Astronomy Outreach Programs with STEM Ambassadors under the C3AOL Project

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ABSTRACT

This paper reports our experiences in conducting outreach astronomy programs involving high school students and the general public. These programs are part of an interdisciplinary research project entitled Cross-cultural Computer supported Collaborative Learning for Student Capacity Building in Multifaceted Competencies through Astronomy Online Labs (C3AOL). As part of this research project, two selected undergraduate Physics students were named as STEM ambassadors and tasked in disseminating astronomical facts and concepts via outreach activities, thus consolidating their knowledge, creativity, and identity as STEM ambassadors. The STEM ambassadors have planned and conducted an Astronomy outreach program with high school students from the Pusat PERMATApintar Negara (currently known as Pusat GENIUS@Pintar Negara), UKM. This was followed by a public stargazing session at the National Planetarium, Kuala Lumpur that involved planetary and lunar eclipse observations. This project provided a valuable opportunity for the STEM ambassadors to convey astronomical knowledge effectively and interestingly in multiple contexts, whether amongst their peers or junior students, or even with the general public. A short-term impact of this project is the diffusion of their knowledge and enthusiasms in Astronomy to high school students as well as the general public through outreach programs such as dialogues session and talks at space centers and experience sharing via social media.

Keywords: Astronomy education; astronomy outreach program; science literacy

INTRODUCTION

Astronomy is a unique branch of STEM which generates new knowledge about the known universe around us. It also contributes to a country's social and economic development (Miley 2015). One way to capitalise upon the potential of astronomy in education is to invest in the creation, development and implementation of quality astronomy-related materials in an educational setting. This often requires close collaboration between experts across several disciplines such as astronomy, astronomy education, education and educational technology. It is with this motivation that Astronomy and Technology-Enhanced Learning (TEL) experts from Universiti Kebangsaan Malaysia (UKM), Universiti Teknologi Malaysia (UTM) and University of Leicester (ULEIC) have worked closely through an interdisciplinary project referred as C3AOL (Cross-cultural Computer-supported Collaborative Learning for Student Capacity Building in Multifaceted Competencies through Astronomy Online Labs). This project involved undergraduate physics students who participated in interactive and collaborative learning sessions using the Astronomy Online Lab (AOL) applets (Hamid et al. 2018). Based on their performance during these sessions, two students were chosen as STEM ambassadors and given the responsibilities to share their experiences with high school students at the PERMATApintar National Gifted Centre, Universiti Kebangsaan Malaysia, and the general public at the National Planetarium, Kuala Lumpur. These public engagement activities were a continuation of the interactive and collaborative learning session reported earlier by Wan Mohd Kamil et al. (2019). Two undergraduate physics students from the Faculty of Science and Technology, UKM were chosen as STEM ambassadors of the C3AOL project (Figure 1). The interactive and collaborative learning sessions involving the Astronomy Online Labs (AOL) applets enhanced their mastery of astronomy by giving them the opportunities to visualise and analyse various astronomical phenomena via online-based activities (Prather, 2009).

The first outreach program involved high school students from the PERMATApintar National Gifted Centre, UKM on the 6th of May 2018. Four continuous hands-on activities, namely The Galaxy in the Jar, The Great Gravity Escape, Let's Go to Mars and Packing to Mars were carried out under the supervision of lecturer-mentors with the aid of postgraduate students as facilitators.

The second outreach program involved the general public who attended the stargazing event at the National Planetarium Kuala Lumpur on the night of 27th of July 2018. The stargazing event focused on the planetary and lunar eclipse where visitors experienced the longest total lunar eclipse of the century which lasted for 103 minutes. Apart from that, visitors also had the opportunity to observe the planets of Mars, Jupiter and Saturn, made possible via the portable telescopes that were set up.

FIGURE 1. STEM ambassador announcement and award ceremony attended by the Dean of the Faculty of Science and Technology.

METHODOLOGY

ASTRONOMY OUTREACH PROGRAM AT THE PERMATAPINTAR NATIONAL GIFTED CENTER, UKM

A total of 18 high school students from the PERMATApintar National Gifted Centre were selected to participate in the outreach program which lasted for 4.5 hours. The students were divided into four groups and engaged in four consecutive activities conducted by the STEM ambassadors. "The Galaxy in the Jar" activity conducted during the ice-breaking session provided each student with a bulb-shaped jar, cotton wool and glitter (Figure 2). This activity necessitated the STEM ambassadors to apply their interpersonal skills in socialising with the participants aged 13-16 years old. Despite a 5-6 years age difference, the STEM ambassadors managed to generate a friendly atmosphere whilst simultaneously gaining the participant's initial interests in astronomy.

Having successfully generated a friendly atmosphere for the participants, 'The Great Gravity Escape' activity was performed. The aim of this activity was to increase the students' comprehension on the nature of the gravitational force in pulling a spacecraft to move in a closed orbit around a more massive object (Hill et al., 2004). Figure 3 illustrates the worksheet used for this activity. At the end of this activity, students were exposed to the phenomenon that as the orbital speed of the spacecraft increases, the size of the orbit grows larger. In order to enhance such understanding, the students physically spinned a water-filled balloon attached to the end of a long string under the guidance of the STEM ambassadors. The STEM ambassadors also applied similar activity to challenge and rectify a common misconception that gravity does not exist in outer space because 'astronauts appear to float in space'.

FIGURE 2. Basic materials for 'The Galaxy in The Jar' activity

1. What happens as the spacecraft speeds up?
2. An orbit is the balance between the velocity of the object and what force?
3. As velocity decreases, the object gets closer/further from Earth?
4. By using information given below, find escape velocity, V_{esc} for each planet, moon, sun, neutron star and supermassive black hole.

$$V_{esc} = \sqrt{\frac{2GM}{R}}$$

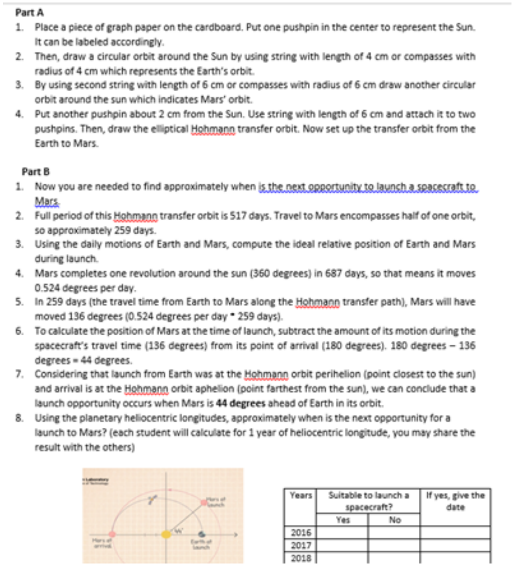
G is gravitational constant = 6.67408×10^{-11} m^3 kg^{-1} s^{-2}

M is mass of object, R is radius of object

	Mass (kg)	Diameter (km)	Escape velocity
Mercury	0.33×10^{24}	4879	
Venus	4.87×10^{24}	12104	
Earth	5.97×10^{24}	12756	
Moon	0.0073×10^{24}	3475	
Mars	0.642×10^{24}	6792	
Jupiter	1898×10^{24}	142984	
Saturn	568×10^{24}	120536	
Uranus	86.8×10^{24}	51118	
Neptune	102×10^{24}	49528	
Pluto	0.0146×10^{24}	2370	
Sun	1.989×10^{30}	1391016	
Neutron star	5.5×10^{12}	20	
Supermassive black hole 3c273	2×10^{39}	287.46×10^{9}	

FIGURE 3. Worksheet for 'The Great Gravity Escape'

The third activity named "Let's go to Mars" was conducted to teach the students on the application and the use of advanced algebraic concepts and skills. The students were tasked in determining the relative positions of Earth and Mars during which an optimal orbital transfer for a Mars-bound spacecraft can occur (Fisher, 2001). The information was then employed in identifying the next launch window for a Mars-bound spacecraft (see Figure 4).



Part A

1. Place a piece of graph paper on the cardboard. Put one pushpin in the center to represent the Sun. It can be labeled accordingly.
2. Then, draw a circular orbit around the Sun by using string with length of 4 cm or compasses with radius of 4 cm which represents the Earth's orbit.
3. By using second string with length of 6 cm or compasses with radius of 6 cm draw another circular orbit around the sun which indicates Mars' orbit.
4. Put another pushpin about 2 cm from the Sun. Use string with length of 6 cm and attach it to two pushpins. Then, draw the elliptical Hohmann transfer orbit. Now set up the transfer orbit from the Earth to Mars.

Part B

1. Now you are needed to find approximately when is the next opportunity to launch a spacecraft to Mars.
2. Full period of this Hohmann transfer orbit is 517 days. Travel to Mars encompasses half of one orbit, so approximately 259 days.
3. Using the daily motions of Earth and Mars, compute the ideal relative position of Earth and Mars during launch.
4. Mars completes one revolution around the sun (360 degrees) in 687 days, so that means it moves 0.524 degrees per day.
5. In 259 days (the travel time from Earth to Mars along the Hohmann transfer path), Mars will have moved 136 degrees (0.524 degrees per day * 259 days).
6. To calculate the position of Mars at the time of launch, subtract the amount of its motion during the spacecraft's travel time (136 degrees) from its point of arrival (180 degrees). 180 degrees – 136 degrees = 44 degrees.
7. Considering that launch from Earth was at the Hohmann orbit perihelion (point closest to the sun) and arrival is at the Hohmann orbit aphelion (point farthest from the sun), we can conclude that a launch opportunity occurs when Mars is **44 degrees** ahead of Earth in its orbit.
8. Using the planetary heliocentric longitudes, approximately when is the next opportunity for a launch to Mars? (each student will calculate for 1 year of heliocentric longitude, you may share the result with the others)

Years	Suitable to launch a spacecraft?		If yes, give the date
	Yes	No	
2016			
2017			
2018			

FIGURE 4. Worksheet for 'Let's Go to Mars.'

The final activity, 'Packing to Mars' required students to role-play as planners for the next human mission to Mars. Specifically, students engaged in brainstorming and planning sessions on the activities, equipment and supplies to be brought with them on their journey to Mars. This activity provided the students with the opportunity to speculate creatively and rigorously while simultaneously learning the real physical, biological and technological limitations of space travels. Each group eventually presented their mission proposals at the end of the session and received feedbacks from other groups, including the STEM ambassadors and lecturer-mentors.

ASTRONOMICAL OBSERVATIONS AT THE NATIONAL PLANETARIUM, KUALA LUMPUR

The second outreach program conducted by the STEM ambassadors was a public stargazing activity at the National Planetarium, Kuala Lumpur. Since this location suffers from extremely high light pollution, the stargazing activity was restricted to bright objects which were planetary and lunar eclipse observations. A number of portable telescopes were set up together with a single 'astrophotography station' that consisted of a telescope attached with a DSLR camera. Figure 5 illustrates the camera and telescope setup used, while Table 1 provides the specifications of these instruments. This camera's efficiency has been verified by previous study (Rasmani et al., 2017) in recordings of sunspot number at the similar location.

The planetary observation session lasted for two hours, starting from 9.00 p.m. until 11.30 p.m., while the lunar eclipse observation commenced at 1.00 a.m. and ended around 7.00 a.m. the next morning. Images of both visible planets and the total lunar eclipse were photographed using suitable camera exposure settings. The exact observation time for each image was noted as per conventional astronomical practice (Bateson, 1955). All the images were digitally processed using the Lightroom CC application.

TABLE 1. Instrument used in observation

I. DSLR camera (Canon EOS 5D mark III) Sensor: 22.3 MP full frame sensor Sensor Size: 36 x 24mm Native ISO Sensitivity: 100-25,600 Boost Low ISO Sensitivity: 50 Boost High ISO Sensitivity: 51,200-102,400 Image Size: 5760 x 3840 Processor: DIGIC 5+ Metering System: iFCL metering with 63-zone dual-layer sensor Metering Types: Centre-weighted, Spot, Evaluative, Partial Shutter: Up to 1/8000 and 30 sec exposure Shutter Durability: 150,000 cycles Viewfinder Type: Optical TTL Viewfinder Coverage: 100% Speed: 6 FPS Autofocus System: Advanced 61-point high-density reticular AF (up to 41 cross-type points) LCD Screen: 3.2-inch diagonal Clear View LCD II with 1.04 million dots
II. Telescope (MEADE LX200 EMC 8") Optical Design: Schmidt-Cassegrain Catadioptric Clear Aperture: 203mm (8") Primary Mirror Diameter: 209.6mm (8.25) Focal Length: 2000mm (80") Focal Ratio: f/10 Resolution: .56 arc sec Limiting Visual Magnitude (approx): 14.0 Limiting Photographic Magnitude (approx.): 16.5 Image Scale (°/inch): 0.72°/inch Maximum Practical Visual Power: 500X Near Focus: 25' Optical Tube Size: 9.1" Dia. x 16" Long Telescope Size, Swung Down: 9.25" x 16" x 25" Secondary Mirror Obstruction: 3.0" (14.1%) Telescope Mounting: Heavy-Duty Fork-Type Double Tine Setting Circle Diameters: Dec.: 6"; R.A.: 8.75" RA Motor Drive System: 9-speed, microprocessor controlled 12v. DC servo motor; 5.75" worm gear with Smart Drive Declination Control System: 9-speed, DC servo controlled 5.75" worm gear with Dec drift software Motor Drive Gear Diameter: 5-3/4" Worm Gear Hand Controller: Motorola 68HC05 microcontroller; 2 line x 16 alphanumeric character display; 19 button keypad, red LED backlit Main Controller: 16 MHz 68000 microprocessor; 1 Meg program memory 16K RAM; 512 byte non-volatile memory (EEROM)

FIGURE 5. Telescope setup used for public stargazing session

RESULTS AND DISCUSSION

This section provides a general overview of the outreach activities at the PERMATApintar National Gifted Centre, UKM and the National Planetarium session through a sequence of images taken during the session. The school students' feedback on the activities is also analysed and discussed in this section. The planetary and total lunar eclipse images obtained during the public stargazing session at the National Planetarium, Kuala Lumpur are also presented in this section.

ASTRONOMY OUTREACH PROGRAM AT THE PERMATAPINTAR NATIONAL GIFTED CENTER, UKM

Figures 6-13 highlight the four activities conducted by the STEM ambassadors with the high school students, starting from the briefing session until the students' presentation of the final activity 'Packing to Mars'.

FIGURE 6. Briefing session with the STEM ambassadors.

FIGURE 7. Introduction by the STEM ambassador, Muhammad Ezzat Abdul Hamid.

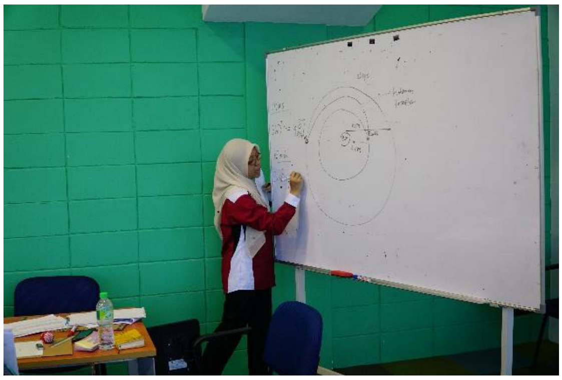


FIGURE 8. Explanation by the STEM ambassador, Siti Nur Razira Razali.

FIGURE 9. A STEM ambassador interacting with students during the first activity, 'Galaxy in the Jar.'

FIGURE 10. The products of the first activity, 'Galaxy in the Jar.'

FIGURE 11. A physical demonstration during the second activity, ‘Great Gravity Escape’ performed by one of the students.

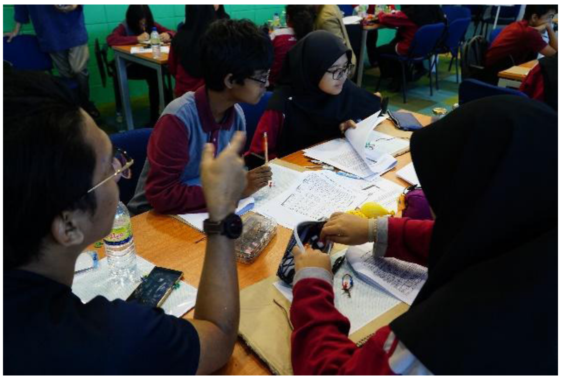


FIGURE 12. Student discussion during the third activity, ‘Let’s Go to Mars.’

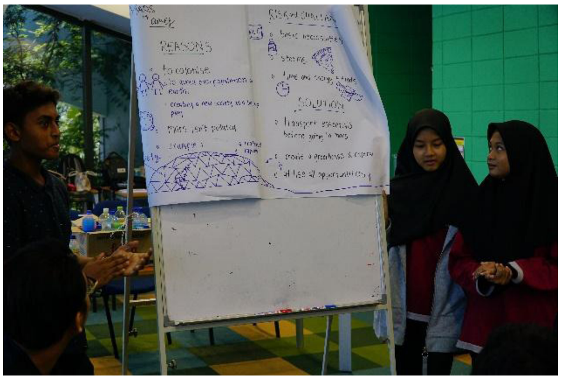


FIGURE 13. Students’ presentation for the final activity, ‘Packing for Mars.’

The survey forms were distributed to the students in order to gauge their perceptions on their overall experiences during the program. The students’ responses can be divided into two categories; Astronomy topics-related responses and soft-skills related responses

The first category of responses gauged the students’ understanding on the three astronomy topics i.e. ‘Great Gravity Escape’, ‘Let’s Go to Mars’ and ‘Packing for Mars’. One student wrote that he “learned to explain how an object will escape from one place to another place depends on its speed and gravity”. The second category of responses evaluates the students’ social and communication skills such as self-introduction, initiating conversations with strangers and team-working. A student wrote that he learned “how to be professional when completing all the tasks together with other students.” Students’ general perception was assessed through a series of statements using a five-point Likert scale. Majority of the students (more than 70%) agreed that they learned better about the introduction to Astronomy through these activities and 66% were satisfied with the flow of the activities. Furthermore, more than 70% of them agreed that all of the learning activities were useful in providing initial exposure to Astronomy subject. The results are presented in Table 2 below.

TABLE 2. Students’ General Perception

Statement	Students’ Preference					Statement
	1	2	3	4	5	
I learn better through this method	72%	28%	0%	0%	0%	I do not learn better through this method
It was satisfying	66%	34%	0%	0%	0%	It was not satisfying
It was useful	71%	23%	6%	0%	0%	It was useless

ASTRONOMICAL OBSERVATIONS AT THE NATIONAL PLANETARIUM, KUALA LUMPUR

The public stargazing program at the National Planetarium resulted in series of images of the planets together with the total lunar eclipse photographed in its various stages.

Planetary Observation The first trial of the planetary imaging was performed several hours before the commencement of the total lunar eclipse on the 27th of July 2018. The resulting images were poor due to several technical issues and difficulties in handling large crowds around the astrophotography station. As shown in Figure 14, the images obtained were small, blurry and the main features of the planets were unable to be resolved. For instance, the Jupiter’s cloud bands, and the rings of Saturn were not visible (see Figure 14 (b) and (c)).

The failure of this planetary imaging session led to another astrophotography session held on the 3rd of August 2018. A clearer image of all the three planets were able to be captured during the second attempt, compared to the images from the first session. This improvement was due to the usage of Barlow lens and specific color filters for planets. A Barlow lens is typically used to magnify objects, while color filters were utilized in enhancing the contrast of objects.

Every color filter has its own different effects depending on the targeted object spectrum (Matys and Mrazek, n.d.). For instance, the usage of the #21 orange filter has enabled the STEM ambassador to enhance the darker surface of Mars and the usage of the #8 light yellow filter has enabled them to resolve Saturn's ring.

The best technique for planetary imaging is to record a video of the planet. The video was then split into individual frames and all the frames were finally stacked together to form one sharp image. Since such technique was rather complicated and time consuming, the STEM ambassadors only photographed the planets and then performed minor image processing to sharpen the images using Lightroom CC application. Figure 15 presents the result of this successful planetary imaging. In these images, Jupiter's cloud bands and the Great Red Spot were visible and Saturn's rings system was evident.

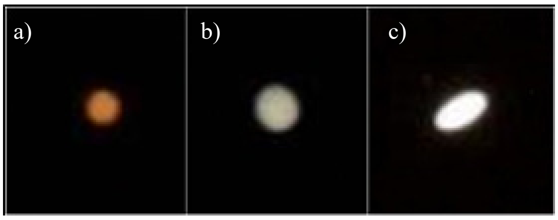


FIGURE 14. First trial of planetary imaging a) Mars, b) Jupiter and c) Saturn.

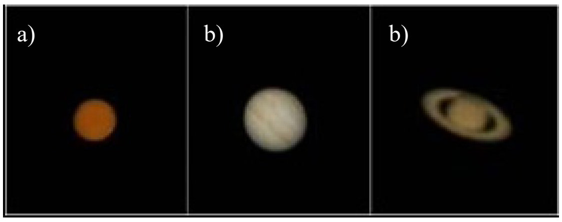


FIGURE 15. Second trial of planetary imaging a) Mars, b) Jupiter and c) Saturn.

The visitors were astonished when they saw the planets through the telescopes. Some of them were in disbelief to see the planets which they initially thought were unreal and only appears in astronomy books. Visitors also had the opportunity to ask questions to the person in charge at every portable telescope, including the STEM ambassadors who were responsible for one of the portable telescope setups.

Total Lunar Eclipse Observation During the stargazing event, the total lunar eclipse was photographed from the beginning to completion. There were no complicated techniques involved in photographing a lunar eclipse despite specific exposure camera settings that should be followed (see Figure 17). Even though difficulties were encountered in setting the camera during the crowd, the STEM ambassadors managed to photograph several phases of the lunar eclipse.

Table 3 listed the time scale recorded for the lunar eclipse phases. The lunar eclipse started at 1.14 a.m. During that time, the Earth's shadow on the Moon was not obvious since the Moon was beginning to enter the penumbra region. The Earth's shadow could be clearly seen when the Moon entered the umbra region at 2.24 a.m., whereby the upper part of the moon became darker. At 3.30 a.m., the Moon fully entered the umbra region and was completely blocked by the Earth's shadow. Despite the Earth's blocking of the sun light from reaching the Moon, the Moon did not appear completely dark. Instead, the Moon turned red because of the Rayleigh scattering phenomenon. The totality lasted for 103 minutes, making the total lunar eclipse the longest total lunar eclipse of the century. During the maximum phase, the STEM ambassador did not manage to photograph the eclipse because the Moon was blocked by the clouds. At 5.13 a.m., the total eclipse ended as the Moon started to leave the umbra region. The partial eclipse was photographed at 5.17 a.m. when the clouds parted, and the Moon reappeared. The partial eclipse ended at 6.19 a.m. Figure 16 shows the phases of the lunar eclipse. All the images were photographed by specific exposure settings following the guideline by Fred Espenak (2008) (see Figure 17). These images also underwent minor editing using Lightroom CC application in creating sharper images. The STEM ambassadors experienced a very challenging task in obtaining perfect images of lunar eclipse due to several technical problems and the large crowd during the stargazing program.

TABLE 3. Phases of lunar eclipse

Time (LT)	Phases
01:14:47	Penumbra phases started
02:24:27	Partial eclipse started
03:30:15	Total eclipse started
04:21:44	Peak/Maximum of total eclipse
05:13:11	Total eclipse ended
06:19:00	Partial eclipse ended
07:28:38	Penumbra phases ended

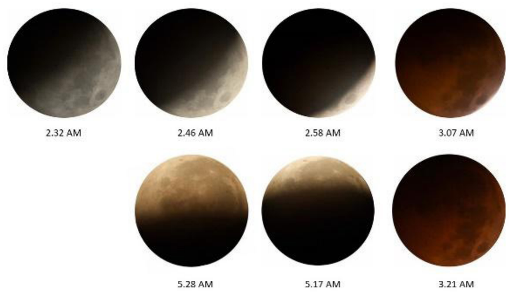


FIGURE 16. Images of various phases of the lunar eclipse.

The public stargazing event has also tested the STEM ambassadors' communicative skills in explaining scientific facts using laymen's terms to the public. It was a great opportunity for them to stand out as STEM ambassadors in cultivating astronomy interests among students and the public as well as in learning to organize and manage large crowds during public astronomical events.

Lunar Eclipse Exposure Guide

ISO		*f*/Number								
25		1.4	2	2.8	4	5.6	8	11	16	22
50		2	2.8	4	5.6	8	11	16	22	32
100		2.8	4	5.6	8	11	16	22	32	44
200		4	5.6	8	11	16	22	32	44	64
400		5.6	8	11	16	22	32	44	64	88
800		8	11	16	22	32	44	64	88	128
1600		11	16	22	32	44	64	88	128	176

Eclipse Phase	Q	Shutter Speed								
No Eclipse										
Full Moon	8	1/4000	1/2000	1/1000	1/500	1/250	1/125	1/60	1/30	1/15
Penumbral Eclipse										
Magnitude = 1.0	7	1/2000	1/1000	1/500	1/250	1/125	1/60	1/30	1/15	1/8
Partial Eclipse										
Magnitude = 0.00	7	1/2000	1/1000	1/500	1/250	1/125	1/60	1/30	1/15	1/8
Magnitude = 0.30	6	1/1000	1/500	1/250	1/125	1/60	1/30	1/15	1/8	1/4
Magnitude = 0.60	5	1/500	1/250	1/125	1/60	1/30	1/15	1/8	1/4	1/2
Magnitude = 0.80	4	1/250	1/125	1/60	1/30	1/15	1/8	1/4	1/2	1 sec
Magnitude = 0.90	3	1/125	1/60	1/30	1/15	1/8	1/4	1/2	1 sec	2 sec
Magnitude = 0.95	2	1/60	1/30	1/15	1/8	1/4	1/2	1 sec	2 sec	4 sec
Total Eclipse										
Danjon Value: L=4	-3	1/2	1 sec	2 sec	4 sec	8 sec	15 sec	30 sec	1 min	2 min
Danjon Value: L=3	-5	2 sec	4 sec	8 sec	15 sec	30 sec	1 min	2 min	4 min	8 min
Danjon Value: L=2	-7	8 sec	15 sec	30 sec	1 min	2 min	4 min	8 min	15 min	30 min
Danjon Value: L=1	-9	30 sec	1 min	2 min	4 min	8 min	15 min	30 min	—	—
Danjon Value: L=0	-11	2 min	4 min	8 min	15 min	30 min	—	—	—	—

Instructions

Choose the ISO speed in the upper left column. Next, select the f/number of the lens or telescope (on same line as ISO). Finally, drop straight down to the bottom table to get the correct exposure for each stage of the lunar eclipse. The magnitude of a partial eclipse is the fraction of the Moon's diameter immersed in Earth's umbral shadow (in the case of a penumbral eclipse, it is the penumbral shadow).

Note that the brightness of a total eclipse varies with different Danjon values (L). All exposure times in this guide are estimates. For best results, use them as a guide and bracket your exposures.

Exposure Formula: $t = f^2 / (I \times 2^Q)$ where: t = exposure time (sec); *f* = f/number; I = ISO speed; Q = brightness value

www.mreclipse.com/LEphoto/LEphoto.html ©2008 *Fred Espenak*

FIGURE 17. Lunar eclipse exposure guide

CONCLUSIONS

STEM ambassadors carries enormous responsibilities in disseminating their knowledge to the school students and the public. They are also responsible to communicate the importance of science, technology, engineering and mathematics through their lenses as STEM students and researchers. Through both programs, the STEM ambassadors experienced social, intellectual and logistical challenges that enabled them to grow as representatives for stimulating broader interest in STEM. In addition, the STEM ambassadors were able to improve their cognitive, emotional and psychomotor skills, thus enhancing their life-long learning outlook. The 'educational cycle' from classroom-school-general public has enriched their skills in contextualizing their knowledge under various circumstances. From the start of their journey during the interactive and collaborative learning sessions using AOL applets at UKM, to their outreach programs at PERMATApintar National Gifted Center, UKM and at the National Planetarium, Kuala Lumpur, the STEM ambassadors have grown and matured significantly, and ready to change the world.

DECLARATION OF COMPETING INTEREST

None.

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