

Contributions of Islamic scholars to the scientific enterprise

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This paper presents a discussion regarding the role that Muslim scholars played in the development of scientific thinking in the Middle Ages. It argues that the Muslims were not just the preservers of the ancient and Greek knowledge, but that they contributed original works to the different fields of science. They were inspired by the Islamic view of nature that is, mankind had a duty to 'study nature in order to discover God and to use nature for the benefit of mankind'. This knowledge was transferred to Western Europe and subsequently played an important role in revitalising a climate of learning and exploration in Europe, leading to the Renaissance in the sixteenth and seventeenth centuries.

Muslim scholars, scientific thinking, Islamic view of nature, knowledge transfer, Western science

INTRODUCTION

Over the last 50 years there has been renewed interest in Islamic countries in examining the relationship between Islam and science in the spectrum of its history. After gaining independence most of the Islamic countries have been struggling to come to terms with their religious beliefs and the Western concepts of science and education. The education systems adopted by the most of the Islamic countries have been based on 'so-called secular Western education'. Consequently a cultural dichotomy is observed in their societies between a traditional Islamic education on the one hand restricted to religious groups, and a secular Western education in main stream schools, colleges and universities. Education is viewed as a means of acquiring scientific knowledge and technology, in order to progress economically in the modern world. However, education has unsuccessfully tried to blend Islamic thinking with this Western education system (Al-Faruqi and Nasseef, 1981).

The period between the seventh to the fifteenth centuries is considered as the 'Golden Age of Islamic Civilisation'. During this period there was great emphasis on the pursuit of knowledge. Consequently there were individuals who lived scholarly and pious lives, such as Ibn Sina, Al-Khwarizmi, and Al-Biruni, who in addition to excellence in the study of religious texts also excelled in mathematics, geography, astronomy, physics, chemistry, and medicine. At this time Islam was not just a set of religious beliefs, but a set of ideas, ethics and ideals encompassing all aspects of human life. This resulted in the establishment of an Islamic civilisation. Thus the motivating force of this civilisation was its Islamic faith (used here both in the spiritual and temporal sense) and its language was Arabic (Khattani, 1976).

While the progress of scientific knowledge in Europe languished during the Dark Ages, science flourished in the Golden Age of Islam. The renaissance that subsequently occurred in Europe might not have taken place without the contribution of Muslim science in the preceding period. This was acknowledged by Sarton (1927, p. 17) who wrote:

From the second half of the eighth to the end of the eleventh century, Arabic was the scientific, the progressive language of mankind. It is suffice here to evoke a few glorious names without contemporary equivalents in the West: Jabir Ibn Haiyan, al-Kindi, al-Khwarizmi, al-Farghani, al-Razi, Thabit ibn Qurra, al-Battani, Hunain ibn Ishaq, al-Farabi, Ibrahim ibn Sinan, al-Masudi, al-Tarabi, Abu ibn Wafa, Ali ibn Abbas, Abu-l-Qasim, Ibn al-Jazzar, al-Biruni, Ibn Sina, Ibn Yunus, al-Karkhi, Ibn al-Haitham, Ali ibn Isa, al-Ghazzali, al-Zarqali, Omar Khayyam!

Many Muslims scholars in the Golden Age of Islam studied nature in the context of the *Quran*. The *Quran* depicted the relationship between nature and man, and this inspired the Muslim scholars to study natural phenomena, in order to understand God. Islam's contribution to the scientific enterprise was complex and rich and it spanned over three continents and nearly a millennium of time.

ISLAMIC VIEW OF NATURE

The Islamic view of nature during the Golden Age was for mankind 'to study nature in order to discover God and to use nature for the benefit of mankind'. Nature could be used to provide food for mankind and its bounty was to be equally distributed among all peoples. All activities that caused harm to mankind and in turn destroyed nature were forbidden. Destruction of the natural balance was discouraged, for example, unnecessary killing of animals or removal of vegetation might in turn lead to starvation due to lack of food. This view was an extension of the idea that 'man' had been placed on earth as God's representative.

The Islamic view of nature during the Golden Age had its roots in the *Quran*, the very word of God and the basis of Islam. Muslim scholars at that time were inspired to study nature in the context of the *Quran*. The following passages from the *Quran* illustrate the relationship between nature and man and how this relationship inspired Muslim scholars to study natural phenomenon, in order to understand God. The following verses also show the way the *Quran* presents the whole universe:

We created not the heavens, the earth, and all between them, merely in (idle) sport. We created them not except for just ends: But most of them do not understand, (Surah Al-Baqara 44: 38-39, (Pickthall, 1977)).

Behold! In the creation of the heavens and the earth; in the alternation of the night and the day; in the sailing of the ships through the ocean for the profit of mankind; in the rain which Allah sends down from the skies and the life which He gives therewith to an earth that is dead; in the beasts of all kinds that He scatters through the earth; in the change of the winds and the clouds which they trail like their slaves between the sky and the earth; (here) indeed are signs for a people that are wise, (Surah Ad-Dukham 2: 164, (Pickthall, 1977)).

Thus it was concluded that God created the world and placed man in it as trustee, to benefit from it, to use it wisely and to understand his purpose in the universe. Iqbal has emphasised this point eloquently as follows:

It is the lot of man to share in the deeper aspirations of the universe around him and to shape his own destiny as well as that of the universe, now by putting the whole of his energy to mould its forces to his own ends and purposes. And in this process of progressive change of God becomes a co-worker with him, provided man takes the initiative:

'Verily God will not change the condition of men, till they change what is in themselves (13:11).' (Iqbal, 1986, p.10)

Thus mankind was inspired to study, understand and mould the natural forces for its own purposes. The point to note is the general empirical attitude of the *Quran* which engendered in its followers a feeling of reverence and thus made them founders of an enlightened society (Iqbal, 1986).

THE CONTRIBUTIONS OF ISLAMIC SCHOLARS

The Islamic Empire consisted of a society that was multicultural in terms of languages, customs, traditions and religion. As Muslims went forth from Arabia to conquer the countries surrounding them, they encompassed vast lands with peoples of different faiths and cultures. Thus the Islamic Empire not only consisted of Muslims from three continents, Arabs, Persians, Turks, Africans, Indians and other Asians, but also Jews, Christians and other faiths. Therefore scholars from all faiths worked under the umbrella of Islam to produce a unique culture of knowledge and learning. In the paragraphs that follow each major known field of science is considered and examined for the contributions made by scholars from the Islamic world.

Medicine

Muslims gained access to the Greek medical knowledge of Hippocrates, Dioscorides, and Galen through the translations of their works in the seventh and eighth centuries. These initiatives by Muslims could be seen in the different aspects of the healing arts that were developed. The translation movement of the twelfth century in Latin Europe affected every known field of science, none more so than medicine (Meyers, 1964).

Two Muslim physicians who become known in Europe during this period were Ibn Sina (980-1037) and Al-Razi (865-925). Ibn Sina devoted his life to the study of medicine, philosophy and other branches of science. Renowned throughout medieval Europe as Avicenna, he established free hospitals and developed treatments for diseases using herbs, hot baths, and even major surgery. His famous book *The Canon of Medicine* was translated into Latin in the twelfth century and it was used in medical schools throughout Europe until the advent of modern science (Beshore, 1998; Meyers, 1964). *The Canon of Medicine* contained all Greek medical knowledge together with Arabic interpretations and contributions.

Ibn-Sina wrote some 99 books dealing with philosophy, medicine, geometry, astronomy, theology, philosophy, and art. Ibn-Sina was also known for *Kitab al Shifa (Book of Healing)*, in which he divided practical knowledge into ethics, economics, and politics, and theoretical knowledge into mathematics, physics, and metaphysics (Meyers, 1964).

Al-Razi, known in Latin as Rhazes, excelled in the powers of observations and wrote some 184 works on topics that he studied as a practising doctor. One of Al-Razi's books, *Treatise on Smallpox and Measles*, was translated into Latin, then English and other European languages, and "went through forty editions between the fifteenth and nineteenth century" (Turner, 1995, p.135). Furthermore, he established separate wards in hospitals for the mentally ill, thereby creating the means for clinical observations of these diseases. Al-Razi also included in his studies ideas involving human behaviour and he was a pioneer in the field of psychology, thus removing the theories of demons and witchcraft associated with these diseases in the Christian world.

By the twelfth century Muslim physicians had produced many works: encyclopaedias, medical biographies, texts on medical ethics, and on specialist topics such as ophthalmology. Ibn An-Nafis contradicted the theories of blood circulation as put forward by Galen. He advanced a theory of blood circulation between the compartments of the heart and the lungs, and of pulmonary circulation or lesser circulation. In 1553, three centuries later, a Spaniard Miguel Serveto (Michael Servetus) forwarded a similar theory (Meyerhof, 1935). Ibn An-Nafis's theory from the thirteenth

century was largely ignored. But he was among the initial precursors to Harvey's scholarly work that revealed the circulation of blood in the human body.

Muslims using their clinical and surgical knowledge established hospitals. These institutions were far superior to any that existed in ancient times or in lands beyond the Islamic Empire. In medieval Europe most hospitals were attached to religious orders and monasteries. In the Islamic world, during the eighth century the first hospital was built in Damascus; having separate wards for males and females, and special wards for internal diseases, surgery, orthopaedics and other diseases. These hospitals were to become models for hospitals as we know them today (Turner, 1995).

Important surgical treatises were written in the tenth and the eleventh centuries in Andalusia by Abu'l-Qasim al-Zahrawi, known in Europe as Abulcasis. His book *Kitab al-Tasrif (Book of Concessions)*, a medical almanac, was translated into Latin and used by Muslims and in European medical schools. The twelfth century physician in Muslim Spain, Ibn Zuhr, known as Avenzoar, wrote works especially in anatomy that had a great influence on medical practice in medieval Europe. Thus in the medical field scholars from the Islamic world had much to contribute both in terms of working with ancient knowledge and through the major developments of their own. Moreover, they verified their theories through careful observations in the hospitals that they had established.

Chemistry, Pharmacology and Pharmacy

In chemistry, the works of Jaber ibn Haiyan and Al-Razi formed the basis of modern science. Jaber, known as Geber in Latin, described in his works the preparation of many chemical substances: the sulphide of mercury, oxides and arsenic compounds. Al-Razi in his book *Secret of Secrets* known as *Liber secretorum bubacaris*, described the chemical processes and experiments he conducted. Hill (1993, p.83) has stated that Al-Razi's book *Secret of Secrets* 'foreshadows a laboratory manual' it deals with substances, equipment and procedures. Muslim chemists developed recipes for products that had industrial and military applications. The discovery of inorganic acids during chemical experiments had valuable industrial applications in the centuries that followed.

In the fields of pharmacology and pharmacy Muslims made notable progress. These fields involved scientific investigation into the composition, dosages, uses and therapeutic effects of drugs. Having translations of Dioscorides' *De Materis Medica*, along with knowledge from Syria, Persia, India and the Far East, Muslim scholars and physicians showed great innovative skills. They developed the procedures for the manufacture of syrups and juleps, and established apothecary shops (Turner, 1995). Ibn al-Baytar's book *Al-Jami' fi al-Tibb (Collection of Simple Diets and Drugs)* contained detailed records of the plants in the lands along the length of the Mediterranean coast between Spain and Syria. In addition, he systematically compared this knowledge with that of the scientists of previous eras. His book on botany was used until the Renaissance by Europeans.

Mathematical Sciences

The mathematical sciences as practised in the Islamic world during this period consisted of mathematics, algebra, and geometry as well as mathematical geography, astronomy and optics. Muslims derived their theory of numbers (*'ilm al-a'dad*) in arithmetic from translations of the Greek sources such as Books VII through to IX of Euclid's *Elements* and the *Introduction to the Science of Numbers* by Nicomachus of Gerasa (Berggren, 1997). Moreover, they acquired numerals from India (Hindu) and possibly China and made their use widespread. Mohammad Bin Ahmed in the tenth century invented the concept of zero or *sifr*. Thus replacing the cumbersome

Roman numerals and creating a revolution in mathematics (Badawi, 2002). This led to advances in the prediction of the movement of the planets and advances in the fields of astronomy and geography.

Muslim mathematics had inherited both the Babylonian sexagesimal system and the Indian (Hindu) decimal system, and this provided the basis for numerical techniques in mathematics (Folkerts, 2001; Rajagopal, 1993). Muslims built mathematical models using the decimal system, expressing all numbers by means of ten symbols, and each symbol accorded the value of position as well as absolute value (Kettani, 1976). Many creative methods of doing multiplications were developed by Muslims; methods of checking by casting out nines, and decimal fractions (Anawati, 1976). Thus Muslim scholars contributed and laid the foundations of modern mathematics and the use of mathematics in the fields of science and engineering (Høytrup, 1987).

Thabit bin Qurrah not only translated Greek works but also argued against and elaborated on the widely accepted views of Aristotle. In arithmetic there emerged the concept of irrational numbers with Islamic mathematicians starting from a non-Euclidean concept. Both Umar Khayyam (1048-1131) and Nasir al-Din al-Tusi (1201-1274) contributed to research on this concept which did not have its origins in Greek mathematics.

Eastern Muslims derived numerals from Sanskrit-०, १, २, ३, ४, ५, ६, ७, ८ and ९, and they were the first to develop the use of the zero (*sifr*), written as 0 by the Western Muslims and ‘.’ by Eastern Muslims (Kettani, 1976, p.137). Whereas these Eastern Muslims had initially used the Arabic alphabets as numerals, by the ninth century Western Muslims had invented and replaced them with “*al-arqam al-gubariyah*-1,2,3,4,5,6,7,8 and 9-based on a number of angles equal to the weight of each symbol” (Kettani,1976, p.137). Thus the zero with the numerals made it possible for the simple expressions for numbers to have infinite values, thereby helping solve particular problems. Translations of mathematical treatise in Spain subsequently transferred this knowledge to Europe.

Al-Khwarizmi wrote the first book of algebra, the word ‘algebra’ transliterates into the term *al-jabr*. Al-jabr represents the two basic operations used by al-Khwarizmi in solving quadratic equations. In the latter half of the twelfth century, the first part of al-Khwarizmi’s *Kitab al-Jabr wa al-Muqabalah* was translated and made available in Europe (Kettani, 1976; Sarton, 1927). Another famous contributor to this field was Umar Khayyam, who studied cubic equations and algebra came to be regarded as a science in its own right. Subsequently in later centuries Italians took over his methods and extended them (Anawati, 1976). Thus the Muslims not only developed the methods of solving quadratic equations they also produced tables containing sine, cosine, co-tangent and other trigonometrical values. Al-Battani (d.929) systematically developed trigonometry and extended it to spherical trigonometry (Kettani, 1976; Sarton, 1927), with important consequences for astronomy, geography and exploration beyond the known world, thus making the construction of better maps and the reconceptualisation of the structure of the planet Earth.

Arabic geometry absorbed not only materials and methods of Euclid’s *Elements* but also the works of Apollonius and Archimedes. The book, *On the Measurements of Planes and Spherical Figures*, written on Archimedean problems by the three sons of Musa bin Shakir in the ninth century became known in the West through the translation by Gerard of Cremona. In seventeenth century Europe the problems formulated by Ibn al-Haytham (965-1041) became known as “Alhazen’s problem”. Again his work that was translated into Latin made Europeans aware of al-Haytham’s remarkable achievements in the field of *Optics (Kitab al-Manazir)* (Meyers, 1964, p.32). Among his works were included a theory of vision and a theory of light, and was called by his successors of the twelfth century “Ptolemy the Second”. Furthermore by promoting the use of experiments in scientific research, al-Haytham played an important role in setting the scene in modern science (Rashed, 2002, p.773).

Al-Haytham's contributions to geometry and number theory went well beyond the Archimedean tradition. Al-Haytham also worked on analytical geometry and the beginnings of the link between algebra and geometry. Subsequently, this work led in pure mathematics to the harmonious fusion of algebra and geometry that was epitomised by Descartes in geometric analysis and by Newton in the calculus. Al-Haytham was a scientist who made major contributions to the fields of mathematics, physics and astronomy during the latter half of the tenth century. John Peckham in the late-thirteenth century used al-Haytham's *Kitab al-Manazir* and Witelo's *Optics* too has echoes of *Kitab al-Manazir*. Witelo work was used by Johannes Kepler. Roger Bacon, the founder of experimental science, probably used the original Arabic works of al-Haytham as well as Latin translations (Meyers, 1964).

Much work was under-taken by Islamic mathematicians regarding the theory of parallels. This theory consisted of a group of theorems whose proofs depended on Euclidean postulates. The Islamic mathematicians continued their research for over 500 years on these postulates in order to obtain proofs and not just the acceptance of them. However, after these problems were transmitted to Europe in the twelfth century, little further research was done until the sixteenth century. Muslim scholars contributed not only to the use of logic in the development of mathematical ideas and relationships, but also to a workable system of numeration that included zero and led to the solution of equations. Muslims had thus begun the work that led on to mathematical modelling and its application for the purpose of testing their theories. This knowledge and approach was slowly transferred to Europe through Spain and Sicily.

Astronomy

Muslim scholars considered astronomy as one of the mathematical sciences. Muslims came across ancient astronomical manuscripts and translated them into Arabic. They then undertook observations to verify the calculations in these scientific works. The Greek astronomer Ptolemy had developed an astronomical theory about the movements of the moon and planets; and had placed the earth at the centre of the universe. In order to compensate for errors in observation he had attributed additional movements to the planets. Al-Khwarizmi was one of the first scholars to produce a detailed astronomical table (*zij*). This astronomical table provided the means of calculating the positions of the stars and planets. Subsequently, each astronomer wrote his own *zij*, trying to make it more accurate than those prepared before (Beshore, 1998). Al-Farghani, in the ninth century wrote a detailed account of Ptolemy's *Almagest* and his book was used throughout Europe and central Asia for the next 700 years (Beshore, 1998, p. 24). This work was the beginnings of the empirical verification of scientific ideas and relationships.

Muslim philosophers and astronomers had inherited the Ptolemaic planetary system that hypothesised the principle of uniform circular motion allowing the planets to move in epicycles. However, Muslim astronomers eventually came to reject this theory in that the epicyclic movement violated the principle of uniformity of motion. In the thirteenth century, Al-Tusi, a Persian astronomer put forward his concept known as the "Tusi Couple", a hypothetical model of "epicyclic motion that involves a combination of motions each of which was uniform with respect to its own center" (Turner, 1995, p.68). This model was applied by Ibn al-Shatir to the motions of the heavenly bodies in the fourteenth century. Ibn al-Shatir's formulations were the beginnings of verifying theoretical astronomy through systematic observations.

Ibn al-Shatir's theory of lunar motion was very similar to that attributed to Copernicus some 150 years later (Sabra, 2002). Currently researchers are investigating whether it was possible, that Copernicus visiting the Vatican library in Rome had seen Ibn al-Shatir's fourteenth century manuscript illustrating his concept of planetary motion (Saliba, 2002). The reason for this supposition being a diagram in Copernicus' *Commentaries* that was remarkable similar to Ibn al-Shatir's schematic diagrams. Whereas Ibn al-Shatir's concept of planetary motion was conceived

in order to play an important role in an earth-centred planetary model, Copernicus used the same concept of motion to present his sun-centred planetary model. Thus the development of alternative models took place that permitted an empirical testing of the models.

Whether there was a clearly identifiable connection between the works of these two men today remains unclear, but what needs to be noted is that Muslim innovations in astronomical theory contributed to the historical development of astronomical science (Turner, 1995). These innovations provided new directions for investigations during the ages of the Renaissance and Enlightenment in Europe. Another development that was attributed to al-Tusi, the thirteenth century astronomer, was that he treated trigonometry as a separate field from spherical astronomy. Thus astronomers could calculate distances and directions of points on the celestial spheres more efficiently, using this new body of mathematical ideas and relationships.

Muslims also built large observatories in Maragha and Samarkand, and later at Delhi and Jaipur, and in Turkey. They improved on the Greek sundial and astrolabe, adding features by means of which they could calculate the timings of Muslim prayers and the direction to Mecca. The medieval astrolabe could be calibrated for use at different geographical locations to calculate year-long celestial time keeping data, and other astronomical information (Turner, 1995). These medieval astrolabes reached Europe in the late Middle Ages and were mentioned in many texts, and were included in an essay by Geoffrey Chaucer. Celestial globes, astrolabes, quadrants, and sundials all evolved and developed in Islamic countries, and when the compass arrived in the Islamic lands, it too was adapted by the Muslims. However they may not have initiated the use of the compass, because it would seem the origins of the use of the compass have not clearly been identified, and may have originated in China.

Thus Muslim scholars worked in all major branches of astronomy: theoretical and computational planetary astronomy, spherical astronomy and time keeping, instrumentation, and folk astronomy. King (2004) did extensive research on Muslim instrumentation and stated that “*medieval* European instrumentation was highly indebted to the Islamic tradition, and now it is clear *only after ca.1550* did European instrument-makers make technical innovations that had not been known to Muslim astronomers previously” (King, 2004, p.47).

FILTERING OF SCIENTIFIC KNOWLEDGE FROM THE ISLAMIC WORLD TO EUROPE

The conquest of the Eastern Empire by the Arabs meant that Western Christendom was deprived of the main reservoir of Greek learning for centuries by intolerance and mutual suspicion of opposing creeds, as well as the breadth of the Mediterranean Sea (Crombie, 1963). But as early as the end of the tenth century knowledge had begun filtering from the Islamic world to the West. Thompson (1929) in his article “The Introduction of Arabic Science into Lorraine in the Tenth Century” discussed the question of Arabic science being introduced in the schools of Lorraine as early as the end of the tenth century and thereby into Latin Europe. Thus an intellectual avenue through Spain to Europe beyond the Pyrenees was opened by the expansion of the Islamic Empire across North Africa.

Throughout the twelfth and thirteenth centuries in Spain and Sicily, the transmission of scientific knowledge continued with the establishment of an Arabic-Latin translation program. In Sicily after the Norman kingdom was established in 1060, its Latin, Greek and Muslim subjects lived in more favourable conditions than those in Spain (Crombie, 1963) for the growth of intercultural and intellectual exchange. Here the knowledge of antiquity was rediscovered in its original Greek versions and the major developments recorded in Arabic that were subsequently translated into Latin (Burnett, 2001; Schramm: 2001), in corners of Europe prior to the Renaissance.

DISCUSSION

It has been seen that the scholars working in the Islamic Empire spanning over three continents started in the beginning with the translation movement, as well as creating the necessary language tools in Arabic for the translations of the works of the Greeks, Persians, Indians and all ancient knowledge. But having acquired the knowledge they set about not only assimilating, testing and analysing, but also adding important and original contributions to that knowledge.

Beginning from the end of the tenth century this knowledge began to filter back to Europe through the translations of Arabic versions of the Greek knowledge and the original Greek treatises (Burnett, 2001). But also transferred to Europe were the seminal contributions of scholars of the Islamic world. Modern science as we know it today works with theories and models that must be tested empirically, starting in the fields of mathematics, astronomy and medicine. The Muslims developed the procedures for testing knowledge both empirically and logically. However an important characteristic of Islamic science was its experimental character. Islamic scientists were interested especially in the applied sciences, in the construction of apparatus, in testing theories by undertaking observations, and analysis of results through mathematics (Bammate, 1959). These ideas and procedures were all available in Western Europe through the seminal works of Islamic scholars before the times of Galileo, Descartes and Newton to whom they have been largely attributed.

FUTURE RESEARCH

While there is currently research being carried out on the use of single works or the ideas and writings of individual authors, it is too early to draw all possible conclusions. In order to form a comprehensive picture of both the translation processes, and the transmission of scientific knowledge from ancient Greek libraries to the Islamic world, culminating in the eighth and ninth centuries (Sabra, 1996; Sabra, 1987) and the subsequent translation and transmission of Islamic scholarly works to Europe during the twelfth to fourteenth centuries further scholarly work is needed. Fortunately various collections of Arabic manuscripts are still preserved in European libraries. Further detailed investigations would help throw light on the critical role of Islamic scholarly works in the development of Renaissance Europe (Saliba, 1999). What is important to note is that the Islamic conception of God (Bausani, 1974) made possible a major advance in scientific thinking during the period of the eighth to the fifteenth centuries in Islamic lands, while Europe lay largely dormant during the Dark Ages. Developments would only appear to have occurred in Europe where there was direct contact with Islamic knowledge in Spain and France, until the fall of Constantinople in 1453. Thus the initial development of Modern Science did not occur in Italy with the spectacular work of Galileo, but in the Islamic world several centuries earlier, where it slowly and gradually advanced in ways that have been largely ignored but scholars in Western Europe.

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