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Planetarium pedagogy and technical learning experience: an investigation from instructional perspectives

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ABSTRACT

The research focused on the National Planetarium Kuala Lumpur's education programs, investigating the types and target audiences. It examined the educational theories and strategies used, including multiple intelligence theory and cooperative learning. The study also explored the alignment of astrophysics in Pearson Edexcel International General Certificate of Secondary Education (IGCSE) Physics with the Planetarium's programs. Document analysis and participant observation were employed. The results revealed two program types: on-site and online. The programs showed alignment with IGCSE Physics and utilized theories like social cognitive theory. The National Planetarium positively impacted students through multi-intelligence theory, sociocultural theory, experiential theory, and constructivism. Gamification and group activities enhanced the learning experience. The Planetarium's ability to simulate astronomical events made it an effective medium for instructional science institutions. Overall, the study highlighted the diverse education programs of the National Planetarium Kuala Lumpur, their alignment with IGCSE Physics, and their positive impact on students' personal, physical, and social contexts.

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1. INTRODUCTION

A planetarium is a structure that displays images of stars, planets, and constellations on the interior surface of a dome for entertainment or education. Malaysia's National Planetarium Kuala Lumpur (PNKL) is a non-profit science organization that assists the Ministry of Science, Technology, and Innovation (MOSTI) in propagating and disseminating space science awareness and understanding, as well as developing space science resources for the country. This planetarium aims to provide infrastructure and high-quality service to the community in the areas of astronomical activities and space science. PNKL serves four primary purposes: i) to empower the role of the national planetarium as an organization that cultivates the field of astronomy and space science in Malaysia; ii) to cultivate and raise public awareness of the importance of astronomy and space science through screenings, exhibitions, programs, and social media; iii) digital screening, where PNKL provides expertise in optical astronomy and amateur radio digital screening; and iv) human capital development, where PNKL provides recommendations, coordination, and guidance in the field of astronomy and space research in Malaysia.

The PNKL is one of the informal science institutions that offers experience-based learning including on-site learning, off-site learning, and hands-on activities. It plays an important role in promoting space science in general and guiding Malaysia's space science development. Malaysia's education system is

expected to undergo a significant transformation toward 21st-century learning. However, it is in crisis, with the current formal education approach failing to achieve its goals of generating interest in and popularizing science subjects among students [1], [2]. Planetarium also is a science center for outdoor and informal learning [3]–[5]. The students found the planetarium interesting and the visit was very fun [3]. Planetarium activities showed a positive effect on students, especially in science education [3]. Other than that, Planetarium also influences teachers and pre-service teachers [5]. Teachers also needed to be equipped with the informal program as learning tools [5]. As a government entity, there a resource has been allocated to make sure that Planetarium (PNKL) achieves the objective.

Although planetariums are highly regarded for providing a favorable learning environment and for being an excellent instrument for generating public interest, there is a scarcity of studies on how the planetariums' educational programs align with the science subjects in the Standard Based Curriculum for Secondary Schools. Therefore, this research focused on how PNKL's teaching programs align technically with the Physics subject in the International General Certificates of Secondary School (IGCSEs) for upper secondary school students.

2. LITERATURE REVIEW

This section summarizes prior research and conclusions related to the research topic and theories in planetarium education. The review focuses on the contextual model of learning. The review also focuses on the growth of astronomy education through the use of planetariums in pedagogy in this setting.

2.1. Overview of national planetarium as informal STEM learning

The planetarium is a well-known tool for informal science education. In 2016, a study was done to determine the impact of employing a planetarium as an outdoor learning environment [3]. In order to collect students' opinions on the topic of interest, their study adopted a qualitative approach. The findings suggest that using a planetarium as an outdoor learning resource in science teaching has a favorable influence on students by giving them gained new knowledge and experience. A museum or planetarium can provide an informal learning environment for pupils that is distinct from official education [3].

2.1.1. Definition of informal science education

Informal learning is an independent or self-learning approach that is not pre-planned and premeditated, which often takes place in various environments that are not scheduled and oriented. In addition, informal education sets emphasis upon the certainty that through the frequent participation of non-formal learning in daily life activities, individuals can learn and augment their knowledge and skills in various aspects. When the individuals are actively involved in such activities and tasks to bring about the desired outcomes, they are participating in informal education. Informal science education (ISE) is the learning approach related to the science field that happens in the out-of-school contexts and these contexts come from various methods, such as visiting science centers or instructional science institutions that allow students to engage with exhibitions and outreach programs offered there [4], [5].

2.1.2. Background of the national planetarium Kuala Lumpur as a source of outdoor learning

Informal education settings, such as at the PNKL, can be used to enhance students' interest, and awareness of the sciences, especially in the context of astronomical and astrophysics fields. The PNKL is set in a blue domed building that sits atop a hill in the Kuala Lumpur Lake Gardens. The Ministry of Science, Technology, and the Environment was in charge of the building's construction, which began in 1990 and ended in 1993. It is linked to both the Malaysian National Museum and a space theme park. A planetarium is a device that shows how the sun, moon, planets, and stars in the sky are arranged and move. It is a dome-shaped structure that holds equipment for displaying images of the arrangement and motion of stars and planets in the sky. The planetarium serves as a repository of information in the realm of astronomy. It also serves as a stellar theater, simulating the appearance of celestial objects and events in the planetarium space with a specific projector, as well as a location for chronicling numerous astronomical phenomena over time.

2.2. Contextual model of learning

The contextual model of learning (CML) is the theoretical foundation that underpins this research. Contextual learning is a learning strategy that connects academic knowledge learned in the classroom to real-life contexts, tying brain activity to meaningful patterns. This way of learning is crucial because it helps to store not only short-term memory but also gives students the ability to gain long term memory which will help them to apply these memories to their job obligations later in their life. This kind of contextual approach helps the educators to connect the content of the syllabus that students learn academically with the real-world

situations that are usually experienced by students themselves. This will eventually inspire students to make connections between the knowledge gained with their surrounding world [6], [7].

2.2.1. Personal context

According to previous study, the personal context of this technique portrays the individual's entire personal and genetic past as they enter a learning scenario. A museum, which serves the same purpose as a planetarium as an informal science institution, can be used as a free platform for individuals to choose a new learning environment in which visitors are largely motivated by their own desires [8]–[10]. As a result, an informal education platform such as the PNKL can aid visitors in self-directed activities, resulting in a diversity of learning methodologies.

2.2.2. Physical context

Scientific centers aim to connect people by attracting them with a variety of visual components, exhibiting items, creating sensory experiences, and sharing a wide range of science concepts that visitors may recognize or find interesting. Starting with the chosen content and focus, through how it is designed, and from who designs it to the audience for whom it is meant, the way all aspects in the ISIs interact has an impact on how an exhibition is received. Lighting, crowding, color, sound, and space have all been demonstrated to have minor effects on learning [11]–[13]. Accessibility of the scientific center and its contents is a critical prerequisite for assisting visitors in making connections with science. To do this, the layout of the center, the design of the exhibitions, and the format of the actual information must all be presented in a way that is approachable, relevant, and easy to understand by a variety of people. The first impression of the center must be one of comfort for the visitors.

2.2.3. Sociocultural context

The sociocultural framework is founded on the concept that humans are a part of a larger universe in which social and cultural variables influence how we think and learn [14]–[16]. The combination of social and cultural factors can help explain why students have such a wide range of learning styles. As a result, in both formal and informal scientific education settings, educators must address the interactions among students, as well as the interactions between students and guides/teachers, and how these interactions affect learning in each context.

2.3. Experiential learning theory

Kolb's theory of experiential learning proposed that experience is critical in the development of knowledge construction, as learning occurs through discovery and active participation in any activity. Experiences are prior to Kolb's theory, and he viewed experience as a process where something must be transformed or changed. He also believed that merely teaching recollection skills and memorization of ideas is not enough and there is no additional value received by learners [17], [18]. Kolb's learning cycle is based on Piaget's idea that focuses on the fact that learners develop or create knowledge from the interaction with the environment.

2.4. Planetariums in the field of astronomy education

In the field of astronomy and astrophysics, the planetarium provides opportunities for a variety of immersive learning experiences. A finding conducted by the American Museum of Natural History's Hayden Planetarium with other planetarium professionals indicated that the scientific visualizations of planetarium programming have led to the increase in learning outcomes of students, attracted and inspired more people to the field. Their research also highlighted the similarity between the advanced visualization being created by the planetarium and popular digital games that could further help to enhance interest and allow the audience to engage with this informal science institution including those in traditionally underserved audiences [19]. Planetarium technology has advanced to the point where it now assists people in understanding major contents in astronomy and astrophysics.

Planetariums are also able to educate the audience with the knowledge of cosmology; for example the big bang theory, which is a model which implicates the expansion of space and not the explosive event. This cosmology knowledge also explained that galaxies are co-mobile on the expanding space and their light waves are elongated and reddened more and more when the distance between them become increased.

2.5. Introduction of astrophysics education in a new millennium

A study conducted by Dendup *et al.*, they have revealed that most students and teachers in schools are having negative perceptions on Astrophysics [20]. The two prior reasons for this perception were due to the abstract content to teach and the limited information and knowledge for some concepts that appeared in the textbook. Apart from that, students expressed their difficulty to understand the content and the lack of

awareness about the job opportunities offered in that field [21]. The researchers also suggested that students need to be exposed with practical classes or additional instructional tools on Astrophysics to work with real examples that can be related with real world situations. The researchers also indicated that another good alternative to be taken into consideration is through the efforts by school to be affiliated with other science institutes located in and outside of the country to enhance the sharing of knowledge about Astrophysics.

Another recommendation suggested by the researchers is the importance of using a visualization in their teaching approach, especially through technological innovations such as planetariums that had brought unprecedented increase in the understanding of the space and universe via various technologies such as computer simulations to complement what is taught in class [22], [23]. Table 1 illustrates several aspects comparing Cambridge IGCSE Physics and Pearson Edexcel IGCSE Physics that are relevant to planetarium content.

Table 1. Physics syllabus in IGCSE learning: Cambridge IGCSE vs Pearson Edexcel IGCSE

Aspects	Pearson Edexcel IGCSE physics	Cambridge IGCSE physics
Subject code	4PH1	O625
Examination board	Pearson Edexcel examination board offered by subsidiary of the Pearson publishing company	Cambridge international examination board (CIE)
Structure of examination paper	Pearson Edexcel uses only one set of question papers which means that both difficult and easy questions will be put in the same paper.	CIE uses a tiered examination system which offers students the option of entering the Foundation OR Higher Education. Higher education papers are more difficult.
Syllabus	Chapter 1: forces and motion chapter 2: electricity Chapter 3: waves Chapter 4: energy resources and energy transfers Chapter 5: solids, liquids, and gasses Chapter 6: magnetism and electromagnetism Chapter 7: radioactivity and particles Chapter 8: astrophysics	Chapter 1: motion, forces, and energy Chapter 2: thermal physics Chapter 3: waves Chapter 4: electricity and magnetism Chapter 5: nuclear physics chapter 6: space physics (updated in 2023 syllabus)
Subject offered	40 subjects	70 subjects
Exam timing	Jan and May/June	May/June and November
Results timing	Jan - March May/June - August	May/June-August November-January
Grades	Pearson Edexcel IGCSE use the 9-1 grading scales which is also used for the Ofqual regulated GCSEs	Grades are assigned using eight internationally recognized grades (A* to G)

There are several similarities between Cambridge IGCSE Physics (0625) and Pearson Edexcel IGCSE physics (4PHI), including: i) both syllabuses are set-up for students starting at the age of 14 until 16 years old; ii) both are highly regarded international academic qualifications that open doors to admission to institutions of higher learning around the world as well as provide employment opportunities; iii) both textbooks contain clearly illustrated diagrams, step by step calculations and valuable additional support material such as complete formulae/equation summary and glossary of important terms. All syllabus material is clearly highlighted and as a whole helps to guide the learner. The font size is large, and the text is well spaced out and easy on the eyes; and iv) both syllabuses promote and develop vocational skills, encouraging critical thinking, creative problem solving and practical application of knowledge in today's world.

3. RESEARCH METHOD

This study is qualitative research since we chose to respond to research questions that necessitated the use of an exploratory method to uncover the opinions, ideas, and feelings of the research subjects. Qualitative research is used to better comprehend theories and concepts in a certain field. In this regard, the research goals were to investigate the education program run by PNKL and how it relates to the Pearson Edexcel IGCSE that required a rigorous, objective, and methodical process. Participant observation and document analysis were chosen as the qualitative data methods used in this study. Both approaches aid researchers in solving research problems. The use of numerous approaches is a crucial contributor to the case study research's major strength. Table 2 shows a summary of the methods for data analysis used in this research.

3.1. Participant observation

Participant observation is increasingly being more widely used in practical and technical research, especially in program development and assessment, as well as in researching the social processes and dynamics of programmatic intervention. The surge in the development of relevant textbooks, edited readings, and candid first-person experiences of the fieldwork demonstrates the rising interest in participant

observation methodologies. Furthermore, participant observation is a technique that allows researchers to learn about the activities of the individuals being studied in a natural setting by watching and engaging in them. It serves as a backdrop for the creation of sampling rules and interview guides.

Table 2. Summary of methods for data analysis used in this research

Unit	Section	Method
1	RO 1: To determine types of education programs carried out by the PNKL	Content analysis
2	RO 2: To investigate the educational theories, strategies and approaches utilized by PNKL	Field notes and content analysis (participant observation)
3	RO 3: To analyze the physics syllabus content (IGCSEs) that inclined with the PNKL education program content	Content analysis

3.2. Document analysis

In recent years, the number of research papers and journal articles mentioning document analysis as part of the technique has increased. A systematic technique for assessing or evaluating documents, both printed and electronic (computer-based and Internet-transmitted) material, is known as document analysis. Document analysis, like other qualitative research methodologies, necessitates the examination and interpretation of data in order to extract meaning, gain insight, and develop empirical knowledge.

Document analysis is especially useful in qualitative case studies, when researchers do in-depth research to produce detailed descriptions of a specific phenomenon, event, organization, or program. Document analysis has several advantages for researchers when compared to other qualitative research approaches. One of the advantages is that document analysis takes less time and is seen to be more efficient than other research approaches because it needs data selection rather than data collecting. In terms of cost-effectiveness, document analysis is less expensive than other research approaches, therefore it is frequently recommended when collecting new data is not possible. The data included in papers have already been gathered, and all that is left with this procedure is to analyze the content and quality of the documents. In this research, documents that are related to the PNKL, Pearson Edexcel, and Cambridge IGCSE were analyzed thematically, in which the theme in Physics subject's curriculum specification for upper secondary school were linked to education activities and outreach programs conducted in PNKL.

4. RESULTS

In this study, primary data were derived from the researcher's field notes based on participant observation, providing firsthand insights. Meanwhile, secondary data were sourced from documents obtained from PNKL, including curriculum specifications and IGCSE physics textbooks, offering additional perspectives and contextual information. The data collected are consequently classified into three distinct parts, focusing on types of education programs administered by the PNKL, educational theories, approach, and strategies utilized by PNKL and the physics syllabus content (IGCSEs) that inclined with the education programs conducted by the PNKL.

4.1. Types of education programs carried out by the National Planetarium Kuala Lumpur

Through document analysis and observation thought the PNKL, it is shown that PNKL presents a compelling spectrum of educational programs. There are two types of programs in PNKL, on-site or physical programs and online or virtual programs. Delving into a variety of educational theories, strategies, and approaches, these initiatives are crafted with the purpose of propagating and captivating a diverse audience. The overarching objective is to foster an enriched awareness and understanding of space science.

4.1.1. On site/physical programs

There were several types of programs that has been held on site viz., national programs, observation programs, international programs, teacher and student development programs, strategic partner collaboration programs, and astronomical information programs. The national programs were consisted of i.e., i) *Minggu Sains Negara*: The PNKL was chosen as one of the main locations for National Science Week 2020 in Kuala Lumpur and various hands-on and interactive space science activities will be organized that involve Malaysians of all ages; ii) Seminar Global Malaysian Astronomers Convention (GMAC 2020): This program aims to bring together both local and worldwide Malaysian astronomical communities to learn about their interests and ongoing projects, create networks and form long-term research partnerships and collaboration and encourages participants to discuss and build concrete plans to enhance astronomy education in Malaysia at all levels. The target audience for this program are students and society in which it enables both parties to connect with inspiring astronomers in Malaysia to gain inspiration and career guidance in fields related to

astronomy; iii) NSC poster contest: This program is one of the techniques to develop astronomy and space science inspired innovation with its own unique style and creative flare. The public as a target audience, particularly school children, can learn about astronomy and space science in this manner; iv) *Kejohanan Roket Kebangsaan* (KRK): This program is one of the techniques to develop astronomy and space science inspired innovation with its own unique style and creative flare. The public as a target audience, particularly school children, can learn about astronomy and space science in this manner; v) National Space Challenge (NSC 2021): This program is a yearly initiative that aims to inculcate, foster and infuse interests about astronomy in year 4 to year 6 primary school students through "minds-on, hearts-on and learning engagement" at an early level; vi) *Minggu Angkasa Sedunia*: This program targeted audiences from all age levels with the aim to increase knowledge and appreciation of science and technology and to commemorate humanity's success in space exploration; and vii) Sputnik 6.3 km virtual run: This program is a symbol of appreciation for the first man-made satellite named "Sputnik" which was launched into orbit on October 4, 1957. This 6.3 km running program is marked for the 63 years of the satellites' launch. This program targets all communities with the purpose to educate and give awareness about the relevance of satellites in everyday life.

The observation programs consisted of i.e., i) *Pencerapan Gerhana Bulan Penuh*: This program gives visitors the opportunity to use several telescopes provided by the National Planetarium to observe the eclipse phenomenon. This program is open for all Malaysians regardless of age and the public can also witness the eclipse from the observatory location; ii) *Pencerapan Gerhana Bulan Separa*: This program is open for all Malaysians to experience the phenomenon of a partial lunar eclipse directly from the observatory area; and iii) *Program Matahari Tegak Diatas Kaabah (Istiwa' Adzam)*: This program targeted Muslim visitors to discover on how to confirm the direction of the Qibla by looking at the shadow cast by upright objects. The visitors will be exposed to how the sun can give shadows on the Earth surface that will be pointed directly towards the Kaaba in Mecca.

Besides, the International Programs conveyed i.e., i) Asia Pacific Regional Space Agency Forum (APRSAF) water rocket event: this event gives participants the opportunity to study craftsmanship and science technology through the creation of water rockets which also promotes international interaction. The target audience for this program are children aged 12 to 16 as well as the teachers and educators. Annually, the winner of *Kejohanan Roket Kebangsaan* and a representative from MRSM schools will represent Malaysia to compete at this level; ii) APRSAF poster contest: this poster contest aims to enhance creativity and encourage young people to broaden their horizon and knowledge about the universe. This program is open to youngsters aged 8 to 11 around the Asia Pacific region. This competition intends to pique young children's interest in space science and technology; iii) Scientist for a day: this program is an essay competition open to all Malaysian students that aims to send a spacecraft to one of Uranus's three moons. This competition is a worldwide competition that offers a once-in-a-lifetime opportunity for school children to examine three moons of the planet Uranus and role-play as NASA scientists; iv) International Space Station (ISS) contact: The program's goal is to introduce school students about the importance of space technology while also giving them opportunities to learn about the lives of astronauts on the International Space Station. Using amateur radio communication equipment accessible at the National Planetarium Microsatellite Station, selected students from across Malaysia will interact with astronauts currently on duty on the ISS; and v) Telescope for all: This program aims to cultivate and broaden the interest of Malaysians, especially among students in the field of space science. Besides, the intention of organizing this program is to promote equal opportunities to pursue a career in the field of space science. A total of 172 entries were received by the National Planetarium and only 38 out of 172 entries were chosen to be shortlisted for the international judging. On 16th July 2021, the National Planetarium has announced that one of our Malaysian entries has been listed as one of the winners of this program, Mr. Vadivelan A/L Sinnasamy who is a science teacher from Sekolah Jenis Kebangsaan Tamil (SJKT) Jugra, Kuala Langat, Selangor.

The teacher and student development programs were consisted of i.e., i) Planet Kidz: these Planet Kidz activities are designed for pre-school and primary school students in which students will be able to gain a better understanding of astronomy and space science by participating in hands-on activities. This program encourages students and teachers to visit the National Planetarium more than once and allows it to become the primary source of information for teachers and students, particularly in the fields of astronomy and space science; ii) Planetarium golden heart: this event is specially conducted by the National Planetarium to give exposure and experience for visually impaired students about astronomy, focusing on the sun and its function in everyday life. The National Planetarium fully supports the national disability policy by providing accessibility to space science and astronomy education with the hope to cultivate the interest of the disabled in the field of astronomy and space science as well as realize the desire to produce the country's leading astronomy experts from the disabled in the future; iii) Astro spark: this program provides an activity that aims to expose Malaysian school students to a wide range of experience and knowledge covering the earth

and space. It also aims to provide inspiration, aspiration, and opportunities for students to explore learning through groups, hands-on activities, presentations, and even physical activities; iv) Go STEM program (Space Explorer): the space exploration program is a half-day program delivered onsite at the National Planetarium that is designed to provide complementary learning outcomes in line with the national science curriculum. Space explorers engage participants in a series of hands-on activities and presentations that motivate and expand knowledge of fundamental physics principles, our solar system, and the scientific method. It aims to educate parents and students about the educational and employment opportunities available in this field; v) Space explorer program: The space exploration program is a half-day program delivered onsite at the National Planetarium that is designed to provide complementary learning outcomes in line with the national science curriculum. Space explorers engage participants in a series of hands-on activities and presentations that motivate and expand knowledge of fundamental physics principles, our solar system, and the scientific method. It aims to educate parents and students about the educational and employment opportunities available in this field; and vi) The outreach program (6 zones): The Northern zone, Central zone, Southern zone, Eastern zone, Sarawak zone, and Sabah/Labuan zone are the six zones that make up this program. Depending on the suitability of the place, various activities such as sun observation, hands-on activities, workshops, mini-planetarium screenings, and others are carried out during the program. The program encourages and cultivates interest in astronomy and space science among people of all ages and backgrounds.

National Planetarium Kuala Lumpur has lately teamed up with 23 key partners to carry out a variety of national and international programs and events. The strategic partner collaboration programs were consisted of i.e., i) *Apa Di langit* (*Angkasa Cilik*, Space4STEM program, and astro inclusive program AstroX: scientist for a Day); ii) Myrobotz enterprise: Mars challenge; iii) *Kem Angkasa Generasi Marikh*; iv) National Space Challenge Prime Minister's Trophy; v) Big Bang Astronomy Program; and vi) Pusat Citra Universiti UKM: Space at home. Various programs and activities are created based on the age of the participants, their level of exposure, and the goals of the program. *Angkasa Cilik*, Space4STEM, astro inclusive, and observations are among the most popular programs and activities. This program is a collaboration with NASA's Radioisotope Power Systems Program, which provides spacecraft with the power to go to some of the solar system's harshest, darkest, and coldest locations, and it is open to all Malaysian students. The Mars challenge (MRC) is a pilot program in the form of an online competition organized by the National Planetarium in strategic partnership with the Malaysian Ministry of Education's Sports, Co-Curricular, and Arts Division and Myrobotz Enterprise.

In 2021, the competition was open for the first time to school kids aged 13 to 17, drawing on the success of earlier Mars planet exploration mission activities. Moonshot, space race junior, Astronutz, Astropreneur, robotics, and Bladerz science were among the themes covered at *Generasi Marikh* Academy's Space Camps. Each camp is meant to guide and motivate young participants in order to help them attain their greatest potential. National Space Challenge Prime Minister's Trophy is an annual event that takes the shape of "minds-on, hearts-on, hands-on learning engagement" for primary school kids in years 4 and 5. The goals of this program are to increase public awareness of the importance of STIs in daily life, as well as to develop young people's interest in science and technology, particularly in the field of space science, and to provide a platform for knowledge exposure toward the selection of educational and career streams, particularly in science and technology. The big bang astronomy program was created to invite everyone in "Keluarga Malaysia" to join and engage to invigorate and promote the application of Science, Technology, Innovation, and Economics (STIE) as outlined in the Dasar Sains, Teknologi, Inovasi Negara 2021-2030 (DSTIN 2021-2030). The focus of this subject is on women's exposure to astronomy, since this program will inspire and encourage the younger generation, particularly women, to pursue careers in the astronomy and astrophysics fields. The Putra Citra Universiti UKM: Space at Home aimed to pique young people's interest in science and technology, particularly space science, and to share expertise, knowledge, and experience in science and technology among invited academics (KPM).

Other than that, the astronomical information programs consisted of i.e., i) the exhibition gallery; ii) astronomical phenomena program; iii) astronomical figures exhibition; and iv) outdoor exhibition (Stonehenge, Centaurus Room, Orion Room, *Jam Matahari Merdeka*, Titan, Ceres, Arca Al-Asr, *Balai Cerap* Jai Singh, and *Balai Cerap* Guo Shou Jing). Students were exposed to space phenomena as well as information about things in space such as galaxies, planets, stars, the moon, and the sun. The national planetarium offers a variety of events to educate visitors about astronomy and astrophysics, as well as the opportunity to witness firsthand the advanced technologies used to see stars, constellations, planets, the Milky Way, and other celestial objects. The astronomy-themed exhibitions and space exploration are provided so that visitors can experience a unique learning experience through hands-on and minds-on concepts. Interactive exhibits are provided to create simulations of the real space environment. In the main hall are permanent exhibits related to astronomy and space science. When an exciting astronomical phenomenon occurs on specific dates that can be easily observed by the public, the National Planetarium will

organize the Astronomical Phenomenon Program. Whether held at the National Planetarium or elsewhere, the presentation is free and open to the public. A duplicate of Muhammad Ibn Musa Al-Khawarizmi's works, a Persian astronomer born in Bukhara in the 9th-century, is on exhibit at the national planetarium. The contributions of Khwarizmi to astronomy and astronomy substantially assisted the growth of celestial science. His career included work on clocks, equipment that show time using the shadow of the sun, and astronomical instruments. The National Planetarium Kuala Lumpur also offers an outdoor exhibition, which is placed around the exterior area of the planetarium. There are numerous types of exhibitions available to pique the interest of visitors of all ages and backgrounds in learning more about astronomical expertise.

4.1.2. Online or virtual programs

There were four types of virtual programs involved viz., i) Trivia quizzes (astro quizzes); ii) online observation (national planetarium virtual tour: national planetarium Google Street View, *Srikandi Angkasa* Virtual Exhibition, and Canvas to Cosmos); iii) Facebook live streaming (*Bicara Planetarium Sempena Minggu Angkasa Sedunia 2021*, and *Bicara Planetarium Sempena Sambutan Bulan Kebangsaan 2021)*; and iv) online competition program (*Pertandingan Pidato Asteroid: Bertemakan "Asteroid Sebagai Sumber Ekonomi Baharu"*). Astro quiz is an online competition hosted by the national planetarium on its official Facebook page, with questions based on the asteroid webinar "opportunities and threats". The contest is open to everyone, and the three winners who answer the correct and fastest question will receive a DIY telescope prize. This approach will help the national planetarium achieve its goal of providing useful and accurate imagery about its facilities, gallery, space advanced technology, and exhibitions, which can be viewed for educational purposes about the situation and objects that exist in space, thanks to Google Street View. This platform allows visitors the ability to virtually visit the national planetarium. The Srikandi Angkasa Virtual Exhibition is an event that allows people to visit the national planetarium using Google Street View and Facebook.

This event introduced 13 members of Malaysian Women's Astronomy to cosmos space, including the planets (planetary), moon, and deep sky objects, through an object-themed painting. "Canvas to Cosmos" is a virtual exhibition featuring space-themed artwork. This exhibition will allow visitors to marvel at the wonders of the universe. Six webinars were hosted by the national planetarium in partnership with partners as part of world space week celebrations. This webinar series included a panel of Malaysian leaders who will discuss subjects relating to space education and awareness. In honor of the national month 2021, the national planetarium hosted four webinars on the topic of nationhood. Throughout the month of Merdeka, a lineup of prominent astronomical personalities from Malaysia and Southeast Asia provided a webinar series on astronomy themed themes through cultural art, monuments, and other ways, as well as highlighting the achievements of local astronomical figures. Students are required to record a video of their speech with a duration of not more than 5 minutes and upload the video to their YouTube page with the hashtag "*Pidato Asteroid Planetarium 2021*" in order to highlight their talents and improve communication skills and self-efficacy in this speech competition.

4.2. Educational theories utilized by National Planetarium Kuala Lumpur

The findings would explain four types of educational theories, approach, and strategies i.e., i) multiple-intelligence theory; ii) social cognitive theory; iii) experiential theory; and iv) constructivism. According to the multiple intelligence theory, each person has a unique learning style and intellect that they apply in everyday situations. Using several types of intelligence to teach various topics allows each of the diverse learners to excel in their studies. As a result, it is thought that this theory can be thoroughly tested through the National Planetarium's instructional science education. The use of various music, images, special effects, and full-dome projection in the PNKL managed to create an emotional and attention-grabbing show to fulfill the innate search for the theory of observed phenomena, physical processes, and the structure of the universe. People of varying intellect levels can acquire and enjoy the material of the program hosted by the national planetarium in their own unique ways thanks to the numerous methods employed.

Social learning theory is the study of what people learn by witnessing and interacting with others. It is also referred to as a bridge between behaviorist and cognitive learning theories since it involves attention, memory, and motivation. According to Bandura's theory, learning takes place in a social setting with a dynamic and reciprocal connection between the person, their environment, and their behavior. Positive reinforcement received by students to actively participate in the on-site programs carried out by the National Planetarium will generate a supportive environment, followed by intrinsic motivation, where learners become more interested in learning more about the subject matter being learned.

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social setting with a dynamic and reciprocal relationship between the person, their environment, and their behavior. Positive reinforcement obtained by students for actively participating in the National Planetarium's on-site program will create a supportive environment, followed by intrinsic motivation, in which learners grow more interested in learning more about the subject matter related to the astronomical field.

Constructivism is a learning philosophy based on the idea that by reflecting on our experiences, we can develop our own understanding of the world we live in. Standardized schooling should be abolished, according to constructivism. Rather, it encourages students to use a curriculum that is tailored to their prior learning. It also encourages the development of problem-solving abilities. Assessment becomes an important part of the learning process, allowing students to be more involved in evaluating their own progress. Educators that use the constructivism method concentrate on connecting facts and assisting students in developing new knowledge.

4.2.1. Educational strategies and approaches utilized by National Planetarium Kuala Lumpur

The findings showed three types of educational strategies and approaches i.e., i) cooperative learning; ii) game-based learning; and iii) inquiry-based learning. Cooperative learning comprises students working in small groups on exercises or projects. Tasks are created in such a way that each member of the group contributes to the task's completion. Many of the programs offered by the National Planetarium Kuala Lumpur allow students to participate in group discussions, work in groups, and participate in a talking circle, all of which help students gain confidence in their teammates, consider other people's perspectives, and develop effective problem-solving skills.

Game-based learning aims to incorporate learning into games, allowing players to learn useful information and acquire knowledge while having fun. Children are more willing to learn when they are taught in a game-like environment. Learners can flourish in a fun and focused learning environment because games increase students' drive to learn and, as a result, information acquisition. National Planetarium Kuala Lumpur's programs, such as the gamification activities offered in the exhibition gallery and the Space4STEM Program, encourage students to become more interested in learning about astronomy.

Inquiry-based learning is a teaching strategy and method that places a premium on students' questions, ideas, and analysis. As a result, the PNKL's scenario and surroundings will pique visitors' interest in ways that a regular classroom cannot. This is because the National Planetarium helps students to discover sky changes that are part of the important cycle including the days and night because of earth's rotation. Planetariums are places where people can learn more about space and explore and grasp the wonders of the universe.

4.3. The physics syllabus content (IGCSEs) that inclined with the PNKL education program content

The planetarium is an institution primarily dedicated to informal education and fostering awareness of space science. Despite its main focus on informal educational approaches, it is noteworthy that the physics content housed within the planetarium remains aligned with and suitable for formal educational settings, such as the IGCSE. Table 3 shows the physics syllabus (IGCSEs) that inclined with the PNKL content. This alignment signifies the versatility and educational applicability of the planetarium's physics content, making it a valuable resource for both formal and informal learning environments.

Table 3. The physics syllabus content (IGCSEs) that inclined with the PNKL content

Type of program ICGSEs	Syllabus	Summary
Pearson Edexcel physics IGCSEs (4PH1)	Chapter 8: Astrophysics Subtopic 8.1: Units Subtopic 8.2: Motion in the universe Subtopic 8.3: Stellar evolution Subtopic 8.4: Cosmology	The astronomical context included in the Pearson Edexcel IGCSEs Physics syllabus which can be linked to the educational programs and educational instructions conducted by the National Planetarium Kuala Lumpur that focuses on the motion of our universe and the explanation of the life cycle of a star, including the theory of Big Bang that explained about the formation of universe. Those explanations in the textbook can be explained and shown in detail to the participants of the National Planetarium programs.
Cambridge physics IGCSEs (0625)	Chapter 6: Space Physics Subtopic 6.1 The Earth and the Solar System Subtopic 6.2: Stars and the Universe	The astronomical context included in the Cambridge IGCSEs Physics syllabus which can be linked to the educational programs and educational instructions conducted by the National Planetarium Kuala Lumpur focuses on the existence of celestial bodies in the universe such as the sun as a star, the moon, galaxies, and planets. The explanation of the formation and existence of these objects in space are explained in the Physics textbook for upper secondary students.

5. DISCUSSION

National Planetarium Kuala Lumpur offers two different types of education programs: on-site/physical programs and online/virtual programs. The target audience is diverse, including children, adults and people with disabilities. Multiple-intelligence theory, socio-cognitive theory, experiential theory and constructivism theory are among the educational ideas used by PNKL. Meanwhile, cooperative learning, game-based learning, and inquiry-based learning are the three educational techniques identified in this study. The astronomical context included in the physics IGCSE syllabus for upper secondary students that focuses on the existence of celestial bodies in the Universe such as the sun as a star, moons, and planets, and how the formation of universe happened based on the big bang theory can be linked to the education programs and educational instructions conducted by PNKL.

5.1. Research objective 1: the types of education programs carried out by the National Planetarium Kuala Lumpur

Based on the findings, this study found that there are two types of education programs conducted by PNKL which are the on-site/physical programs and online/virtual programs. On-site/physical programs are organized and conducted at PNKL. PNKL has provided exhibition services as well as a variety of on-site programming. Because of its superb facilities and ability to accommodate many visitors at once, the National Planetarium is a good fit for educational settings, not only targeting the students and educators, but the intended audience is diverse including people with many kinds of disabilities. The statistics from MOSTI stated that 54,667 people engaged in the online/physical programs conducted by the National Planetarium in 2021. The programs provided included i) national programs; ii) observatory programs; iii) international programs; iv) teachers and students development programs; v) strategic partner collaboration programs; and vi) astronomical information programs.

Based on the finding obtained, many interesting on-site programs such as the exhibition gallery, the space theater, *Minggu Sains Angkasa*, *Pertandingan Menulis Karangan* Scientist for a Day 2021, *Kejohanan Roket Kebangsaan* (KRK), "The Telescope for All", "Big Bang Astronomy 2021", "*Srikandi Angkasa* Virtual Exhibition", "Planetarium Golden Heart", "Go STEM Program", "The Outreach" program and *Apa Di Langit* program help students to improve their socio-cognitive approach. From the time students entered the planetarium until they leave, the social cognitive approach in the setting was observed. Conversational experiences and the social environment of language development are emphasized in the socio cognitive approach; conversation provides children with both the chance and desire to test and alter their evolving system of language norms.

Online/virtual programs have received a lot of attention, especially during the era of COVID-19 pandemic. Such programs have made it much easier for visitors to virtually explore the National Planetarium which has been making significant contributions to the cultivation of science learning by allowing students to access the space science knowledge no matter where they are. The online programs conducted by PNKL are: i) Trivia quizzes; ii) online observation; iii) Facebook live streaming; and iv) online competitions that resulted in a very positive response and participations from society with 5,170,822 participants engaged during the COVID-19 pandemic. Hence, this finding indicates that the efforts done by PNKL to promote astronomy among the society within this critical period is said to be successful.

5.2. Research objective 2: the educational theories, strategies and approaches utilized through implementation of education program conducted by the National Planetarium Kuala Lumpur

In the aspect of educational strategies, PNKL utilizes: i) cooperative learning; ii) game-based learning; and iii) inquiry-based learning. The evidence from informal education in planetariums suggests that encouraging group learning can be quite useful. Previous studies demonstrated that encouraging students to engage with one another, collaborate, and discuss what they are seeing in the planetarium might be beneficial to their learning [24], [25]. According to Vygotsky, students have a zone of proximal development (ZPD), which is defined as the gap between what a student already understands and what they could potentially grasp given assistance [26], [27].

Students can reach that potential through social interaction with peers, which suggests allowing students to work together in some capacity will be beneficial to learning and all those activities organized by PNKL proved that they worked on getting those benefits. PNKL also foster curiosity by providing opportunities for students to have a choice in their specific selection of learning episodes and sites. The PNKL's facilities and activities adopted a learner-centered approach, which recognizes that students should have some choice over what they learn to keep them motivated to learn in that subject-matter. Students find material on their own topic of research, within the limitations given by the teacher. Students are also encouraged to ask questions and use their planetarium visit to pique their interest in learning more about the topic through the activities provided. While choice recognition is based on personal interest, free-choice

learning can also spark interest. This tip provides a tangible example of how students can bring their enthusiasm back into the classroom by generating questions.

5.2.1. Multiple-intelligence theory

The multiple-intelligence theory was one of the first educational theories applied by PNKL. Gardner, a Harvard University professor of education, developed the multiple intelligences theory in 1983. Gardner offered eight separate skill sets to better understand the complete scope of a child's talents, and it is critical to adopt instructional methodologies that incorporate a variety of these multiple intelligences so that every child can learn in the way that best suits them [28]–[31]. The most useful types of intelligence used by PNKL included: i) spatial intelligence; ii) bodily-kinesthetics intelligence; iii) intrapersonal intelligence; and iv) interpersonal intelligence [32], [33].

5.2.2. Social cognitive theory

The second educational theory and approach applied by PNKL is the social cognitive theory (SCT). According to SCT, parts of an individual's knowledge acquisition can be directly tied to seeing others in the context of social interactions, experiences, and outside media influences, which is utilized in psychology, education, and communication [34], [35]. Social cognition theory makes a distinctive contribution by emphasizing the triadic interplay between the person, behavior, and environment.

Individuals are also regarded to be able to regulate their own thoughts, beliefs, and actions, according to SCT. In all learning attempts, this line of research emphasizes the role of learners as proactive and self-directed seekers. In this line, self-efficacy is viewed as a determinant of actions and a learning agent, while self-regulation is viewed as a growth and development process. Through the activities and programs conducted by PNKL, the students appeared to enjoy the events and appreciated the instructor's questioning. With an experienced instructor in charge of the program, students can be engaged and a conducive learning environment can be established. This includes persons in their immediate social group, such as peers, family members, and teachers, as well as visitors, docents, and presenters from outside the group. The importance of language and connection with others has sparked research into visitor social interaction, collaboration, and conversation, which has revealed that visitors in the planetarium are learning alongside one another [36]–[38].

5.2.3. Experiential theory

Meanwhile the third educational theory used by the PNKL is experiential theory. Experiential learning has been shown to be very engaging for pupils and to improve long-term memory when correctly designed. Proponents also say that it fosters deeper comprehension and the development of digital-age skills including problem-solving, critical thinking, improved communication, and knowledge management. It enables learners to better manage highly complex circumstances that straddle disciplinary boundaries, as well as topic areas with difficult to manage knowledge boundaries [39]–[42]. PNKL applied experiential learning with the goal of bringing students to experience the astronomical field to develop their critical thinking and curiosity about space via activities such as *Minggu Sains Angkasa*, which included various hands-on and interactive space science activities, resulting in enhancing students' interest about the field of astronomy.

5.2.4. Constructivism

The constructivism approach is the most recent teaching theory applied by PNKL. According to the findings, students were able to alter and call upon their knowledge from the planetarium in post-activities. The post-activities assisted students in furthering their thoughts and revealing fresh alternative ideas, which could aid teachers in detecting and assisting students toward normative views [43], [44]. Additionally, it was found that students relied heavily on existing knowledge and experience to further develop their thoughts during the visit and afterwards [45]. This demonstrates the necessity of intellectually preparing the children as well as ongoing exposure after the visit. Programs such as "Big Bang Astronomy 2021" are one of the approaches taken by PNKL to promote constructivism learning and increase astronomy awareness with the goal of sparking a culture of literacy and intellectual curiosity about the existence of the universe in children as early as at kindergarten age [46], [47].

5.3. Research objective 3: the inclination of astrophysics in IGCSE with the education programs content organized by the National Planetarium Kuala Lumpur

In the Pearson Edexcel IGCSE curriculum, the Astrophysics content is included in the Physics syllabus, and it is expected that students will be taught about the astronomical discipline, with a focus on the units used in space, the motion in the universe, the stellar evolution and cosmology. Through the findings obtained in the study, it is determined that the programs and educational theories and strategies implemented by PNKL tend to increase the IGCSE students' interest to learn about Astrophysics in their Physics syllabus.

The investigation indicates that the educational theories and strategies conducted by PNKL has a strong relation with the Pearson IGCSE skills framework, in which both parties are focusing to improve students' cognitive skills, interpersonal skills, intrapersonal skills, intellectual openness or inquiry approach, self-evaluation and regulation, collaboration that work as a teamwork that creates good sociocultural skills and to polish the experimental skills which embedded a practical investigation in learning.

The inclination of the themes in the IGCSE for the Physics subject for upper secondary school students aged 14-16 with the PNKL exhibitions' contents resulted in a positive perception of teaching and learning of Astrophysics, as well as reducing astronomy misconceptions among students and teachers. For example, the "Big Bang Astronomy 2021" program conducted by PNKL was based on the scientific theory of the Big Bang, in which the universe emerged as a result of an enormous mega eruption that caused the onset of space and time, is included in the Physics syllabus under Subtopic 8.4 Cosmology.

The exhibition gallery in PNKL also displays "The Star Life Cycle" and "Made of Stars" exhibitions using hands-on and minds-on concepts supported by beautiful images and art that encourage students to learn more about the stars. These exhibitions are aligned with subtopic 8.3 Stellar evolution, which focuses on the classification of stars, the life cycle of solar mass stars, and the brightness of the stars. Meanwhile, the exhibitions titled "The Sun", "Birth of the Solar Universe" and the "How Life Evolve" also gained students interest to enhance their previous knowledge about the existence of universe, and these topics are aligned with subtopic 8.4 Cosmology that stresses about the origin and evolution of the universe, starting from the theory of Big Bang until today and into the future. This is also aligned with the new syllabus of Space Physics that will be added in Cambridge IGCSEs syllabus in 2023, which shows students the potential of having a career in astronomy.

6. CONCLUSION

The global COVID-19 pandemic of 2020 has caused a rapid transition to online teaching and learning, placing new demands on instructors, students, and educational systems. The PNKL's online and virtual programs, as well as online teaching and learning through the IGCSE curriculum, will help both parties acquire students' enthusiasm for learning about astronomy. By being presented many perspectives and explaining the cause-and-effect relationships through the new techniques and theories that suit this current scenario, students gained a new level of comprehension of the context of astronomy and why we experience occurrences on earth. Meanwhile, PNKL also provides interesting shows on site, with sound effects and realistic visual simulations. Students can participate in physical exercises that they would not be able to do in the classroom. They can be immersed in a virtual space environment that helps them to understand and comprehend the vastness of space. The planetarium reinforces knowledge of cosmology that is included in the physics IGCSEs textbook. From a technical standpoint, the students' personal, physical, and social contexts were positively impacted by PNKL's programs that implemented the multi-intelligence theory, sociocultural theory, experiential theory, and constructivism through gamification and group activities.

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