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Identification of Ethnomathematics in Wat Arun "Temple of Dawn" in Bangkok, Thailand

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Buddhist architecture; ethnomathematics; wat arun; geometric; meaning

Abstract

Using the ethnographic approach, this qualitative descriptive research was conducted to identify ethnomathematics concepts in Wat Arun's "Temple of Dwan" in Bangkok, Thailand. The purpose was to explore and examine the mathematical elements or concepts and the meaning contained in the geometric patterns of the temple. The process involved describing the motif associated with the temple based on specific categories using the data retrieved from documentation, observation, and literature review. The results showed that mathematical and geometric concepts such as triangles, squares, and rhombus were depicted in the geometric and floral motifs, offering compelling evidence of the involuntary implementation of mathematics in traditional motifs. Furthermore, these results can also be applied as a reference to develop mathematics teaching materials and interior design or architecture courses based on local wisdom.

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1. Introduction

Culture and mathematics possess unconsciously mutually supportive knowledge and both play a crucial role in advancing human cognitive abilities (Utami, Muhtadi, Ratnaningsih, Sukirwan, & Hamid, 2020). It has also been observed that mathematics has seamlessly integrated itself into human culture, even though individuals may not consciously realize its pervasive presence and application in their daily lives (Koentjaraningrat, 2010). Mathematics originated and evolved through the cultural process of human learning that was used to produce systems of ideas, actions, and creative outputs to shape and enrich their lives (Edi Supriyadi, 2022). This led to the development of a concept known as ethnomathematics that deeply intertwined the cultural aspect of mathematics into human life (d'Ambrosio, 1985).

Ethnomathematics was further explained as the mathematical activity conducted by specific cultural communities and integrated into their daily lives. These communities include workers, farmers, fishermen, intellectuals, professionals, and others (Cimen, 2014; Hermanto & Nurlaelah, 2019; Muhtadi & Prahmana, 2017). The concept was based on the

activities, experiences, and creative outputs of cultural groups that are related to mathematics (Muzakkir, 2021).

Ethnomathematics, introduced in 1977 by D'Ambrosio, a Brazilian mathematician, originates from the word "ethno," signifying something broad and pertaining to socio-cultural contexts, "mathema" which means explaining, knowing, comprehending, and engaging in activities, and "tics" derived from "techne," meaning technique (D'Ambrosio & Rosa, 2008). Ethnomathematics is a captivating study that delves into the intricate mathematical systems within various cultural contexts, illuminating the profound understanding and reasoning behind their application (Wahyuni, Tias, & Sani, 2013). Another definition by Shirley characterizes it as mathematics that arises and develops within a society, aligning with the local culture and being integral to learning and teaching processes.(Shirley, 1995). Mohammad Zayyadi emphasized the close connection of ethnomathematics with culture, stating that it encompasses various mathematical concepts developed within a tribe, including those manifested in cultural artifacts such as temples, traditional tools, fabric patterns, and settlement patterns (Zayyadi, 2018).

Prehistoric records showed that the ancestors deeply ingrained mathematics since ancient times, even before their conscious recognition of its significance. The analysis of Borobudur Temple exemplified this as a remarkable instance of ethnomathematics (Utami et al., 2020). Temple was reported to serve as a testament to the interplay of religion, morality, culture, and mathematics as indicated by the deliberate utilization of mathematical concepts in its construction(Utami et al., 2020) . This showed that mathematics cannot be separated from culture because it is a part of human activities and also a social and cultural phenomenon (Polprateep, 2010).

Krung Thep, also known as Bangkok to foreigners, is home to numerous historical and cultural treasures, such as several fascinating temples along the Chao Phraya River. The area's most prominent and famous temple is Wat Arun Ratchawararam Ratchawaramaha, commonly known as Wat Arun. This temple was built during the Ayutthaya era, the second of the four eras in Thailand after Sukhothai, followed by Thonburi and Rattanakosin. It was observed to have several significant roles, including being the Main Temple during the Thonburi era. The temple is also the house of valuable Buddha statues such as the Emerald Buddha, which is the crown temple of King Rama II (Weerataweemat, 1999).

Wat Arun was designated as one of the national heritage buildings of Thailand in 1949 due to its valuable tangible and intangible cultural heritage. This can also be linked to the ability of the temple to showcase stunning Buddhist architectural form and layout as well as a notable front structure known as Phra Prang, which resembles a Chedi and stands 67 meters tall. Another unique feature is that all the buildings are adorned with brightly colored porcelain (สวัสดิ์ & น้อย, 2017). Moreover, its Buddhist architecture is closely intertwined with mathematics, especially the foundation of the building, which was developed using the geometric system known as the mandalas of the Shwedagon Pagoda (Darmayanti & Bahauddin, 2020).

The rich history, distinctive design, and unique patterns of this magnificent structure provided clear evidence and meaning related to the ability of Thai society to construct a grand temple filled with unconscious applications of mathematical concepts that have become an integral part of their life. This also gives meaning to the architecture of this temple. Beauty is seen not only from a tangible point of view but also from an

intangible point of view, namely, values that transcend every element (BK, 2022). In this case is the beauty of Wat Arun. The previous research on Wat Arun primarily focused on sustainable cultural tourism and Buddhist architecture, while there was limited research on architecture, philosophy, and mathematical concepts. It was also discovered that there is a lack of research exploring the building layout, decorative motifs, and structures from a philosophical and mathematical perspective and their interconnections.

2. Research Methodology

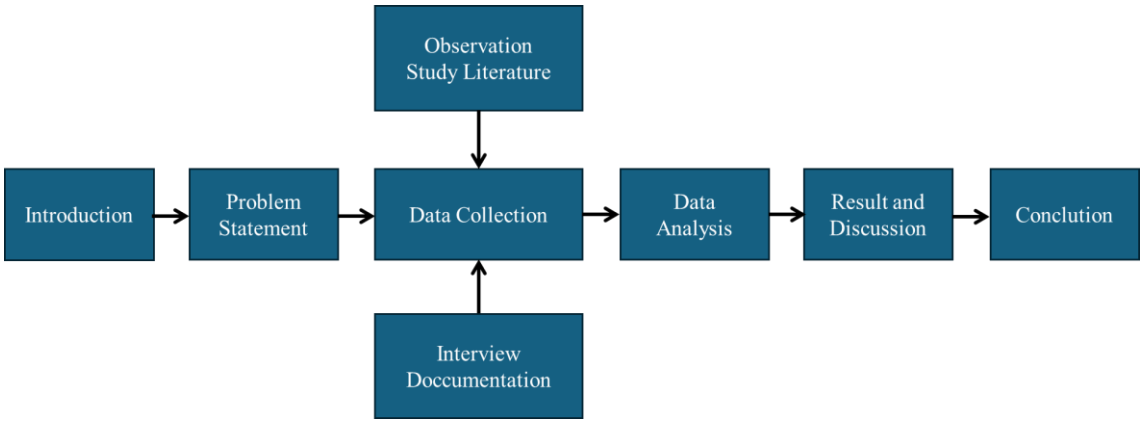


***Figure** 1.* Research Methodology Diagram

This qualitative research primarily focused on understanding, explaining, exploring, discovering, and clarifying the situations, feelings, perceptions, attitudes, values, beliefs, and experiences of a group of people (Arikunto, 2006) using exploratory, historical, and cultural methods. The exploratory aspect was used to extensively explore the history, causes, characteristics, and qualities of the research object (Abdurahman & Safa, 2007). The historical aspect was applied to meticulously and objectively reconstruct phenomena from the past by gathering and evaluating evidence to draw accurate conclusions (Leavy, 2014). Meanwhile, the cultural approach was used to understand the cultural elements and phenomena of the research object using methodologies in cultural science(Denzin & Lincoln, 2011; Muhtadi & Prahmana, 2017; Nursyeli & Puspitasari, 2021).

The focus was on architecture, religious teachings, philosophy, and mathematical concepts inherent in Wat Arun, which is a temple located on the banks of the Chao Praya River in Bangkok, Thailand. The data used were photographs, artifacts, and other recorded items retrieved through observation, documentation, field notes, and a review of past research. These data were further analyzed to produce new questions and hypotheses as well as written results to ensure the readers understand the concepts being researched (Baker, 2014). in this research, the limitations studied are the Wat Arun building's layout, architecture, and ornamentation.

Ethnomathematics in various Research

In a study titled "Ethnomathematics: Geometry Exploration in the Architecture of Pura in Alas Purwo National Park," it was stated that the religious architecture of Pura Luhur Giri Salaka reflects various geometric shapes such as triangles, rectangles, prisms, and pyramids. The study also found interesting geometric transformations such as rotation, translation, and reflection on the axis and gate of the temple. The results of this research provide valuable insights for the development of geometry learning materials.(Safrida et al., 2022).

Another study titled "Ethnomathematics in Sasaknese architecture" provides evidence of the Sasak tribe's ancient use of numbers in making measurements using Ethnomathematics.(Supiyati & Hanum, 2019). Fuzi, Lalu Muhamad, et al. (2022) demonstrated in their research that Indigenous dwellings, as cultural artifacts, possess aesthetic value and embody mathematical ideas, thereby clarifying the relationship between Ethnomathematics and architecture.(Fauzi, Hanum, Jailani, & Jatmiko, 2022). Research by Joko Soebagyo and Fadhilah Izzuk Lutfiyyah proves that Ethnomathematics is manifested symbolically in the great mosque of Al-Barkah in Bekasi City. The research also demonstrates that Ethnomathematics involves an understanding that integrates culture and architecture as a tangible manifestation in developing mathematical concepts within a culture.(Soebagyo & Luthfiyyah, 2023).

In a research conducted by Practise Base, titled "Mamuli" Pattern in East Sumba Woven Fabric as Inspiration for "Kandunnu" Standing Lamp Using the IMOE Method, it was shown that Ethnomathematics significantly contributed as a valuable tool for analyzing traditional fabric patterns to derive inspiration for creating contemporary products.(Halim, Joneurairatana, Vongphantuset, & Jamuni, 2023). More in the research raised by Safitri, R. N. (2023). explained that Ethnomathematics is a tool for integrating mathematics and the culture of the community so that the results in the form of Al-Husna Pondol Dalem Semboro Mosque have Ethnomathematics related to geometric mathematical concepts, such as triangles, hexagons, squares, rectangles, circles, rhombuses, beams, tubes, spheres, cones, pyramids, congruences, and congruence (R. N. Safitri, 2023).

Ethnomathematics research on Acehnese traditional house architecture reveals the presence of mathematical elements, including counting and measurement activities, as well as the use of geometric shapes in Acehnese traditional houses. Ethnomathematics serves as a bridge between mathematics and culture.(Iskandar, Karjanto, Kusumah, & Ihsan, 2022). The research entitled "Ethnomathematics: Graph of Architecture of the Great Mosque of Kediri" found in the Great Mosque of Kediri has Ethnomathematics related to the concept of graphs, such as Line graphs, circle graphs that eventually form a geometric plane that supports and creates new and unique architectural forms (Susanti, Ulya, Asnawi, & Rozi, 2022).

Yuxian Huang, Jinyu Nong, and PeiPei Lai (2021), in their research, aim to examine aspects of Ethnomathematics in Tulou Architecture, China, and in this study, it was found that Tulou Chinese architects contain a lot of mathematical knowledge, including knowledge about geometric space construction (Huang, Nong, & Lai, 2021). Another study explained the significance of geometric Ethnomathematics in the architecture of the Rakakng House in Sahapm Village. It emphasized that education, culture, and architecture are integral aspects of everyday life that cannot be separated. The study

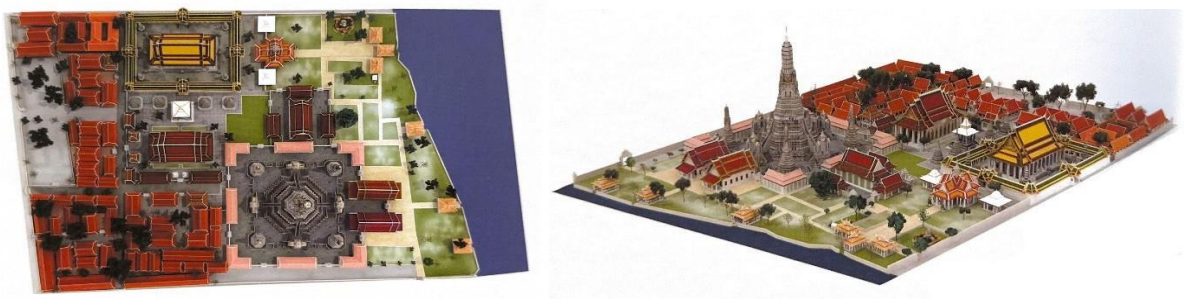
found that mathematical elements, particularly geometric principles, are applied to traditional houses. (Permata, Budiarto, & Ekawati, 2021). The relationship between mathematics and architecture is evident in Indonesian architecture, particularly traditional houses. For example, the basic shape of traditional Acehnese houses is a triangular geometry, which is interpreted as masculine (R. A. Putra & Ekomadyo, 2023).

The study "Exploring Mathematics Concepts in Architectural Mosque Designs: A Study of Brunei Ethnomathematics" explains that ethnomathematics has a significant architectural impact and contributes to mathematics education. The purpose of this study is to explore the mathematical elements contained in mosque buildings (Risdiyanti, Shahrill, Prahmana, & Mahadi, 2024). Purniati, T., & Suhaedi, D. (2020, April). The research revealed that the buildings and ornaments of the Great Mosque of Cimahi feature mathematical concepts such as geometry (plane geometry, spatial geometry, and transformation geometry) and algebra (decoration groups). It is hoped that by studying the buildings and ornaments in the mosque, students will find it easier to learn these mathematical concepts (Purniati & Suhaedi, 2020).

The results indicate a strong connection with the local culture. The architecture of traditional Tharu houses demonstrates a sophisticated use of geometrical elements such as angles, lines, triangles, lengths, squares, pentagons, and circles. These elements showcase the diversity and complexity of mathematical practices in Tharu houses, laying a strong foundation.(Chaudhary, Panthi, & Bhatta, 2023). By examining previous research, it can be concluded that mathematics is intended to explain everyday life experiences by providing solutions to social, cultural, and natural ecosystem problems.

3. Results and Discussion

Wat Arun has 16 important structures with a unique appeal to visitors, and they are presented in detail in the following figures.

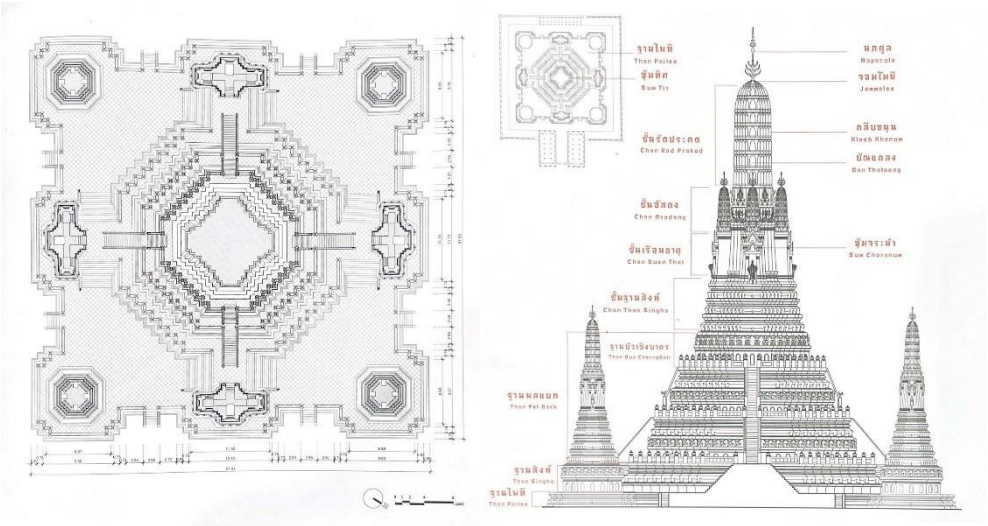


(a) (b)

***Figure* 2.** a. Buildings maps b. 3D buildings maps
Source: The Philosophical Constructs of Wat Arun (2014)

1. The Principle Prang or Phra Prang
2. The Satellite Prang or Prang Thit
3. The Porches or Mondop Thit
4. The Chaple or Phra Viharn
5. The Buddha's Footprint Niche

6. The Four Satellite Pagoda or Chedi
7. The Peripheral Balcony or Phra Viharn Kot
8. The Ordination Hall or Phra Ubosoth
9. The Entrance with a Spire Roof
10. The Demons
11. The Nai Ruang Pavilion
12. The Nai Nok Pavilion
13. The Riverside Pavilion
14. The King Rama II Monument
15. The Old Ordination Hall or Bot-Noi
16. The Old Chapel or Viharn Noi



(a) (b)

Figure 3. a. Floor Plan of Phra Prang b. Elevation of Phra Prang
Source: Measured and Drawn: The Architectural Survey of Wat Arun (2018)

The first monument was the Principle Prang or Phra Prang, which was estimated to have been built in the late Ayutthaya era (Weerataweemat, 1999). It symbolized the Hindu-Buddhist cosmological architectural style with the existence of the Tridhatu or The Three Realms concept. The monument was constructed with a centralized concept representing Mount Semeru in Buddhist cosmology, as indicated in Figure 2. This Mount Semeru was believed to be a mountain surrounded by the sun, moon, and mountain springs (Wayman, 1981). The main Prang has three levels which are stated as follows:

1. Trayastrimsa: the highest peak which symbolized the life of the gods.
2. Caturmaharajikakayika: the middle part with 4 guardians, including Kumbhandas (dwarfs), Gandharvas (fairies), Nagas (Dragons), and Yaksas (jinns).
3. Asuras: the lowest area which represented the vast ocean.

The body of Wat Arun building consisted of:

1. The most essential part of the foundation was called Tan Phai Tee and was constructed through piles of stones.
2. The terrace on the second level was called Taksin or Pre-Taksin.
3. The ceramics in the form of flowers, trees, and leaves on the second floor symbolized the Himavant Forest at the foot of Mount Meru.
4. a cave on level 2 with the reliefs of Kinnorn and Kinnaree used to represent half- bird humans living in the Himavant Forest.

Cheung Bart was at the very top of each level.

1. On the second level of Cheung Bart, there was a giant relief called Marn Bak.
2. At Cheung Bart, there were 64 giant reliefs.
3. 46 monkey reliefs or Krabi Bak adorned the Cheung Bart area on the third level.
4. On the fourth level of Cheung Bart, the creator god was relieved, according to Hinduism, known as Brahma/Brahma Bak.
5. At Cheung Bart, there were 52 reliefs of Brahma.
6. Statue of God Indra, the leader of the gods, was at the very top.
7. There was also a relief of God Vishnu/Rama, the protective deity that used the Garuda Bird as its vehicle.
8. Yod Noppasoon was the golden crown used to represent Buddha. It was designed with a
    a. Height of 1.2 m
    b. Weight of 185 kg
    c. Width of 52 cm

The small temple surrounding the main temple was called Prang Thit with Marn Bak, Krabi Bak, and other reliefs such as:

a. Statue of Wind God Phra Pai with a horse as the vehicle.

b. Statue of God and Narasingha, half lion and half human, that was considered to be the reincarnation of God Vishnu.

There was a Mondop in Prang Thit, the building customarily used to tell the story of Buddha's journey. Moreover, Wat Arun was mainly decorated with ceramics and porcelain, obtained mainly from Cinna and donations from residents in the form of bowls known as Banjarong.

3. Discussion

Architecture as the Embodiment of Mathematical Knowledge

Mathematics and architecture are closely intertwined and have a strong connection. The creation of impressive architecture requires a deep understanding of mathematics. Therefore, architectural forms are underpinned by mathematical concepts. According to Ostwald and Williams, creating and designing buildings involves applying geometric and mathematical knowledge practically. This relationship is further evidenced in practice, as the design and construction of buildings require meticulous calculations. In summary, this research highlights the essential connection between architecture and mathematics. Architects at Wat Arun have incorporated mathematics and geometry into their designs, demonstrating that mathematical knowledge is indispensable in architectural activities (Williams & Ostwald, 2015).

With the above understanding of the connection between mathematics and architecture, this study reveals the mathematical side of Wat Arun religious buildings, the description is as follows:

Mathematical Concepts and Patterns in Wat Arun

Wat Arun Layout

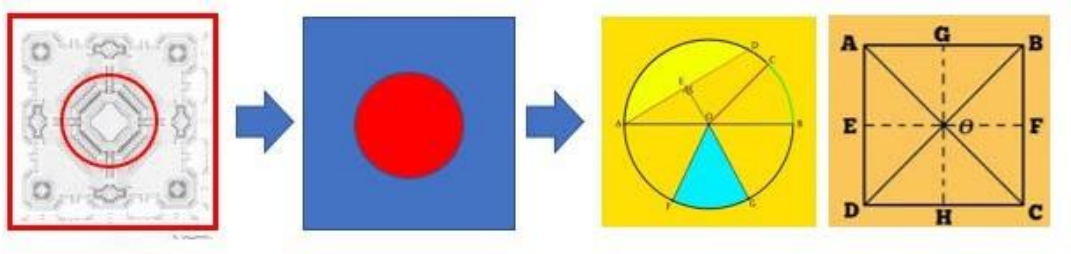


Figure 4. Mathematical concepts in Wat Arun Layout

Source: Erwin Ardianto Halim (2023)

Some mathematical concepts were demonstrated in the layout of Wat Arun buildings and their ornaments which were observed to resemble planes and solid geometry. The layout was found to be in the form of Euclidean Geometry, consisting of two main shapes, including concentric circles and squares. This was in line with the results of previous research, which indicated a close relationship between Buddhist architecture and mathematics, as indicated by the utilization of Sulva Sultra principles in the layout of mandala forms to emphasize the relationship between circles and squares. The principles were used as the temple's foundational structure and were proven by applying the Pythagorean theorem to calculate the desired side lengths (Darmayanti &

Bahauddin, 2020). This was further exemplified in the foundation of Borobudur Temple combined squares and circles using mandala calculation (A. H. I. Safitri, Novaldin, & Supiarmo, 2021) as presented in Figure 4. It was discovered that the Wat Arun layout had square structures with the following properties:

- 4 equal sides: AB = BC = CD = DA
- 2 equal angles: ∟A = ∟B = ∟C = ∟D = 90°
- 4 rotating and 4 folding symmetries

Architectural Elevation of Phra Prang

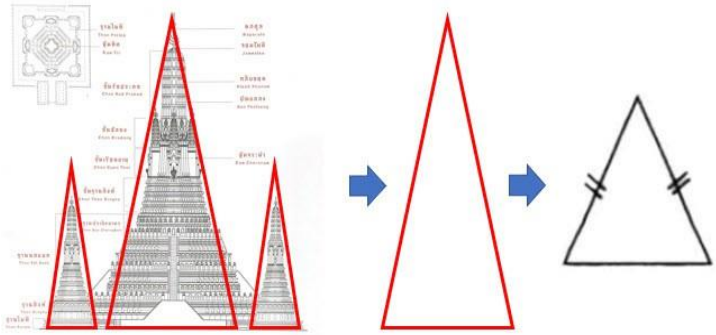


Figure 5. Mathematical concept in Phra Prang building
Source: Erwin Ardianto Halim (2023)

The mathematical concept evident in the overall building of Phra Prang was an isosceles triangle. The equal lengths and angles of both sides indicated this. The pointed top represented the distinctive feature of Thai architecture known as the pitched roof, which was characterized by a tall and steeply sloping design as observed in Rumah Gadang (Nawi, Rahmawati, & Iswadi, 2019). Moreover, the isosceles triangle aligned with the Wat Arun building, so the shortest side was positioned in front of the smallest angle. It is important to note that all three sides of an equilateral triangle usually have equal lengths, and all three angles measure 90º. Meanwhile, in an isosceles triangle, only two sides and two angles are equal (Zahroh, 2019).

Statue of Indra on Airavaata Elephant

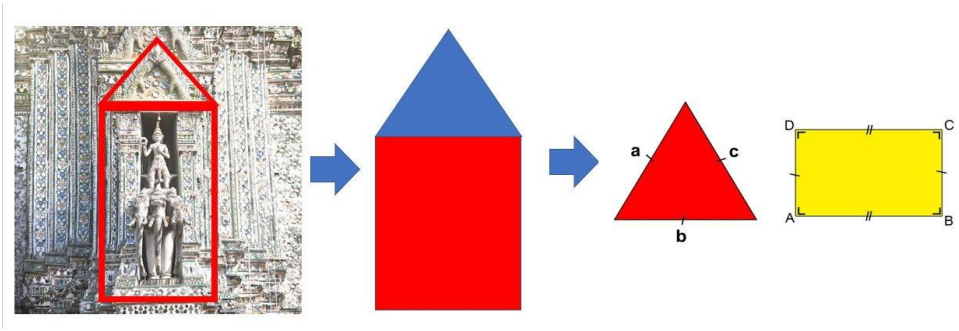


Figure 6. The mathematical concept in the Statue of Indra on Airavaata Elephant
Source: Erwin Ardianto Halim (2023)

According to Buddhist teachings, Indra is known as the King of Gods and resides at the highest peak of Mount Semeru. Its statue, located at the topmost part of Wat Arun,

was observed to have showcased an isosceles triangle characterized by two equal sides and equal angles. Another notable activity was the rectangle with 4 sides consisting of 2 pairs of equal sides, 2 axes of symmetry, 2 folding symmetries, and 2 rotating symmetries (A. S. Putra, Santoso, & Palit, 2016). Moreover, there was a mathematical repetition of triangular shapes in the statue, known as pediments in Roman and Greek temple architecture.

Ornaments on Wat Arun Body

Royal Temple Ornaments

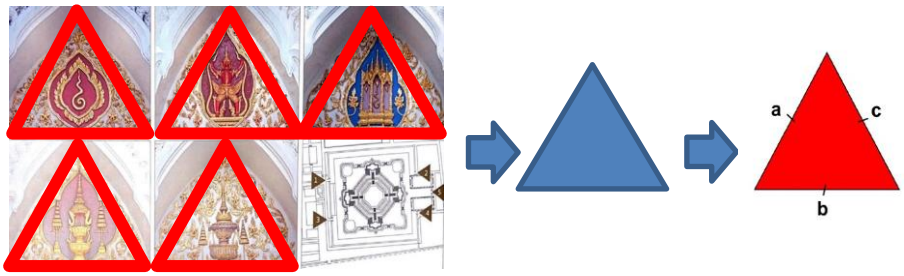


Figure 7. Mathematical concepts in the entrance ornaments of Phra Prang Source: Erwin Ardianto Halim (2023)

The ornaments at Phra Prang Wat Arun's entrance exhibited mathematical concepts primarily dominated by equilateral triangles. They were also bounded by a base and apex that reflected triangular shapes with sides forming vertical squares (Hari, 2019). Moreover, the doors had an upward-pointing triangular pediment, and the ornament of the main door was observed to form a triangle formula such that the Surface Area, A = (2 x Base Area) + (Perimeter of Base x Height) (Desmayanasari & Hardianti, 2021).

Ceramic Ornaments at Wat Arun

The ceramic ornaments on Wat Arun's body served as an appeal to attract visitors but also exhibited several mathematical concepts as follows:

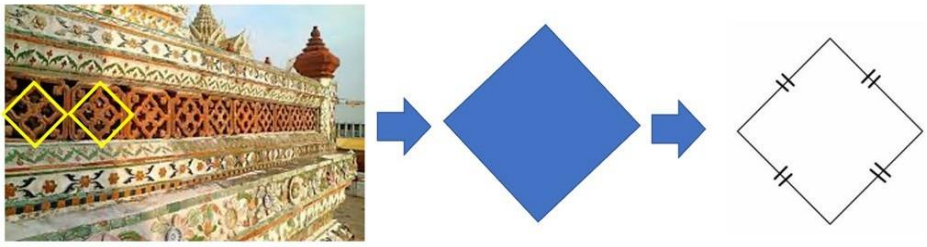


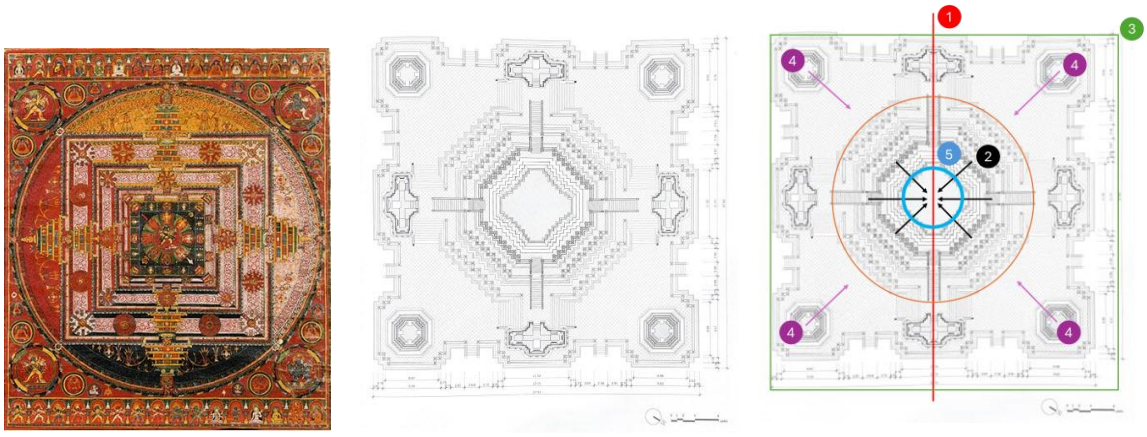
Figure 8. Mathematical concept in the wall ornaments of Phra Prang Source: Erwin Ardianto Halim (2023)

Figure 8 shows that the structure of the rhombus with 4 equal sides and 2 equal opposing angles was found in the wall ornaments of Wat Arun (Tanudjaja, 2005). Another notable activity was the repetition system of the structure, and this was explained by the Gestalt theory that humans tend to group stimuli based on similarity and continuity(Brandt & Chernoff, 2015).

The Relationship of Wat Arun Buddhist Architectural Philosophy and Ethnomathematics to Wat Arun

Ethnomathematical discoveries in Wat Arun architecture are closely related to philosophy for Buddhist Architecture, especially in religious buildings. Buddhism is the world's premier religion and philosophy. Buddhist religious architecture flourished in South Asia in the third century BC. There are two types of structures attributed to the religious architecture of early Buddhism, namely. Vihara and Stupa. The monastery was originally only a temporary shelter used by wandering monks during the rainy season but was later developed to accommodate the growing and formal Buddhist monasticism. An existing example is in ancient Nalanda. It was a typical type of fort architecture found in Buddhist Kingdoms then and now (Shah Thakuri & Ranjit, 2014). Buddhist architecture emerged slowly in the period after Buddha's life. It was built on Hindu models but incorporated specific Buddhist symbols. In the philosophy of religious buildings, Buddha has a basic form of geometry that has a deep philosophical meaning as a foundation in building, such as the shape of a square and circle, the shape of a plan with this geometric shape has survived to this day when it will build a Buddhist paste in the world.

Circle shape in Buddhist architecture Named Mandala, mandala is a circle of sacral Buddhism, which has basic concepts such as: (1). The diagram is very symmetrical, (2). Centering, (3). Four sides of equal size, (4). Centered circles and squares, (5). A simple circle/disc becomes the sacred center.



(a) (b) (c)

Figure 9. (a). Mandala, (b). Wat Arun Layout, (c). Mandala Analysis on Wat Arun Layout
Source: Erwin Ardianto Halim (2024)

In the analysis above (Figure 9), it is clearly seen that the creation of the architectural layout at Wat Arun temple follows the pattern of the circular form called a mandala, where the five fundamental concepts in the mandala are fulfilled in the layout of Wat Arun, and it is also clear that mathematical and geometric concepts are used in the concept of mandala and wat arun like a circle that has the meaning of movement such as

the 'wheel of dharma' that continues to rotate from the universal cosmos there is no beginning and end, a continuous, transcendental and spiritual process that Buddhists hope to focus on in worship where the midpoint is central and aesthetically and structurally.

4. Conclusion

The conclusions drawn from this research were that (1) Wat Arun, as a cultural ethnomathematics product, significantly showcased different concepts of religion, culture, and mathematics, (2) the mathematical activities were generally interconnected, and (3) implemented unconsciously on different parts of Wat Arun such as the building layout, ornaments, and main entrance. It was also discovered that (4) Wat Arun served as an example of a monument with ethnomathematics, and this means (5) mathematics can serve as a means of abstract knowledge, a structure of truth, and a body of knowledge as well as a tool for creativity and thought processes of designers (Sukoco). Thus, through this research, culture and mathematics have a significant affinity so that we can use mathematics to solve cultural artifacts in the design world. Conversely, culture can be a tool to make math lessons more enjoyable. Recommendations for future research can examine the relationship of mathematics with the placement of shapes in Wat Arun based on the religious meaning therein.

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