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The Modern Dimension of the Astrolabe as an Innovation of Ancient Technology

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The astrolabe was a very important instrument used by astronomers and navigators in every civilisation for centuries. It became more famous at the peak of Islamic astronomy during the Golden Age of the Islamic civilisation, as an instrument to show direction and time in the fields of astronomy and navigation. However, later it became less known and is increasingly forgotten. Hence, the purpose of this paper is to review the continuity of this legacy of the Islamic Golden Age, through the study of the astrolabe in Malaysia, specifically in astrofiqh and STEM education. This research has a qualitative approach using document analysis, observation and interview methods. Research results find that knowledge of astrolabe is increasingly abandoned and its use becomes more irrelevant in view of a variety of sophisticated and modern inventions. However, there are efforts to gradually increase knowledge of the astrolabe. This scenario should be given attention in order to continue efforts to restore the legacy of the Golden Age of the past Islamic Civilisation, in addition to maintaining the supremacy of the astrolabe as the basis of developing current digital instruments of astronomy.

Keywords: *Astrolabe, STEM, Islamic Astronomy, Astrofiqh, Cosmofiqh.*

Introduction

Advancements in current modern technology can be seen in the sophisticated multi-functions of the computer. The computer is used on a daily basis and constitutes a vital need of today's humanity. The machine is updated and its systems upgraded, parallel with the advancement of modern era technology (De Weck, Roos & Magee, 2011). However, many of us do not know that computers have actually been used centuries ago before our time. The current computer is a digital computer which creates digital and mathematical models and uses both items according to programmed on-commands to create a system for task execution automatically (Randell, 1973), compared to the previous analog computer that operates on analog systems. According to Battacharya (2016), the analog computer is a physical-based system that requires the user to have knowledge and skills to operate the computer manually in order for it to function.

An analog computer used in past civilisations before the digital computer, is the astrolabe which functioned as a solution tool related to calculations. In general, an astrolabe is a traditional astronomical instrument that was used for observation activities and calculations of celestial objects (Safiai, Ibrahim & Jamsari, 2014). It was one of the astronomical instruments frequently used in ancient civilisations, particularly in the past Islamic civilisation. But in spite of its past glory, the astrolabe is not studied these days, and knowledge of it is quite forgotten. This fact is supported by Van Brummelen (2005) in his article where he discussed the expertise of past scientists in science and mathematics on using the astrolabe. In addition, he also explained that the making of astrolabes and its development was only known in the past. Further, his view is that the skills of using an astrolabe are increasingly forgotten today because of the emergence of more advanced modern instruments of technology replacing the astrolabe.

Through the invention of the astrolabe as an analog computer, the Islamic civilisation had shown its excellence in the field of astronomical sciences and its legacy should be studied and continued so that its knowledge will not be lost over time. A concerted effort by various parties such as the government, academics and students should be made in order to preserve and advance the knowledge. Therefore, the aim of this research is to review the continuity of the astrolabe as an excellent legacy of the past Islamic civilisation in Malaysia. Research such as this is appropriate to help increase knowledge of astronomy in Malaysia, at once restoring the glory of the Islamic civilisation in the eyes of the world.

Literature Review

This study includes previous research on the astrolabe in the context of Malaysia, such as 'Astrolabe as Portal to Universe, Inventions across Civilisations' by Safiai et al. (2017), 'The Continuity of Astrolabe as a Multipurpose Astrofiqh Instrument' by Safiai et al. (2016), and

'Tracing the History of Astrolabe Inventions Across Civilisations' by Safiai & Ibrahim (2016). The articles above discuss the historical development of its invention. Furthermore, studies on astrolabes are fairly limited. This article refers to previous international research and discussions on the astrolabe to obtain additional information such as 'The Astrolabe: Mechanism for reading the stars' by Aterini (2019), 'Astrolabe: Curating, linking, and computing astronomy's dark data' by Bryan, Stahlman & Steffen (2018), 'Star taker: Art, science and mathematics in an astrolabe from fourteenth-century Spain' by Bentley (2018), and 'Transmedial technics in Chaucer's Treatise on the astrolabe: Translation, instrumentation, and scientific imagination' by Mitchell (2018). The research finds that education on astrolabe sciences is rapidly in progress at the international level, particularly Europe as compared to other countries. Therefore, this research examines discussions of the astrolabe in the context of Malaysia.

The excellence of a civilisation is determined by its degree of intellectuality and successful contribution to humanity. Success of a civilisation is considered not from only one aspect but includes many aspects such as mastery of knowledge. Knowledge represents the main weapon or strength of a civilisation. During that time, those who mastered knowledge were feared and respected (Pingree, 1973). This was also the situation in the history of the Islamic civilisation that took place centuries ago. The decline of civilisations of Ancient Greece, Persia, India, Northern Africa and Mesopotamia gave rise to the rich Islamic civilisation (Nussbaumer, 2006).

Throughout the history of the Islamic civilisations, many events can be made as examples of success symbols through mastery of knowledge. One example is, the peak of excellence in astronomy during the Abbasid Caliphate (Falagas, Zarkadoulia & Samonis 2006). Its history began when Caliph al-Mansur ruled from Baghdad from the year 762 AD, and it marks as an important date for the development of astronomy (Faruqi, 2006). Al-Mansur had a deep interest in the study of constellations, which was later continued by his son Caliph Harun al-Rashid. Many of his stories were narrated in the book 1001 Nights, which is well-known among the Arabs. However, the interest did not end there, it passed down to the son of Caliph Harun al-Rashid, Caliph al-Ma'mun. Through his efforts, the treasure of old books on astronomy were collected (Islam, 2011).

In that era, knowledge was spread rapidly and widely to every corner of Muslim states. The Muslim society at that time participated in the race for seeking knowledge. Many infrastructures were developed to provide public facilities such as administration buildings, mosques, libraries, hospitals and observatories. As acknowledged, Baghdad was known for being the centre of learning as it has a public academy known as The House of Wisdom (Bayt al-Hikmah). Bayt al-Hikmah existed since the rule of Caliph al-Mansur as it served as an academy where scholars gathered at that time (Anjum, 2014). Scholars at that time came from

many backgrounds including Christians, Jews, Pagans and Muslims, collaborating their intellectual works and translating the works of the Greeks, Persians and Syrians to Arabic (Rababah, 2015). These enormous efforts from scholars helped the ruling government at that time to preserve priceless manuscripts from being destroyed, such as Almagest by Ptolemy. According to Kennedy (2005), the translation process continued until it became part of Islamic culture. In addition, the Arabic language became the lingua franca in scientific fields which spread throughout the world.

Achievements made in astronomy at that time led to the construction of observatories which played a vital role in conducting research. The main purpose for the construction of observatories was to help scholars in studying the universe. Furthermore, observatories became a meeting point for scholars to have their discussions and exchange of opinions among each other (Mujani, Ibrahim & Safiai, 2012). Observatories showed the excellence of Muslim scientists, especially in observation activities. However, Muslim scientists were not the pioneers in this field. As a matter of fact, observation activities had been carried out during the time of the ancient Greek civilisation (Jones, 1991), but the outcomes of those observations did not benefit the Muslims at the time in managing their daily worship practices. Therefore, Muslim scholars were born to continue observations sightings for the purpose of facilitating the daily worship practices of the Muslims.

Some achievements of Muslim scientists can be seen from the works of al-Battani and his observation research on the time period of a year, from which he concluded the existence of Sun's inclination or tilt and the precession rate of the Earth's orbit (Ikbal, 2015). In addition, al-Biruni through his observations also discovered that the Sun moved but at a slower rate (Ahmad, 2009). This fact clearly contradicts Ptolemy's views that the Sun is static and not in motion. As it is known, the pioneers for observation activities did not come from Muslim scientists. However, the constructions of observatories was pioneered by Muslim scientists with the observatory, known as Syammsiyyah observatory in Baghdad, being the first in the world (Ibrahim, Ahmad & Safiai, 2013). Following that, other constructions of observatories spread throughout the Islamic civilisation and many of the observatories became famous names as exemplary for their excellence in the Islamic civilisation, such as Maraghah observatory, Samarkand observatory, or better known as Ulugh Beg observatory, and Istanbul observatory (Safiai, Jamsari & Ibrahim, 2014).

Methodology

This is a qualitative research which is conducted through content analysis method. Working with inductive and deductive qualitative content analysis, this research analysed the uses of the astrolabe and its prospects as an innovation of ancient technology. Besides, interviews were conducted as well, and it was recorded, stored and encrypted in the computer. Later, the

recording was removed, synthesised and analysed in order for analysis of the information. The results of qualitative research showed that the astrolabe has a lot of functions and the instrument itself is a good prospect to be highlighted as a modern innovation of ancient astronomy.

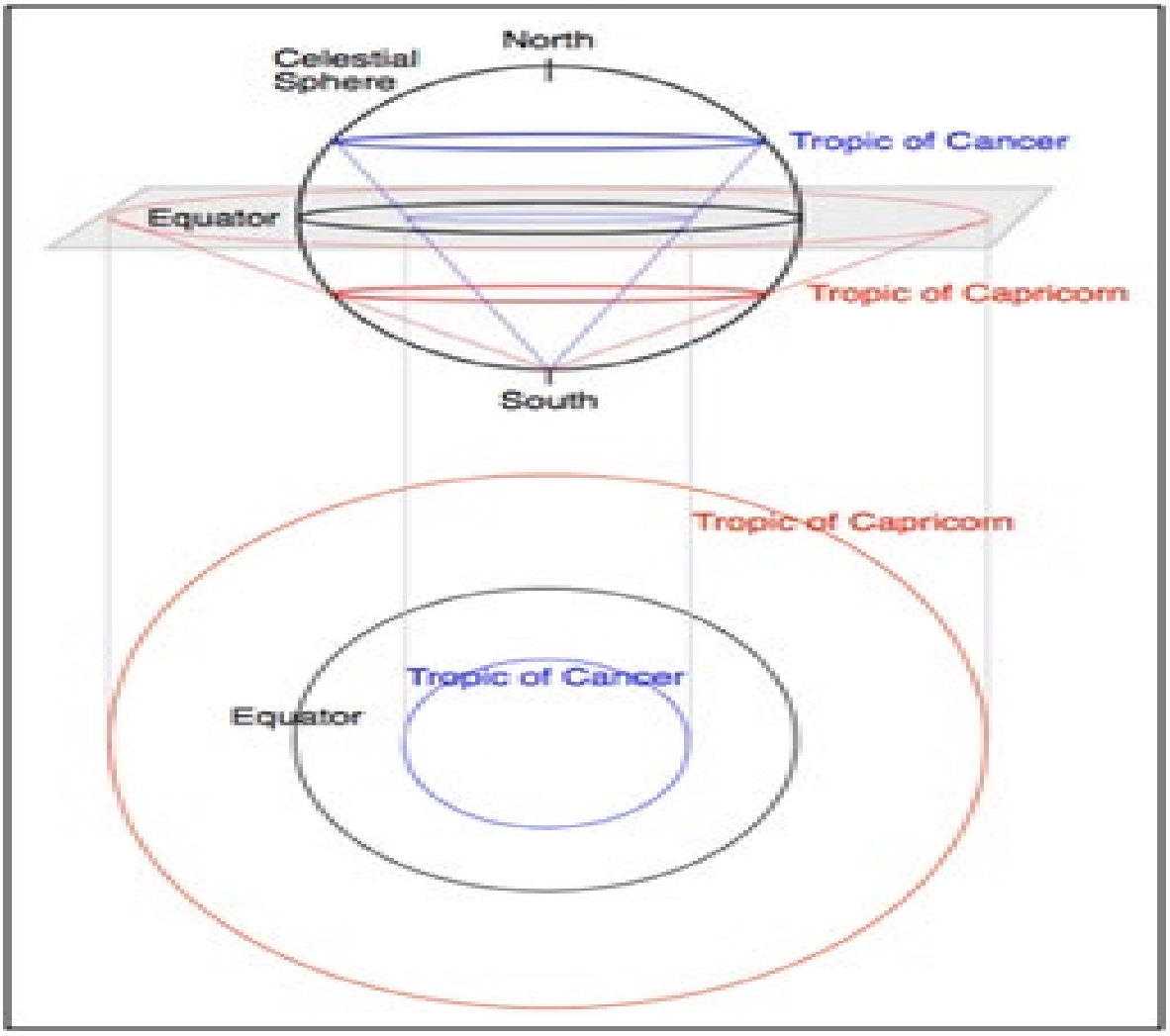
Result and Discussion

Observation activities in past civilisations were done with the naked eye or with the aid of instruments. The use of an instrument gives better results with its precision and accuracy in producing data. Therefore, many instruments began to be invented for scientists to use in observatory sightings or daily use (Ibrahim, Safiai & Jamsari, 2014). However, there were some instruments invented and considered as a masterpiece due to their excellent functions, besides being aesthetically attractive and beautiful. Many astronomical instruments were invented during that time and the most famous of all was the astrolabe which was a traditional instrument that served as a tool for observation and calculations of coordinates and movements of celestial objects. Astrolabes were first invented and used in the time of Ancient Greece by Ptolemy, using the stereographic display theory of Hipparchus which was an important basic concept in the invention of the astrolabe (Van Der Waerden, 1951).

However, according to Latham (1917) the astrolabe invented in the past was not the same as what we have now. The former was simple in form. Its lack of style and simple structure made it look plain. Furthermore, its functions were limited to the needs of that time. The astrolabe was used to identify coordinates of place, calculate time and directions, and also to measure the height of an object or a building. One of the techniques for its invention was explained by Ptolemy in his work, *Planisphaerium*. Without doubt, this fact proves that Ptolemy was exceptionally knowledgeable in making astrolabes (Goldstein, 1997).

The astrolabe was popular among scientists in the past for observation activities. It functioned as an instrument to project actual images of the sky with certain latitudes on a flat surface. There were many types of astrolabes invented such as planisphere, universal, nautical/mariner, Islamic, quadrant, and Rojas, but most famous of all was planisphere. According to Penfield (1901), the concept of stereographic projection used in the astrolabe was the display of celestial spheres projected on a flat surface based on the equatorial line. Therefore, there are lines and circles projected that correlate with coordinates and movements of celestial objects and recorded for star mapping so that the instruments can function in the process of calculations and so on.

Figure 1. Stereographic Projection of an Astrolabe



The concept used in astrolabe invention proves the determination and success of past scientists in their research. Looking back at their technological capability, which was less sophisticated and more traditional at the time, they still made new discoveries in their respective fields, proving the relevancy and suitability of their theories for application today. For example, al-Khawarizmi proved his theory on algebra in mathematics and was the famous *Sufi* who made observations in proving the coordinates and movements of the sun and discovering constellations. Ibn Yunus also used the astrolabe and made excellent observations of celestial objects. Furthermore, all of their theories and discoveries are being used by Western scholars as references still today (Zaimeche, 2002).

In Malaysia, there is a dearth of materials on the astrolabe. There are undeniably a few published works on the astrolabe, but there is no discussion on the standards of constructing an astrolabe in Malaysia. This issue was discussed by Wan Mohd Saghir (2005) whose opinion is

that published astronomy materials are scarce in Malaysia, at once making the development of astronomy very slow. He suggests that research on astronomy should be emphasised to put Malaysia on the map of astronomy. This matter should be taken seriously and acted upon as the astrolabe is an important instrument of the legacy of the Golden Age of the Islamic civilisation.

Nor Azam (2004a) in his writings discussed the functions of an astrolabe. In addition to his work, he also explained the history of the invention of the astrolabe that began in the Greek civilisation. However, in his other published article, he discussed the use of the astrolabe by navigators to show direction. He also stated his opinion that the astrolabe may have been used by the Portuguese to reach Malacca and Penang Island. By taking the latitude and altitude of the sun, the astrolabe can be used to show direction at sea. As a result, he found that it took about 250 to 300 days for the Portuguese to reach Malacca. Furthermore, he stated in his other article, that Bugis people also used the astrolabe in their sea navigations, and among them was Raja Haji.

Nor Azam (2004b) shared an interesting account about the selection of Independence Day by Shekih Abdullah Fahim. The date 31st August 1957 was chosen as the day of Malaya's independence after it was suggested by Sheikd Abdullah Fahim. He considered the coordinates and movements of constellations as guidelines in suggesting the date. Nor Azam also mentioned that a school teacher who served at Sekolah Agama Da'irah al-Ma'arif al-Wataniah (DMW*)* in Kepala Batas, Seberang Perai Utara, Penang Island claimed that an astrolabe belonging to Syeikh Abdullah Fahim was kept in the principal's office and that it was usually used to calculate the coordinates and movements of celestial objects, particularly constellations. This indirectly proves the influence of using the astrolabe by Sheikh Abdullah Fahim in determining the independence day of Malaya.

One of the ways in reviving knowledge of the astrolabe in Malaysia is through seminars and workshops, such as the workshop entitled 'The Astrolabe: Its History and Application' which was held from the 25th to 26th of February 2016 at Universiti Teknologi Malaysia, Kuala Lumpur. The 2-day workshop was organised by the Centre for Advanced Studies on Islam, Science and Civilisation (CASIS), Universiti Teknologi Malaysia, Kuala Lumpur. There were about 50 participants in the seminar from various fields and backgrounds. Many researchers were invited to present at the seminar, among them were Prof. Dr. Robert H. van Gent (Holland), Dr. Wilfred de Graaf (Holland), Prof. Dr. Salim Ayduz (Turkey), Prof. Dr. Muhammad Zainiy Uthman (Malaysia), Dr. Tatiana Denisova (Russian in Malaysia) and Dr. Zakiah Saparmin (Malaysia). Besides the topic on the study of the astrolabe, many interesting topics were discussed in the seminar, such as the astronomical element of stone inscription in Terengganu, the methods used in sea navigations according to the Malay historiography in the

14th-19th centuries, and cosmographic texts which contained drawings and illustrations including traditional Arabic texts in numerical form (Safiai, 2015).

One of the initiatives of Malaysia's Ministry of Science, Technology, & Innovation (MOSTI) is to offer the public information about the astrolabe through an interactive software located at the National Planetarium as an exhibit. Visitors may use the software for free and learn how an astrolabe works and how to use one on their own. Moreover, visitors can gain information uploaded into the software on the history of astrolabe invention by solving the quizzes provided. This seems to be a very good innovation in STEM education of Malaysia.

In the era of the Islamic civilisation, the astrolabe was widely used among different groups, whether it was the ruling family, scientists or the public. Therefore, many inventors learnt to make the astrolabe and developed their skills which allowed it to be sold for many decades. As explained before, the astrolabe was first invented by the Greek scientists. However, Muslim scientists also managed to develop the astrolabe further by referring to Greek works on its fundamental aspects. Later on, Muslim scientists improved the capabilities of the astrolabe by adding functions related to Islamic daily worship practices. In Malaysia, the astrolabe can be used in the future for multiple purposes as follows:

1) Determining Direction of Kaabah in Mecca *(*Qibla*)*

It is indeed complicated to use an astrolabe to determine the direction of the Kaabah. The task requires advanced knowledge and skills in science and technology. The ability of Muslim scientists in determining the direction of qibla using an astrolabe displayed high intellectuality of their time. The word qibla is taken from the Arabic word meaning a centre point for the location of Kaabah at *Masjid al-Haram,* Mecca. Bagvi (1972) held the opinion that certain practices require the direction of qibla to be emphasised and that the method of determining qibla should be taught to Muslims in perfecting their daily practices to be accepted by Allah SWT.

An important aspect in the *shariah* is that facing the direction of qibla during prayer is an obligation for *fard* prayers and *sunnah* prayers. In addition, it is also compulsory in burial of a Muslim and other practices in which it is a *sunnah* to face the qibla. The whole body must be facing the Kaabah in Mecca during prayer (Bagvi, 1972). Facing the Kaabah in prayer was commanded by Allah SWT in the year of 2nd Hijrah. Before the Kaabah, the qibla of the Muslims was Jerusalem in Palestine. During Prophet Muhammad's PBUH stay in Medina, Muslims prayed facing Jerusalem for about 16 months before changing to Kaabah on Monday, 17th of Rejab when the Prophet Muhammad PBUH was praying at Bani Salamah mosque. The Masjid of Bani Salamah was named after the owners of the land on which it was constructed, located in a northern hilly part of Harrah Wabrah, Medina. Today it is known as al-Qiblatain

mosque, which means mosque of the two qibla due to the event of Allah's command to change the qibla there (Mubarakpuri, 2002).

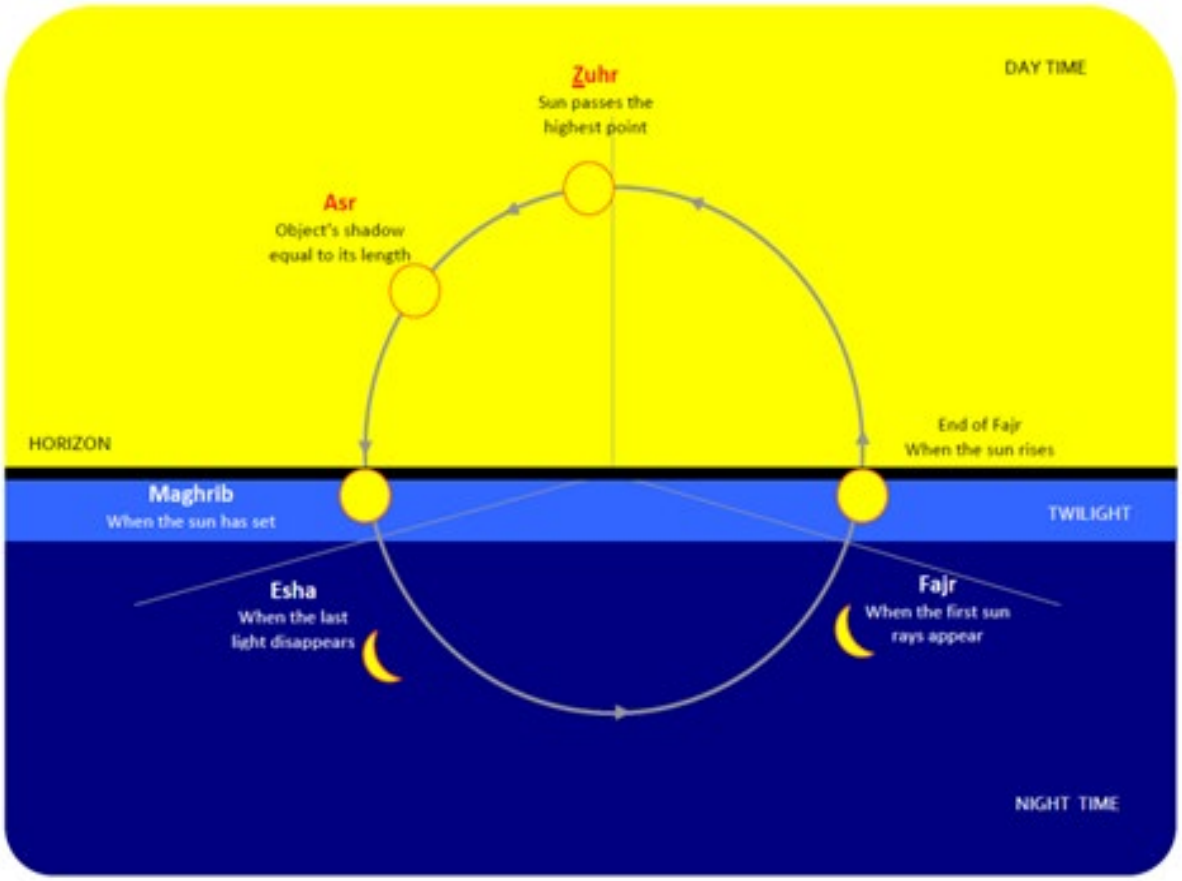
In Malaysia, the azimuth of qibla is between 291-294 degrees, and if the average is taken, the value is 292 degree. The azimuth direction facing west of Malaysia is due to consideration of the difference of coordinates between Malaysia and Mecca. Determining the azimuth direction is done by referring to the astronomy calculation formula based on the Earth's spherical triangle concept (Hajar et al., 2020).

Figure 2. Direction of Makkah from Malaysia

2) Calculation of Prayer Times

By using an astrolabe, the basis of calculation in astronomy depends on the movements of celestial bodies such as the sun, moon and stars in relation to us on earth. Prayer times that have been estimated depend on the movement of the sun, therefore prayer times may differ from day to day. The calculation done is based on celestial sphere concept and certain trigonometric formulas. It is an obligation to pray 5 times a day as the Prophet Muhammad PBUH received the revelation during Isra' & Mi'raj (The Ascension) directly from Allah SWT. The calculation for prayer times are important for the Muslim community, as prayers are obligatory daily practices to be performed at specified times. Neglecting prayers is a major sin in Islam (Abbas, 2010).

Figure 3. Circle of Prayer Times



As discussed above, the specification of prayer times is based on the Quran and hadith. The two main sources are discussed in detail by jurists for the easy understanding and practice of the Muslim community. The interpretation of jurists to finalise precise prayer times are based on astronomical calculations and correlated to proper time instruments, such as a clock. The result is that the Muslim community can now easily know the prayer times by referring to the clock and by being guided by prayer schedules provided by the authorities (Che Awang, 1994).

3) STEM Teaching Aids

Method of teaching is an important determining factor of the effectiveness of teaching and learning (P&P), particularly in STEM. There are various teaching methods in the teaching and learning process. Therefore, selecting a suitable method for teaching plays an important role in evaluating the aspect of effectiveness. This is supported by the opinion of al-Kaylany & Iyad (1986) who state that the teaching method must be compatible with the learning objective, be age-appropriate, be capable of application by the teacher and be suitable for the facilities available and the teaching goals.

An astrolabe can be a very good teaching aid due to its multi-functions. Knowledge of this unique astrolabe should be taught and introduced in STEM. One of the ways to do this is to insert the astrolabe in the school learning syllabus, as was done with the abacus which was available all this while. With that, the teaching and learning process will be more interesting and effective in view of students directly handling it themselves with the help and guidance of teachers. Furthermore, students can visit observatories in Malaysia for exposure on STEM education, especially astronomy (Ibrahim, Safiai & Jamsari, 2015).

In learning astronomy, using an instrument is very important. A teaching and learning process based merely on theories is less effective to students. Through the process of handling instruments in teaching and learning, students can better understand knowledge and indirectly improve their skills to manage their daily lives productively, especially relating to religious practices.

Conclusion

Based on the research conducted, literature review shows that research and writings on the astrolabe in Malaysia are limited. Over the past 15 years in Malaysia, only a few writings have been published on the astrolabe and not all are meant for general reading. This issue has consequences on the development of the astrolabe because there is not enough exposure to the public. However, there is still room and opportunities that may be developed through the instrument itself, especially from the aspect of its functions. Many topics about its applications can be further researched, such as using astrolabe to determine the direction of qibla, calculation of prayer times, in agriculture and war. In addition, parallel to advancement of current technology, the process of digitalising astrolabes could make significant contributions and also preserve and develop it as an excellent tool. Therefore, research on this matter is important in developing traditional or classical skills which are increasingly forgotten and advancing astronomical sciences in Malaysia.

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