Abu Nasr Mansur b. 'Ali b. ‘Iraq (lived circa 950-1036) and Abu l-Rayhan al-Biruni (lived from 973-after 1050) as students, teachers, and companions

Sonja Brentjes
Max Planck Institute of history sciences , Berlin, Germany

Abstract

This paper discusses issues of a history of teaching the mathematical sciences in the so-called classical or foundational period of Islamicate societies. This history does not exist so far since all research on the history of the mathematical sciences in Islamicate societies before 1300 during the last fifty years focused on translations from Greek and occasionally other languages into Arabic as well as innovative methods, theories and instruments. I discuss how to build such a history on the basis of a case study.

Key words: *history of teaching; mathematical sciences; Islamicate societies; foundational period; Abu Nasr b. 'Ali b. 'Iraq; Abu l-Rayhan al-Biruni; methodology*

The history of teaching the mathematical sciences in Islamicate societies is still in its infancy. Most academic research concentrates on the editions, translation, and interpretation of texts, rarely studying at any depth they social, cultural, or economic conctexts of the authors and their contemporaries. So far, my own work focused primarily on the mathematical sciences at madrasas in Egypt and Syria after 1200, since their presence in classes taught there was denied by earlier researchers and since most of the biographical material related to the mathematical sciences at madrasas has been written by scholars from those regions.

In this paper, I focus on an earlier period which as a rule is exlusively approached from the perspective of high-level mathematical achievements, i.e. research. Although we know the one or the other detail with regard to teaching, there is paper dedicated to this part of mathematical practice in any Islamicate society before 1200. Working on an introductory book on the history of teaching the sciences in Islamicate societies until 1700, I am not able to fully compensate this lack of research for such a long period of time. Hence, I decided to treat a few selected examples. One pair of well-known scholars, whose engagement in teaching I wish to include in that book, are the friends and colleagues Abu Nasr Mansur b. 'Ali b. 'Iraq and Abu l-Rayhan al-Biruni. I present in this paper my survey on their activities in this regard with some reflections on methodological issues.

The methodological issues that I address concern the biographies of the two men, how to differentiat teaching from research texts, and problems of how to understand relationships and forms of style and rhetoric.

1. Biographical issues

Our knowledge about the ancestors of Abu Nasr Mansur b. 'Iraq (from now on: Abu Nasr or Ibn ‘Iraq) and therewith his family rests on two different kinds of sources: al-Biruni's works and archeological excavations with its recovered objects and sites. These two sources of knowledge do not agree in most of their details, but it is not easy to determine which problem causes the greater inaccuracies: al-Biruni's lack of ancient sources and his prejudices against the Arabic invaders of the eighth and ninth centuries or the loss of most written sources of pre-Islamic Khwarazm. (Bosworth 2011, vol. 1, fasc. 7, 743-745) Hence, for the purpose of this paper I simply register that Abu Nasr possibly was a prince of the ruling dynasty of the Khwarazmshahs (Afrighid family) and that al-Biruni is believed to have been born in a suburb of Kat, the ancient capital of this state. Al-Biruni describes himself in a poem as an orphan and his mother as coming from a lowly family.

Ibn ‘Iraq's family was overthrown in 995 by the neighboring Ma'munid emir of Gurganj, possible as ripple effect of the westward drive of Nomadic tribes in central Asia. For Biruni began a long time of traveling. He apparently went first to Rayy, which was a Buyyid stronghold. (Bulgakov 1966, 13) But in 997, he was back in Kat observing in cooperation with Abu l-Wafa' (948-998) in Baghdad a lunar eclipse. One year later, he left again moving to the court of the Ziyarid ruler Qabus b. Vushmgir (reigned 977-981, 997-1012) in Gurgan at the south-eastern shores of the Caspian Sea. Although the Ziyarid court was a

flourishing cultural and scholarly center in that time, al-Biruni was not too happy there complaining in his later works about the lack of instruments and opportunities for scholarly research. (Rozenfel'd, Rozhanskaya and Sokolovskaya 1971, 11) Possibly receiving an invitation, al-Biruni returned during the first decade of the eleventh century (the precise year is contested) to Khwarazm serving until 1017 at the last Ma'munid ruler's court in Urgench as a boon companion, princely adviser, and skilled diplomat. (Bosworth 2011, vol. 4, 274-276) There he made the acquaintance of Ibn Sina and one of his teachers, Abu Sahl 'Isa b. Yahya al-Masihi (died 1012). At some unknown point in time, Ibn ʻIraq came to serve at the court in Kat. There he survived the overthrow of his family and became a courtier of the Ma'munid rulers 'Ali b. Ma'mun (reigned 997-1009) and Abu l-'Abbas Ma'mun (reigned 1009-1017).

In 1017, the political turmoil of those years once again changed the lives of both men dramatically. Since 1008, the new Ghaznavid dynasty with their capital in Ghazna (today in Afghanistan) was the new regional superpower. The Khwarazmshahs tried to maintain their dominion by trying to forge alliances both with the Abbasid caliphs in Baghdad and the Ghaznavid ruler Mahmud (reigned 997-1030). This policy finally failed in 1017 when Mahmud sent an ultimatum to Abu al-'Abbas Ma'mun demanding to be accepted as Ma'mun's overlord, to receive a hefty tribute, and to be sent the group of leading scholars assembled at Ma'mun's court. According to an anecdote told by Nizami Arudi (flourished between 1110 and 1161) from Samarqand, Ma'mun read the missive to the said scholars and offered them the opportunity to make their own decision. (Browne 1921, 85-87) Ibn Sina and Abu Sahl al-Masihi decided to flee in southwestern direction. During this flight, Abu Sahl died due to thirst and exhaustion. Al-Biruni, Ibn ʻIraq, and at least two further scholars chose to go to Mahmud's court in Ghazna. This report is ostensibly wrong, since IbnSina had left al-Ma'mun's court in 1012, and Abu Sahl al-Masihi had died during that voyage towards the Ziyarid court in Gurganj. Moreover, al-Ma'mun paid his willingness to obey Mahmud with his life. His nobles and army leaders rebelled. He was killed in March 1017, and his young nephew Abu l-Harith Muhammad b. 'Ali (died 1017?) was enthroned. Four months later, Mahmud's army conquered Khwarazm "avenging his brother-in-law's murder". (Bosworth 2011, vol. 1, fasc. 7, 744) It seems that only then al-Biruni, Ibn ʻIraq, and two other scholars were moved to Ghazna, where they spent the remaining decades of their lives with varying fortunes in the Ghaznavid empire and at its dynasty's court.

2. Teachers, Students, Companions

On the basis of Abu Nasr's and al-Biruni's later scholarly papers we can gain some glimpses of the kind of education both boys received. It included classical Arabic, New Persian, and the mathematical sciences. Since by then the Islamic faith was widely spread in Khwarazm and the ruling dynasty had converted to it a century earlier, they will also have learned to recite the Qur'an and studied other religious literature. Poetry also seems to have been part of their education. Philosophy and medicine, on the other hand, do not figure prominently in their work and thus may not have been an important part of their school years. In addition, al-Biruni remembers as an old man, being a curious child he went to visit someone from Byzantium who happened to live in Kat, bringing plants, seeds, and other items to him, asking for their names in his mother tongue, and writing them down. (Bulgakov 1972, 31)

Given this scarcity of information, it is very difficult to determine who their teachers were. Ibn ʻIraq allegeldy received his mathematical and astronomical training from one of the leading scholars of the mathematical sciences of the Buyid era during the tenth century - Abu l-Wafa' (940-998) from Buzjan in eastern Iran. Since Abu l-Wafa' moved in 959 to Baghdad, when Ibn ʻIraq was at best nine years old, this is difficult to accept, because there is no evidence that Ibn ʻIraq spent a longer period of his life in the Abbasid capital. Thus, if the two men met and talked about the mathematical sciences, this must have happened somewhere in Iran, possibly at one of the Buyid courts. At an unidentified date, but before 998, Abu Nasr wrote a treatise on azimuths about which he said that Abu l-Wafa' had read it. (Samsò 1969, 28-29)

In 997, one year before Abu l-Wafa's death, al-Biruni exchanged letters with him about a joint astronomical project. During this decade, al-Biruni also constructed astronomical instruments and perhaps a terrestrial globe and observed the altitude of the Sun in his hometown for the Spring and Autumn equinoxes. (Bulgakov 1972, 27) Thus, al-Biruni's higher education in the mathematical sciences must have taken place before 990, when he celebrated his seventeenth birthday, or at least must have had been in its advanced stage by then. Perhaps his early observations, constructions of instruments and a globe as well as his early texts written in the same period may be regarded as components of his training as a young scholar.

The following quote describes one of these early observations made by al-Biruni in the age of 22 according to his recital in the *Geodesy* situating it in the period of the overthrow of Ibn ʻIraq's family:

> I measured the solar altitude twice. In the first time, I measured it in the village called Bushkanz (?) at the western shores of the Jayhun [Amu Darya], between Jurjaniyya and the [main] city of Khwarazm [i.e. Kat] in the year three hundred eighty four or three Hijra, with a circle of fifteen cubits in the plane of the horizon. I measured on the shortest shadow the Sun cast its greatest altitude and found it to be 71°59'45". Then at the same day, I got the value of the shadow, when it reached the line of day and night equality. But I forgot it because of the riots and commotion [in Khwarazm], which forced me to leave the country and to interrupt the works. But I remember that the value of the greatest inclination, which I got from these two [altitudes], was 23°35'45" and the longitude of the said village was 41°36'. (Bulgakov 1972, 32)

Analyzing several of Ibn ʻIraq's and al-Biruni's extant writings, Julio Samsò pointed to al-Biruni's unique approach to several scholars in his environment. They allegedly wrote treatises in al-Biruni's name. (Samsò 1969, 18-19) Two of them are said to have written each twelve such shorter or longer treatises: Ibn ʻIraq and Abu Sahl al-Masihi. Al-Biruni asked Abu Nasr for an explanation and proof of problems in works by earlier authors or in practices of craftsmen or for determining their errors. Ibn ʻIraq appears here in a double role - that of a teacher and perhaps the technically more apt scholar and that of an adjunct of al-Biruni whom - Samsò believes - Ibn ʻIraq wished to free from detailed, pedantic labor for more ambitious projects. (Samsò 1969, 21) If Samsò's reflections on the possible dating of some of these texts are correct then al-Biruni continued to ask for such services over a period of almost three decades, i.e. when he was already almost 50 years old and Ibn ʻIraq complied with such requests even when he was beyond the seventies.

It is impossible to decide whether there was a shift from one relationship to the other or whether all those texts reflect Ibn Ira's auxiliary work for al-Biruni, because except for certain passages where Abu Nasr addresses al-Biruni directly, his language otherwise is very formal. It agrees with that of Euclid's *Elements* by presenting a proposition, followed sometimes by an explanation, and then continued by a proof with the standard terminating formula that this was what one wished to do, explain or know. The direct talk to al-Biruni clarifies that Ibn ʻIraq responds to questions and requests posed to him by al-Biruni. Their style corresponds to the question-and-answer texts written in Baghdad since the ninth century for students and curious acquaintances. In his *Epistle about the Intersections of the Azimuthal Circles on the Astrolabe*, Ibn ʻIraq writes for instance:

> You said, may God honor you, that the procedures based on the calculation for finding on the astrolabe the intersection of the azimuthal circles with the horizon and the tropics of Capricorn as well as the procedures of the craftsmen for obtaining this were arrived at according to your knowledge without proofs, which (would) make you trust them. (You added) that even when they were related to the most reputed people in the profession, you did not achieve (complete) certainty that they were free of errors and (mistakes due to) the lack of attentention by copyists of which the copies are only rarely free, unless you would obtain proofs and (take the time to) consider the test of such rules.
>
> You asked me to explain to you that what I clearly see in this matter and I acceded to your request ... (Samsò 1969, 20)

Such direct approaches to al-Biruni are also found occasionally between theorems or proofs. Al-Biruni asked Ibn ʻIraq in most cases for either one of the two points raised in the just quoted introduction: to prove that what an earlier scholar had provided was correct or to correct the errors and ommissions found in a copy of their work available to al-Biruni. (Samsò 1969, 28-32) When answering al-Biruni's questions or dealing with the tasks he posed, Ibn ʻIraq excerpted earlier research texts, commented on them, corrected them, or added proofs to them, when they had not been provided, and proposed his own solutions. He clearly treated the matter in a thorough manner, merging thus the genre of questions and answers with that of a textbook.

3. Al-Biruni's questions to Ibn Sina

Of a different nature are the three letters with philosophical, astronomical, optical, and related scientific questions which al-Biruni sent to Ibn Sina. They incorporate curiosity, challenge, dissatisfaction, and criticism. It is believed that this exachange took place around 1000, when al-Biruni was at the court of Qabus b. Vushmgir and Ibn Sina, about 20 years old, was still in Bukhara. (Glick 2005, 88; for the date of Ibn Sina's flight from Bukhara see Gutas 1987-1988, 334) Ibn Sina is said to have defended "orthodox Aristotelian" views, while al-Biruni showed his "independent" mind by accusing Aristotle to rely too much on authority and to abstain from making observations. (Glick 2005, 88) The year 1000 as a date for the exchange is, however, doubtful in terms of chronology. While Ibn Sina answered the first two letters with eighteen

questions in person, he gave al-Biruni's last reply to his student Abu Sa'id Ahmad b. 'Ali al-Mas'umi (late tenth-first half eleventh centuries), exasperated and angry about al-Biruni's choice of words and continued challenge. (Reisman 2007, 197) The fact that al-Mas'umi answered al-Biruni's third letter also contradicts an early dating of the exchange, since Ibn Sina seems to have had students whose names we know only from 1013 onwards. (Gutas 2014, 19)

With regard to Ibn Sina's and al-Biruni's intellectual positions in these letters, things are neither simple and clear cut. One strong current in them is al-Biruni's rejection of any theoretical claim that can be shown to deviate from empirical observations. Ibn Sina, on the other hand, points to al-Biruni's weaknesses in his knowledge and interpretation of philosophical theories and tries to determine the books from which he might have derived his views. This does not mean that Ibn Sina does not mention experiments in his replies. But he embeds them as a rule in references to mostly Aristotelian books, in particular *On the Heavens*, *On the Soul*, *On Generation and Corruption*, *Meteorology*, and *On Sense and Sensibility*.

The overall character of al-Biruni's questions and Ibn Sina's and al-Ma'umi's answers is that of a scientific dispute, in which al-Biruni mostly, but not always challenges Aristotelian positions. But he also asked questions free of polemical character, which might imply that one reason for this exchange might indeed have been to acquire knowledge which he did not possess, i.e. to learn. The following is an example for such a non-polemical question:

> The Tenth Question: What causes transformation of elements into each other? Is it the result of their proximity or intermingling or some other process? Let us take the example of air and water: when water transforms into air, does it become air in reality, or is it because its particles spread out until they become invisible to the sight so that one cannot see these separate particles?

(https://internationsocietyofclassicalastrologers.files.wordpress.com/2013/04/ al-biruni_ibn-sina-correspondence.pdf, unpaginated, but numbered according to entries: 42)

Ibn Sina's reply here begins with a brief summary of his views, then names Aristotle's books (*On Generation and Corruption*; *Meteorology*; *On the Heavens*, Book III) where al-Biruni could find more detailed information, and finally offers an example with the aim to clarify the philosophical methods and demonstrations used for this problem. In this sense, we can consider the letters between al-Biruni and Ibn Sina as documents of high level teaching and learning perhaps in a postdoctoral phase, to use our own concepts.

Ibn Sina's answer:

> The transformation of elements into one another does not occur the way you mentioned. Water does not transform into air by the separation and the spread of its particles in the air until they disappear from the sight; rather, the water particles take off their watery identity and put on an airy identity. For more details, one can see the commentaries on *Kitab al-Kawn wa'l-Fasad* and *Kitab al- Athar al-'ulwiyah* and the Book III of *Kitab al-Sama'*. But here I clarify this case according to their methods and the following logical example that they used to prove their sayings.
>
> Increase in the size of bodies <can be explained> by means of an example: <Suppose>, we took a flask filled with water, sealed it tightly and exposed it to intense heat. The water particles in the flask would expand and crack the flask because their size increased when they transformed into air. This happened either because of the spread of the space between the water particles, but not because of the spread of particles. But the void is impossible; therefore, it is necessary that the latter is true. <Thus> the reason for transformation <of water into air> is not the spread of its particles, but the acceptance of another identity by its parts.
>
> If it would be said that air or something else entered the flask and increased its volume, we would say: that is impossible because a full container cannot accept another body inside it until it is emptied of the first occupant, and the water cannot leave the flask because it is tightly sealed and there is no way out. I observed a little flask. We tightly sealed it and put it in a kiln. It did not take long before it cracked and everything that was in it exploded into the fire. And it is known that nothing mixed with the particles of the water that were inside the flask that could cause a change, because, firstly, the fire was not inside the flask and, secondly, it did not enter it because there was no way into the flask. It is, therefore, obvious that this transformation occurred through a change in the air and fire natures of <air and fire> and not through the spread of parts. I have provided an example which supports Aristotle's views on the generation and change as parts of nature; and this suffices, for further elaboration would demand tenuous efforts. Many objections could arise in this matter and if you encounter any, please convey your questions and I would explain to you, God willing.

(https://internationsocietyofclassicalastrologers.files.wordpress.com/2013/04/al-biruni_ibn-sina-correspondence.pdf, entry 43-45)[1]

4. Science for Rayhana

Between 1027 and 1029, al-Biruni wrote in Ghazna a voluminous book in form of 530 questions and answers on astronomy and astrology calling it *The Book on the Understanding of the Principles of the Art of the Stars* [from now on: *The Book on the Stars*]. The recipient was a young woman by name of Rayhana, daughter of al-Hasan. According to al-Biruni's introduction to the book, Rayhana was from Khwarazm and had asked for instruction. Al-Biruni must have highly appreciated her intelligence and capacity to learn since instead of writing a little epistle for her, he wrote a full-fleged course about the four sciences of the quadrivium extended in various directions. He introduced Rayhana into plane and solid geometry, geometry of the sphere, theory of proportions, number theory, systems of counting and calculating, algebra, Ptolemaic astronomy, timekeeping, and the astrological doctrines of Hellenistic and late antique, Indian, Iranian, and Muslim authors. Some questions also pertain to balances and weighing, roots and powers defined in accordance with definitions of Book X of Euclid's *Elements*, or arithmetical rules not found in Greek treatises. Al-Biruni justifies his choice of the dialogical format as being better suited for learning and easier to understand. (Abu Raykhan Beruni 1975, 21) Given the broad scale and the complexity of knowledge that al-Biruni presented to the young woman, this was certainly a good choice.

Since it is impossible to survey the entire 530 questions and answers here, a few need to suffice for presenting al-Biruni as a teacher. I chose the briefest ones, ignoring those that run over a page or more. When reading different answers, it becomes clear that al-Biruni indeed had the goal to enable Rayhana to become fully qualified to read research texts. This text is one of the very rare products of a medieval scholar of the mathematical sciences which surveys knowledge in a disciplinary sense. Even more, it is the only text I have ever seen in Arabic that teaches a beginner an understanding of all the disciplines united in the concept of the mathematical sciences with the addition of astrology.

[Question 1:] What is geometry?

[Answer 1:] It is the science of the magnitudes and the quantities in relationship to each other, the teaching of the properties of their forms and figures, as they pertain to a body. It transforms the science of the numbers from the particular into the universal and transfers astronomy from guesswork and opinions into truth. (Abu Raykhan Beruni 1975, 21)[2]

[Question 7:] What is a point?

[Answer 7:] If a line has an end, this end is a point. A point has one dimension less than a line: a line has length; a point has neither length nor breadth or depth. A point is the end of the ends; that is why it does not have parts. It is illustrated from among the sensible things by the head of the acute needle. Each one of the line, the surface, and the point exist in the body, which carries them. Outside of the body, one can only imagine them in the mind. (*Abu Raykhan Beruni* 1975, 23)

[Question 16:] What is the upright sine?

[Answer 16:] That is half of the chord of the doubled arc or, if you like, the perpendicular, which is placed from one of the two ends of the arc to the diameter, which is drawn from the other end of the arc. When you see "sine" free (from any qualification), know that this is the upright sine. (*Abu Raykhan* 1975, 24)

[Question 32:] How does one multiply a line with a line?

[Answer 32:] This is the procedure if one line is marked off on the other until a rectangular surface results, which those lines enclose. If the two are equal, then the mentioned surface is a square. If the two are different, it is an oblong (figure). (*Abu Raykhan Beruni* 1975, 27)

[Question 55:] What is an inverse proportion?

[Answer 55:] That is when the second and the third [magnitude] are on one side. That is obvious for loads of the steelyard, which is the *qabban*: the ratio of the distance from the cancer on it until the suspension is to the distance of the moveable counterweight until it like the weight of the counterweight to the load, which equilibrates it in the scale. (*Abu Raykhan Beruni* 1975, 33)

[1] The Engish translation used here as a basis often modernizes the terminology in a manner that does not respect the philosophical theories of the period. I replaced such modernizations by more adequate terms, avoiding thus a language which is anchored in Newtonian physics.

[2] I did not reproduce Ramsay Wright's English translation, which is not always correct: *The Book of Instruction in the Elements of the Art of Astrology*, by Abu'l-Rayḥān Muḥammad Ibn Aḥmad Al-Bīrūnī, translated by R. Ramsay Wright, London: Luzac & Co., 1934. But I compared the Arabic text of the facsimile reproduced by Wright, which I felt was often necessary. Hence, the translation of the extracts is my modification of the Russion translation on the basis of the Arabic text of MS London, British Library, Or 8349.

[Question 64:] How many figures can enclose a sphere?

[Answer 64:] If they have equal sides and angles, which are from one genus, then there are five only, which relate to the four elements and the celestial sphere from the side of similarity. But if they are composed from different kinds, then they are neither limited nor numbered. As for the first five figures, one of them is the cube with six square faces. It is called the earthy (one). The second has twenty equal-sided faces. It is the watery (one). The third has eight triangles (of the same kind). It is the airy (one). The fourth, the spiny (one), has four triangular faces. It is the fiery (one). The fifth has twelve pentagons as faces. (*Abu Raykhan Beruni* 1975, 36)

[Question 123:] What is the heaven?

[Answer 123:] The word "heaven" means everything that is above you and towers above you so that by restriction this word means the clouds and the roofs of the houses. In a free (sense), it is the ceiling that is visible to the world, which is the heavenly sphere whose description was introduced before. The Persians call it in their language *asmãn*, i.e. (something) similar to a millstone (due to?) its circular movement. (*Abu Raykhan Beruni* 1975, 51)

[Question 264: How many (periods) has a solar eclipse?

[Anser 264:] There are three, because there is no perceptable stay; they is nothing else than the beginning of the occultation, its middle, and the completion of the disappearance. (*Abu Raykhan Beruni* 1975, 125)

[Question 385:] Which are the male and which are the female planets?

[Answer 385:] The three upper panets and the Sun are male, whereas Saturn is a Eunuch [having no influence on the birth]. Venus and Moon are female. Mercury is a hermaphrodite, because it is male together with the male planets and female together with the female (ones). When it is, however, alone, it is male. Some consider Mars as female, but this opinion is not accepted. (*Abu Raykhan Beruni* 1975, 180-181)

[Question 491:] What are the "dead" degrees?

[Answer 491:] These are the five degrees before the degree of the ascendant in (the direction) opposite to the sequence (of the zodiacal signs). Ptolemy does not count them in the twelfth (house) and does not consider them as belonging to the horoscope. But if the planet is in them, then he considers them in the horoscope. (*Abu Raykhan Beruni* 1975, 239)

These few examples indicate that al-Biruni created a superb teaching document not merely by his comprehensiveness. He continuuously talks directly to Rayhana, explaining one matter, comparing the other, or offering a name in another language. The many terms, concepts, and possible difficulties are represented by diagrams and tables visualizing and ordering the taught knowledge. As a result, Rayhana, if she ever read the book from cover to cover, would have been capable of understanding fairly high-level scientific texts or participating in scholarly conversations, if allowed into the male circle. She could also have acted as a teacher to other women. But nothing of that aroused a historian's curiosity and hence remains hidden in the dust of history. One thing, however, al-Biruni did not teach her in his book: technical skills, ie. how to observe and measure the altitude, declinations, azimuths, and other coordinates of heavenly bodies, and to calculate values derived from them.

Although *The Book of the Stars* shows al-Biruni as a gifted teacher, no other teaching activities of his are known. But due to his transfer to Ghazna and the military campaigns into northern India, which he had to accompany, he engaged in his adult life in a series of learning activities.

5. al-Biruni's Acquisition and Distribution of Knowledge in India

Al-Biruni's learning of knowledge from non-Islamicate sources in India was part of his upbringing in the mathematical sciences as a result of the translation of Sanskrit texts on astronomical, astrological, and chronological subjets during the eighth and the ninth centuries and the integration of this Indian knowledge into arithmetic, astronomy, astrology, chronology, and to a limited degree geometry. Despite the overwhelming preference for translations of ancient Greek texts in most of these disciplines by professional experts, a good number of particulars from Sanskrit traditions remained within Arabic and Persian scientific knowledge practices.

During the first two decades in South Asia, al-Biruni learned Sanskrit and probably at least one of its spoken forms. He outlines fairly well the difficulties one can encounter in such an endeavor, although he does not name all of them. Then he went to look for teachers of philosophy, astronomy/astrology, arithmetic, and literature. He was upset about the socio-cultural ideas of the Brahmins who considered him impure and refused to interact with him. In his view, the Buddhists were not much more welcoming. But he himself harbored his own ideas of superiority:

> At first I stood to their astronomers in the relation of a pupil to his master, being a stranger among them and not acquainted with their peculiar national and traditional methods of science. On having made some

progress, I begann to show them the elements on which this science rests, to point out to them some rules of logical deduction and the scientific methods of all mathematics, and then they flocked together around me from all parts, wondering, and most eager to learn from me, asking me at the same time from what Hindu master I had learnt those things, whilst in reality I showed them what they were worth, and thought myself a great deal superior to them, disdaining to be put on a level with them. (*Alberuni's India* 1992, 23)

As alrady Sachau pointed out in his edition and English translation, al-Biruni does not provide any information about the men who taught him the language and any of the other kinds of knowledge found in his book. (*Alberuni's India* 1992, xxxv) Equally, he did not talk much about his learning experience. Only once does he state that it was very difficult for him to enter into Indian scientific doctrines, despite his love for the subject. He admits to have spent much time and money for buying books, even from remote places, and paying teachers. (*Alberuni's India* 1992, 24) Al-Biruni rather emphazises that the goal in writing his book was to teach its readers. (*Alberuni's India* 1992, 110, 122, 147)

While the words teacher and teaching appear in al-Biruni's *India* mostly within stories about Indian gods, kings, princes, grammarians, the word learning is mentioned at least three times with regard to himself. In one instance, he quotes from a single page of a book by Brahmagupta (died after 665) about arithmetic, which arithmetical procedures he described for metric. (*Alberuni's India* 1992, 147) He expresses his hope to find one day the complete book, because much could be learned about Indian arithmetic from it. (*Alberuni's India* 1992, 150-151) In the chapter on weights, compiled so that the reader can better understand the various terms used throughout the book, al-Biruni briefly remarks that he learned about weights and coins and their equivalents with those used in his home region or by Muslim traders from some unspecified Indians. (*Alberuni's India* 1992, 160) This seems to suggest that he did not limit his acquisition of knowledge to the formal ways of learning with a teacher or a book. In the chapter on witchcraft, al-Biruni begins with discussing alchemy saying that the could not learn much from the Indian adepts of this art, which he himself does not think highly of. Nonetheless he managed to acquire some basic information about methods (sublimation, calcination, analysis, waxing of talc). On this basis he concludes "that they incline towards the mineralogical method of alchemy". (*Alberuni's India* 1992, 188) He also knew that the Indians practiced a science related to alchemy: rasayana, but that it was mostly plant-based and dealt with drugs and compound medicines. Further information provided by al-Biruni shows that he did not merely inquire about the content of a scientific discipline, but was apparently always eager to learn about its most famous practioners and their books. (*Alberuni's India* 1992, 189) This corresponds well with his approach in the chapters on astronomy, astrology, and chronology.

He decidated an entire chapter to the authors and books on astronomy, where he presents information acquired from Brahmagupta's *Siddhanta*, i.e. his *Brāhmasphutasiddānta*. ((*Alberuni's India* 1992, 152-159) He had begun translating it as well as the *Paulisha Siddhanta* (circa fourth century?), which he also had been able to buy. But when writing the *India*, he had not finished yet his translations. (*Alberuni's India* 1992, 155-156) However, he reports that he had finished his Arabic translation of Varahamihira's (505-587) smaller *Jataka* on astrology. (*Alberuni's India* 1992, 5) He also quotes repeatedly from Varahamihira's *Samhita*, having been obviously well familiar with his works. (*Alberuni's India* 1992, 162, 166-167) In addition to these three most often mentioned authors and their works, al-Biruni also quotes from commentaries by Balabhadra, who may have lived in the first half of the ninth century. This implies that his learning of Indian astronomy, astrology, and chronology rested mainly on books, some of which he may have read with a teacher. This is hinted at by al-Biruni, when he adds to the title of an astronomical handbook "which shows, as I am told, how the corrected places of the stars are derived from one another". (*Alberuni's India* 1992, 157)

In addition to books, authors, methods, terms, or parameters, al-Biruni also was very eager to collect stories. Across his entire book, he tells a great number of stories about all sorts of themes. One of these stories explains why Brahmagupta named one of his astronomical books *Karanakhandakadyaka*, where *khanda* refers to an Indian sweetmeat:

Sugriva, the Buddhist, had composed an astronomical handbook, which he called *Dadhi-sagraha*, i.e. the sea of sour milk; and a pupil of his composed a book of the same kind which he called K*uri-babaya* (?), i.e. a mountain of rice. Afterwards he composed another book which he called *Lavana-mushti*, i.e. a handful of salt. Therefore Brahmagupta called his book the Sweetmeat-khadyaka- in order that all kinds of victuals (sour-milk, rice, salt,

&c.) should occur in the titles of the books on this science. (*Alberuni's India* 1992, 156)

These stories as well as the level of technicalities in al-Biruni's book on India confirm his statement in the preface to the book that he wished to compile a reader-oriented book, not an introduction into the intellectual world of the Indians and its technicalities. The *India* was meant to provide information and entertainment, certainly important elements of learning. But it was not meant to teach specific, applicable knowledge in the styles of the various religious and scholarly communities of the subcontinent.

6. Conclusions

Studying extant mathematical, chronological, and historical works of Abu Nasr and al-Biruni does not lead to a complete picture of how the two boys learned and the two men taught. But it highlights specific features of their educational processes. Books played an important role in their understanding of how to acquire, produce, and teach scholarly knowledge. Reading and correcting books, checking their technical procedures, inquiring about practical implementations of methods and theories, challenging data and explanations, and exploring unknown cultures of knowledge are important components of Abu Nasr's and al-Biruni's lifelong practices of learning and sharing knowledge. Constructing instruments, carrying out observations and measurements, and cooperating with other scholars shaped al-Biruni's years of higher education, in all likelihood supervised by Abu Nasr. The cooperative relationships between al-Biruni and his colleagues portray him certainly as a highly gifted man and clever organizer of scholarly work. But they also speak of the respect Abu Nasr and others paid to him and the seriousness with which they participated in his investigations.

Al-Biruni's books on the mathematical sciences for Rayhana and on India for a broad range of readers show him as a gifted teacher with a clear eye for the scope of the sciences and an entertaining narrator with insights into foreign cultures of knowledge, but also limitations created by his own cultural identity.

Although some of these aspects look very familiar to us and thus speak for a shared intellectual bond over time, we should nonetheless abstain from demanding too much from them in terms of their similarity to our own practices and values. But with proper caution and respect for their own circumenstances and possibilities, their learning and teaching experiences as left to us in their writings can - I believe - inspire today's high school and university students.

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