Indian numbers were written left to right. On the other hand Indian numbers were positional and mathematical operations were much more easier with them. So Taqi al-Dîn offered a combined number system with the first nine Ebced and zero and they were written in the same direction with Arabic letters i.e. right to left. But the Numbers were positional just like the Indian numbers. Like many other Islamic scholars Taqi al-Dîn also did not consider negative numbers in his system and he also didn't use symbolism he express his opinions rhetorically. But his contemporaries in Europe were using both negative numbers and symbolism at that time.

Taqi al-Dîn's Mathematical Studies

- **Buğyat al-Tullâb min 'İlm al-Hisâb (Our Expectations from Computation):** Written in Arabic. It has three chapters, first is about *Hisâb al-Hindî*, the second is about *Hisâb al-Nucûmî* and the third is about finding the unknowns. The copies exist in Dar al-Kutub (İhsanoğlu, 1999: 85).
- **Cevâbu Su'âl 'an Musallas min al-'İzâm Gayri Kâ'im al-Zâviya va Laysa fi Azlâhî mâ Yabluğ al-Rub'a ve Azlâ'uhû Ma'lûma bi Asrihâ Hal Yumkinu Ma'rifatu Zavâyâhu:** Written in Arabic. It is about finding the angles of a triangle which have no right angle and has a certain edges. Taqi al-Dîn writes that treatise to in response to a question. The copies exist in Yeni Cami.
- **Risâle fi 'Amal al-Mîzân al-Tabî'î (A Treatise about Nature's Scale) :** That was about Archimedes scale. It was written in Arabic. It's copy exist in Alexandria City Library.
- **Risâle fi Tahkîki mâ Kâlahu'l-'Allâma Ğiyâsuddîn Camşid fi Bayân al-Nisba Bayn al-Muhit val-Kutr (A Treatise About The Ratio of the Diameter to Circumference):** It was written in Arabic. It is about the ratio of the diameter to circumference of the circle. As we all know this ratio is equal to the number pi. It's copy exist in Kandilli Observatory.
- **Tahrir Ukar Theodosius (Ukar of Theodosius) :** It was written in Arabic. That is a reduction of Ukar of Theodosius. The famous historian Katip Çelebi (1609-1657) mentioned this book, but the manuscript or copy doesn't exist.
- **Tastih al-Ukar:** It was written in Arabic. It is about stereographic projection. It's copy exist in Kandilli Observatory(İhsanoğlu, 1999: 86).

- **Kitâb al-Nisab al- Mutaşâkila fi 'l Cabr val Mukabela (Proportion of the Numbers):** Written in Arabic. It is about the difficulties of Algebra. It has one introduction (mukaddima), three sections (bab), and one conclusion (hatime) parts. It is translated and published by Prof. Dr. Melak Dosay Gökdoğan with the name "The Algebra of Taqi al-Dîn". The manuscript preserved in Oxford, I.881,3 1. In the first chapter of the treatise Taqi al-Dîn explained the four arithmetical operations and their rules. In the second chapter of the treatise he investigated *cabr* and *hat* operations.

Cabir (completing): Let A > 0 be a constant rational number, and coefficient of x as Ax. In that case if A < 1, then cabr is completing that number to 1.

Hat (degrade): Hat is the opposite of cabr. Let A>0 be a constant rational number, and coefficient of x as Ax. In that case if A > 1, then hat is decreasing this number to 1.

Taqi al-Dîn has prepared his solution formulas for the A=1. So before giving his equations and their solutions, he explained how to arrange the equations for that rule. In both cases in order to make A=1 the coefficient which would be multiplied with the all equation was founded with the proportion.

The third chapter of the treatise was about *Algebraic Equations.* He separated the equations in a two parts as *müfred equations* (simple) and *mukterinat equations* (complex)

Simple (Müfred) Equations:

1. $ax^2 = bx$

2. $ax^2 = c$

3. $bx = c$

Combined (Mukterinat) Equations:

1. $ax^2 + bx = c$

2. $x^2 + c = bx$

3. $x^2 = bx + c$

After that Taqi al-Dîn explained how tp solve these equations.

MAGHRÎBÎ

Another mathematician that we will mention is Ali ibn Veli ibn Hamza al-Maghrîbî (ö. 1022/1614). His book *Tuhfetü-'l A'dad li zevi'l-Rüşd val-Sedad (The gift of Numbers)* is considered as the most comprehensive book ever written in Ottoman Empire about commercial mathematics. He was born in Algeria. After

completing his first education in Algeria then he traveled to Istanbul and completed his education in there. At that time Istanbul's madrasa's, especially Fatih and Süleymaniye madrasas, were very famous about having best quality scholars and comprehensive libraries. After he took his "icazet", Maghrîbî become a mathematics teacher in Hâşiye-i Tecrid and Miftah madrasas. In 1586 went back to the lands he born and became qadı in Algeria and Tripolis. Later he traveled to Mecca to become Haji (pilgrim) and completed his monumental treatise *Tuhfetü-'l A'dad li zevi'l-Rüşd val-Sedad.* He died in 1614.

- **Tuhfetü-'l A'dad li zevi'l-Rüşd val-Sedad:** At the end of this book he stated that completing this book takes his 3 months and 9 days. This book has written in Turkish. The manuscripts exists in Süleymaniye (Esad Efendi, 3151,2), Kavala (Riyaziye Turkî, Number 1) and Talat (Riyaziye Turkî, Number 1) libraries. He completed this book in 11 April 1591. The book has one introduction chapter, four main chapters and a conclusion chapter.

In the introduction part Maghrîbî states that book has written for the "muvakkit"s (i.e. person who attached to a mosque whose chief duty was to determine the time for the azans and namaze), tradesmen, qadıs. He also defined "hesab" (calculation) in this chapter, as a "discipline that helps finding unknowns". He used Gubâr numbers. Instead of *devre-i mütevaliye* system in which the numbers read three by three, he used *yük* system in which the numbers read five by five. He separated the numbers as *müfred* (simple) and *mürekkeb* (combined). While müfred numbers are numbers like 2, 20, 2000, mürekkep numbers are the combined numbers with two ore more figures in it like 123.

In the first main chapter Maghrîbî defines four main operations in positive integers. While he was mentioning the summation of consecutive even numbers sequence. He gave the formula rhetorically that we are using in high schools today.

For example;

When the question is the summation of the even numbers till 10.

2+4+.....+10 =?

He explains the answer will be;

2n=10, n=5

n.(n+1)

5.6=30.

In the second chapter, the main topic is rational numbers and irrational num-

bers[5]. He defines the operations in the rational numbers. He also defines the roots of the numbers and the operations in that kinds of numbers.

In the third chapter he defines how to find unknown in the equations and he proposed three methods for that.

1. Falsity

2. Algebra

3. Proportions: It is for the problems with one unknown and four known quantities.

The fourth chapter is about geometry:

1. The area of the rectangles.

2. The area of the triangles.

3. The area of the circle segments.

4. The areas and volumes of sphere and solids (Gökdoğan, 2009: 666-675).

In that time most arithmetic books had chapters about algebra and geometry.

Last but not the least in the conclusion chapter Maghrîbî covers topics: problems about interest calculation, income account, profit and loss statement, traveling problems. We should stress that as he mentioned in the introduction he was targeting the tradesman and these problems are supporting his statement. That book is translated and published by Prof. Dr. Melek Dosay Gökdoğan with the name "A Mathematician, Maghrîbî, Who Found Attractive the City of Istanbul ".

From now on we will investigate some books which are written in 16th century Ottoman in order to have an idea about general characteristic. I separated the books in three groups that is Arithmetic, Geometry and Algebra.

ARITHMETIC (CALCULATION - ACCOUNTING)

The Arithmetic notion usually includes number theories, measuring, and all kinds of calculations. For that reason in this section we will consider accounting books, and the calculation books (hesap) as arithmetic books. "Hesap" has been the most popular area of mathematics during centuries in each civilization. Also among Ottomans most treatise about mathematics was about "hesap". Again in 16th century % 68.65 of the books was about arithmetic and hesap. Ottomans needed arithmetic for shopping, trading, velocity and timing calculations, accounting, legacy sharing, engineering and in astronomy. In later centuries, they needed

[5] Exponentials.

further calculations for engineering as limits, logarithms, differentiation and integration and they studied those themes in arithmetic books. The language of the arithmetic books were %71.74'u Arabic, %6.52 Persian and %21.74 Turkish. Here are some example names of books written in Turkish 16th century.

Miftâh al-Muşkilât fi'l-Hisâb (The Key of the Difficulties in Arithmetic): The author of this book is Sa'adî b. Halîl (alive in1549). The author is accountant of Kanuni Sultan Suleyman (1494-1566).

Miftâh al-Hussâb (The Key of the Arithmetic): İlyâs b. 'Îsa al-Akhisârî (d.1560) The author is more known with his alchemy and cifir (a kind of fortune telling) studies. But he has some mathematical works too.

Şems-i Leyân (The Sparkle of The Sun): Hacı Muhammed Ağa b. Abdullâh al-Akpınârî (16th century) wrote that book in 1546. In this book he examined some mathematical rules and problems. The book has presented to son of the Kanuni Sultan Suleyman, Mustafa.

Camâl al Kuttâb va Kamâl al-Hussâb (The Views of the Clerks and The Excellence of Arithmetic): Nasûh al-Matrâkî (d.1564) he rewrite the same book by adding a geometry chapter at the time of Kanuni with the name *Umdet ül-Hussâb (The Principles of Arithmetic)*

Risâla fi 'İlm al-Hisâb (A Treatise About Arithmetic): The author is Taşköprülü Zâde (ö.1561). He also studied logic and science history.

Another treatise we frequently come up is commentaries to **Nuzhat al-Nuzzâr fi 'İlm al-Ğubâr (Explanation for Gubar Numbers)** of ibn al-Hâ'im (1412). Many 16th century Ottoman mathematicians wrote commentary for that book. (Al-Hattâb al-Ru'aynî, ibn al-Hanbalî, ibn Abi'l-Hayr al-Ermayûnî, Abdulkâdir al-Fayyûmî) As we can understand by its name it is about Gubar numbers.

GEOMETRY

Although the Ottoman-Turkish terminology of geometry has developed much more later than arithmetic, medicine and astronomy; geometry (mesaha as they calles) has been the second favorite field of Ottoman mathematicians. The Ottoman astronomers in 16th century developed some protractors in order to use in trigonometric calculations. There are 14 books written in 16th century, about geometry. Two of these books were commentary. The books only assigned for geometry that is % 20.90 of all. And %57.14 of the books were in Arabic, %7.14 were in Persian and %35.72 were in Turkish. They are;

Mecma' al-Gar'ib fi al-Mesâha (Surprising Points about Geometry): Emrî Çelebi (d.1574) completed that book on 4th of November in 1560. That is the first Ottoman-Turkish text assigned geometry.

Risâla fi Kısmet al-Kabbân bi'l-Tarîk al-Hendasa va'l-Mesâha va'l-Hisâb bi'l-Nisab al-Arbâ (Division in Scales by Geometry): This book has written by al-Sûfî (d.1543) in Arabic. It is a commentary of Kâzi'l-Humâmîya's *Ğunyat al-Hussâb fî 'İlm al-Hisâb.*

Mahâyil al-Milâha fi Masâ'il al-Mesâha (Abstracts and The Matters of Geometry): Hanbalî (1563) book written in Arabic.

Kitab al-İknâ fi 'İlm al-Hisâb va al-Mesâha (The Book makes us Belive Arithmetic and Geometry) : The author Abu'l-Valîd b. 'Abdul'aziz (1568) wrote this book in Persian.

Risâla fi Tasâvi'l-Zavâya'l-Sâlâş (A Treatise About Division of an Angle In to Tree Equal Parts) : Al-Bihişti (b. beginning of the 16th century) wrote that treatise to find a solution one of the most famous Ancient Greek *Delos Problems* "Teslisi zaviye": Division of an Angle In to Tree Equal Parts.

Risâla fi'i-Bahs al-Hendasa (A Treatise About Geometry): Muhammed Zilk al-Halabî's (alive in 1579) treatise in Arabic.

Risâla fi Ma'rifat Kemmiyat Muhit al-Dâira (The Feat of The Quantity Determines the Area of a Circle): That book is Yûsuf b. Muhammed al-Azhari's (16th century) book about area of a circle written in Arabic.

Kurrat al-'Aynayn fi Mesâhat Zarf al-Kullatayn (Result of a Intensive Work and Content of al-Kullatayn): This book has written by al-Şinvarî (16th c.) in Arabic. It is a commentary of Zakariyyâ al-Anşarî's (d.1520) *Mesâhat al-Kullatayn.* The book is about volumes of solids.

Risâla fi Mas'alat al-Luzûm Ğayr al-Bayyin ve İzâh al-Vasat al-Hendasî Fîhâ (A Treatise Which is About Required Matters): Mustafa b. Mahmûd al-Tosyavî (d. 1596) wrote that book in Arabic.

Cavâb 'alâ Su'al Hendasiyyin Yata'allaku bi'l-Mesâha (The Answer of The Question About Geometry): Ibn Abi'l-Hayr al-Ermayûnî wrote that book in Arabic.

The other geometry books are Taqi al-Dîn's books.

ALGEBRA

Ottomans were not sifting algebra from arithmetic. They were examining algebra under a name of *Cabr and Mukâbela* in arithmetic books. Cabr means completing to 1 and mukabela means gathering similar terms to the same sides of the equation. There are 6 books written in 16th century only assigned for algebra. 16th century. That is % 10.45 of all. And %86 of the them are in Arabic and %14 are in Turkish. They aren't any algebra books written in Persian. These six books are,

Fath al-Mubdi' fi Şarh al-Mukni (Convincing Commentory of al-Mubdi' fi Şarh al-Mukni): This book has written by Zakariyyâ al-Anşarî in Arabic. It is a commentary of ibn al-Ha'im's *al-Mubdi' fi Şerh al-Mukni'*.

Nuhzat al-Albâb ve Zubdat al-Talhîs (Summary of the Obvious Chapters and Conclusions): This book has written by al-Miknâsî (d.1557) in Arabic.

Câmi' al-Hisâb (Collection of Arithmetic): The author of this book is Yûsuf b. Kemâl al-Burusavî. The author is accountant of Kanuni Sultan Suleyman (1494-1566). This book has written in Ottoman-Turkish. It is about algebra and arithmetic.

Risâle fi al-Cabr val-Mukâbela (A Treatise About Algebra): This book has written by Dâvûd al-Antâkî (d.1599) in Arabic.

Ğayat al-Sa'ûl fi Kayfiyyat İstihrâc al-Mechûl (An Inquiry for Understanding the Quality of the Unknown): This book has written by al-Kıbâbî (alive in 1599) in Arabic.

Şerh al-Mukni' fi al-Cabr val-Mukâbela (The Convincing Commentory About Algebra): This book has written by Abdulkâdir al-Fayyûmî (d.1613) in Arabic. It is a commentary of ibn al-Ha'im's *al-Mukni' fi al-Cabr ve al-Mukâbala*.

CONCLUSION AND EVALUATION

16th century is the golden of the Ottoman science. That broad conclusion is also valid for mathematics. In that century Ottomans produced original treaties and commentaries more than ever. As we stressed before, not all the Ottoman texts has translated and examined yet. So all the conclusions and the evaluations about the general characteristics of the Ottoman mathematics, will be in inadequate and insufficient. Nevertheless, when the 16th century compared with all periods, it is possible to revise an acceptable conclusion.

The Ottoman Sultans who lived in that era had a special interest of science. They supported the scholars and they demand some specific translations. That attitude of theirs plays important part on visible features of 16th century mathematics. Again in that era the most comprehensive treaties of all times has produced and the observatory that we mentioned before has been established.

In order to summarize the general features of 16th century Ottoman mathematics we should take a glance the following table.

	Arithmetic	Geometry	Algebra
Arabic	33	8	6
Persian	3	1	0
Turkish	10	5	1

In this chart we can obviously see that the applied mathematics attracts more attention among scholars. That trammels to contribute theoretical mathematics. Deficiency in theoretical contributions confronts some probable progresses. That has been the main reason constitutes the level difference in mathematics between Ottomans and Westerns at the end of the century. Another challenge was the language of science. Since it was Arabic, that limited the mass of people who can reach knowledge, because not all Ottomans knew Arabic. Despite those challenges the scholars made brilliant progresses.

All the holy knowledge of science has taken from the Medieval Islam and protected by Ottoman scholars like a sacred legacy. Westerns learned the same knowledge from the same source, but they tried to prevail it. That may be the second difference between Ottomans and Westerns. One of them was trying to preserve a legacy while the other was trying to overcome it by some sociologic reasons. Also as we all know Western scholars compared the original Greek texts with the Arabic translations and commentaries, so they had a chance internalize the structure of the science which is unrestricted. Any how the original contributions and recommendations existed in Ottomans like in Taqi al-Dîn's example but they are underestimated by other scholars and didn't interchange by the sacred Medieval Islamic knowledge.

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